REN21 Renewable Energy Policy Network for the 21st Century

RENEWABLES 2016
GLOBAL STATUS REPORT

2016

REN21 STEERING COMMITTEE

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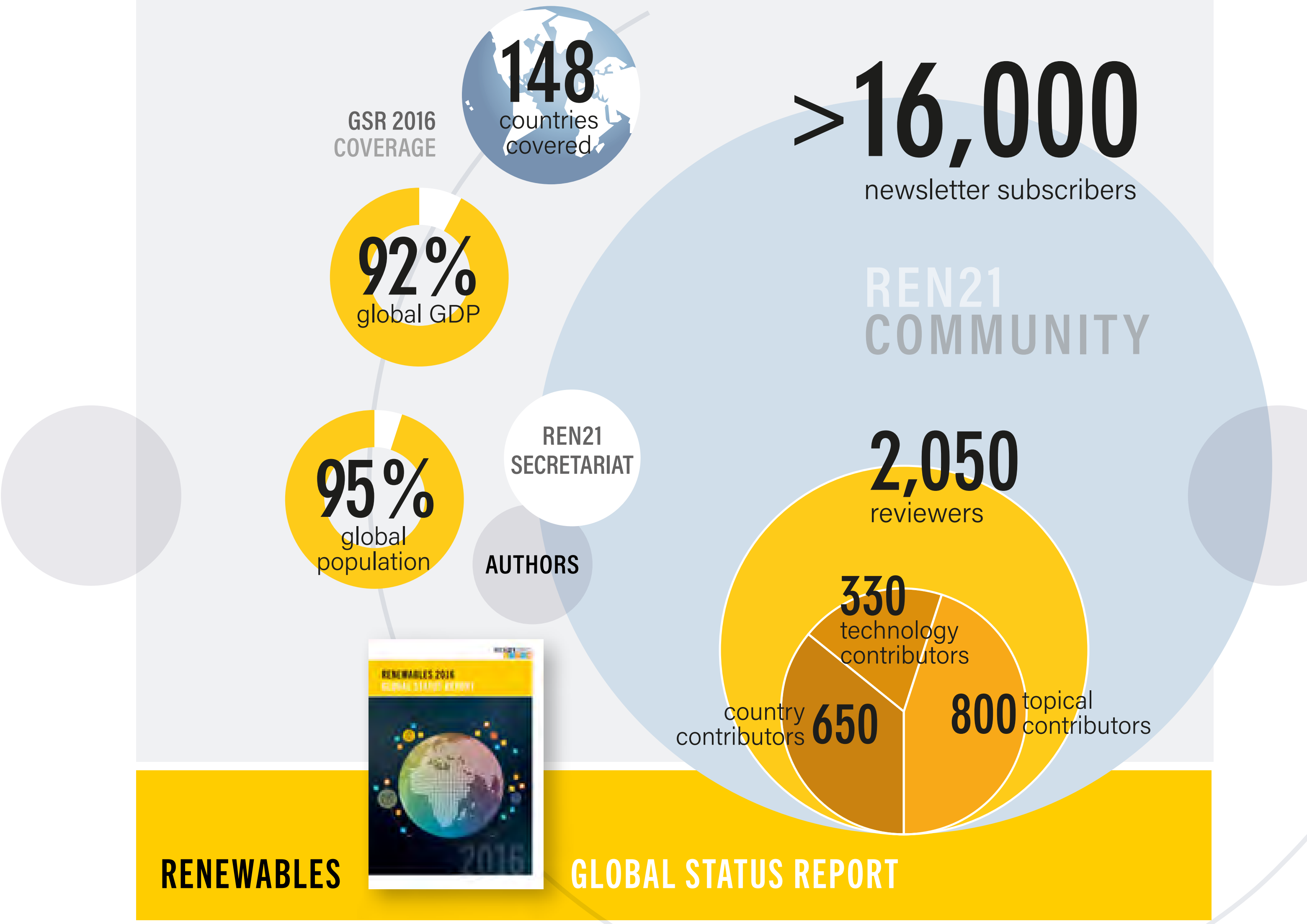
REN21 COMMUNITY

REN21 is a multi-stakeholder network; collectively this network shares its insight and knowledge, helping the REN21 Secretariat produce its annual *Renewables Global Status Report* as well as regional reports. Today the network stands at 700 renewable energy, energy access and energy efficiency experts. For GSR 2016, 180 experts joined the report process, equivalent to the total number of GSR experts in 2012.

These experts engage in the GSR process, giving their time, contributing data and providing comment in the peer review process. The result of this collaboration is an annual publication that has established itself as the world's most frequently referenced report on the global renewable energy market, industry and policy landscape.



FOREWORD

The year 2015 was an extraordinary one for renewable energy. High-profile agreements were made by G7 and G20 governments to accelerate access to renewable energy and to advance energy efficiency. The United Nations General Assembly adopted a dedicated Sustainable Development Goal on Sustainable Energy for All (SDG 7). Despite a dramatic decline in global fossil fuel prices, the world saw the largest global capacity additions from renewables to date. However, continuing fossil fuel subsidies and low fossil fuel prices did slow growth in the heating and cooling sector, in particular.

Precedent-setting commitments to renewable energy were made by regional, state and local governments as well as by the private sector. Global investment in renewables reached a new high, with investment in developing countries surpassing that of industrialised countries. The year culminated with the United Nations Framework Convention on Climate Change's (UNFCCC) 21st Conference of the Parties (COP21) in Paris, where 195 countries agreed to limit global warming to well below 2 degrees Celsius.

Renewables are now cost-competitive with fossil fuels in many markets and are established around the world as mainstream sources of energy. Renewable power generating capacity saw its largest increase ever. Modern renewable heat capacity also continued to rise, and renewables use expanded in the transport sector. Distributed renewable energy is advancing rapidly to close the gap between the energy haves and have-nots.

However, in order to increase energy access while at the same time meeting the target of limiting global temperature increase to 2 degrees Celsius, remaining fossil fuel reserves will have to be kept in the ground, and both renewable energy and energy efficiency will have to be scaled up dramatically.

Similar to the renewable energy field itself, the Renewables Global Status Report is the sum of many parts. At its heart is a multi-stakeholder network that collectively shares its insight and knowledge. These experts engage in the GSR process, giving their time, contributing data and providing comment. Today the network stands at 700 renewable energy, energy access and energy efficiency experts.

On behalf of the REN21 Secretariat, I would like to thank all those who have contributed to the successful production of this year's report. These include primary lead author Janet L. Sawin, lead authoring team members Kristen M. Seyboth and Freyr Sverrisson, the section authors, GSR project manager, Rana Adib and the entire team at the REN21 Secretariat, under the leadership of REN21's Executive Secretary Christine Lins.

This year's report clearly demonstrates the enormous potential of renewables. However, to accelerate the transition to a healthier, more secure and climate-safe future, we need to build a smarter, more flexible system that maximises the use of variable sources of renewable energy and that accommodates both centralised and decentralised as well as community-based generation.

Arthouros Zervos

Chairman of REN21

RENEWABLE ENERGY POLICY NETWORK
FOR THE 21ST CENTURY

REN21 is the global renewable energy policy multi-stakeholder network that connects a wide range of key actors. REN21's goal is to facilitate knowledge exchange, policy development and joint action towards a rapid global transition to renewable energy.

REN21 brings together governments, nongovernmental organisations, research and academic institutions, international organisations and industry to learn from one another and build on successes that advance renewable energy. To assist policy decision making, REN21 provides high-quality information, catalyses discussion and debate, and supports the development of thematic networks.

REN21 facilitates the collection of comprehensive and timely information on renewable energy. This information reflects diverse viewpoints from both private and public sector actors, serving to dispel myths about renewable energy and to catalyse policy change. It does this through six product lines:

Global Status Report: yearly publication since 2005

	2004	2005	2006	2007	2008	2009	2010
REN21 publications:		First GSR published				Chinese Renewable Energy Status Report	Indian Renewable Energy Status Report; Renewables Interactive Map
REN21 events:	Renewables 2004, Bonn	BIREC, Beijing International Renewable Energy Conference			WIREC, Washington International Renewable Energy Conference		DIREC, Delhi International Renewable Energy Conference

RENEWABLES GLOBAL STATUS REPORT (GSR)

First released in 2005, REN21's *Renewables Global Status Report* (GSR) has grown to become a truly collaborative effort, drawing on an international network of over 500 authors, contributors and reviewers. Today it is the most frequently referenced report on renewable energy market, industry and policy trends.

REGIONAL REPORTS

These reports detail the renewable energy developments of a particular region; their production also supports regional data collection processes and informed decision making.

RENEWABLES INTERACTIVE MAP

The Renewables Interactive Map is a research tool for tracking the development of renewable energy worldwide. It complements the perspectives and findings of REN21's Global and Regional Status Reports by providing continually updated market and policy information as well as offering detailed, exportable country profiles.

GLOBAL FUTURE REPORTS (GFR)

REN21 produces reports that illustrate the credible possibilities for the future of renewables within particular thematic areas.

RENEWABLES ACADEMY

The REN21 Renewables Academy provides an opportunity for lively exchange among the growing community of REN21 contributors. It offers a venue to brainstorm on future-orientated policy solutions and allows participants to actively contribute on issues central to a renewable energy transition.

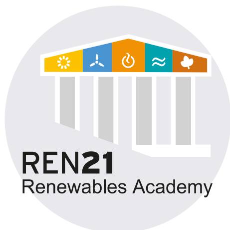
INTERNATIONAL RENEWABLE ENERGY CONFERENCES (IRECS)

The International Renewable Energy Conference (IREC) is a high-level political conference series. Dedicated exclusively to the renewable energy sector, the bi-ennial IREC is hosted by a national government and convened by REN21.

Regional Reports

Global Futures Report

www.ren21.net/map



REN21 Renewables Academy

International Renewable Energy Conferences

2011
Global Status Report on Local Renewable Energy Policies

2012

2013
Global Futures Report
MENA Renewable Energy Status Report
ADIREC, Abu Dhabi International Renewable Energy Conference

2014
ECOWAS Renewable Energy and Energy Efficiency Status Report
First REN21 Renewables Academy, Bonn

2015
SADC and UNECE Renewable Energy and Energy Efficiency Status Reports
Renewables Interactive Map revamp
SAIREC, South Africa International Renewable Energy Conference

2016
EAC Renewable Energy and Energy Efficiency Status Report

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SUSTAINABLE
ENERGY FOR ALL

The UN Secretary-General's initiative Sustainable Energy for All mobilises global action to achieve universal access to modern energy services, double the global rate of improvement in energy efficiency and double the share of renewable energy in the global energy mix by 2030. REN21's Renewables *2016 Global Status Report* contributes to this initiative by demonstrating the role of renewables in increasing energy access. A chapter on distributed renewable energy – based on input from local experts primarily from developing countries – illustrates how renewables are providing needed energy services and contributing to a better quality of life through the use of modern cooking, heating/cooling and electricity technologies. REN21 is working closely with the SE4All initiative towards achieving the three objectives of the Decade for Sustainable Energy for All (2014–2024).

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The *Global Trends in Renewable Energy Investment* report (GTR), formerly *Global Trends in Sustainable Energy Investment*, was first published by the Frankfurt School–UNEP Collaborating Centre for Climate & Sustainable Energy Finance in 2011. This annual report was produced previously (starting in 2007) under UNEP's Sustainable Energy Finance Initiative (SEFI). It grew out of efforts to track and publish comprehensive information about international investments in renewable energy. The latest edition of this authoritative annual report tells the story of the most recent developments, signs and signals in the financing of renewable power and fuels. It explores the issues affecting each type of investment, technology and type of economy. The GTR is produced jointly with Bloomberg New Energy Finance and is the sister publication to the *REN21 Renewables Global Status Report* (GSR). The latest edition was released in March 2016 and is available for download at www.fs-unep-centre.org.

ES

Community energy fosters integrated energy concept

Ten years ago, citizens of Jühnde village – 770 inhabitants – aimed to demonstrate the economic and organisational feasibility of creating a community-driven bioenergy village. Having successfully installed a biogas-based CHP plant, the community's objective has shifted to optimising the plant's overall efficiency and flexibility, to allow for a complete use of the power and heat produced and to increase the income generated by the sale of surplus power. Bioenergy village Jühnde also aims to extend the energy use to the transport sector.

Jühnde, Germany | Created: 2006 | Members: 195

Solid biomass and biogas CHP plant (550 kW_{th}, 716 kW_{el}) – district heating network for 144 households

EXECUTIVE SUMMARY

GLOBAL OVERVIEW

An extraordinary year for renewable energy

The year 2015 was an extraordinary one for renewable energy, with the largest global capacity additions seen to date, although challenges remain, particularly beyond the power sector. The year saw several developments that all have a bearing on renewable energy, including a dramatic decline in global fossil fuel prices; a series of announcements regarding the lowest-ever prices for renewable power long-term contracts; a significant increase in attention to energy storage; and a historic climate agreement in Paris that brought together the global community.

Renewables are now established around the world as mainstream sources of energy. Rapid growth, particularly in the power sector, is driven by several factors, including the improving cost-competiveness of renewable technologies, dedicated policy initiatives, better access to financing, energy security and environmental concerns, growing demand for energy in developing and emerging economies, and the need for access to modern energy. Consequently, new markets for both centralised and distributed renewable energy are emerging in all regions.

2015 was a year of firsts and high-profile agreements and announcements related to renewable energy. These include commitments by both the G7 and the G20 to accelerate access to renewable energy and to advance energy efficiency, and the United Nations General Assembly's adoption of a dedicated Sustainable Development Goal on Sustainable Energy for All (SDG 7).

The year's events culminated in December at the United Nations Framework Convention on Climate Change's (UNFCCC) 21st Conference of the Parties (COP21) in Paris, where 195 countries agreed to limit global warming to well below 2 degrees Celsius. A majority of countries committed to scaling up renewable energy and energy efficiency through their Intended Nationally Determined Contributions (INDCs). Out of the 189 countries that submitted INDCs, 147 countries mentioned renewable energy, and 167 countries mentioned energy efficiency; in addition, some countries committed to reforming their subsidies for fossil fuels. Precedent-setting commitments to renewable energy also were made by regional, state and local governments as well as by the private sector.

Although many of the initiatives announced in Paris and elsewhere did not start to affect renewable markets in 2015, there already were signs that a global energy transition is under way. Renewable energy provided an estimated 19.2% of global final energy consumption in 2014, and growth in capacity and generation continued in 2015.

An estimated 147 gigawatts (GW) of renewable power capacity was added in 2015, the largest annual increase ever, while renewable heat capacity increased by around 38 gigawatts-thermal (GW_{th}), and total biofuels production also rose. This growth occurred despite tumbling global prices for all fossil fuels, ongoing fossil fuel subsidies and other challenges facing renewables, including the integration of rising shares of renewable generation, policy and political instability, regulatory barriers and fiscal constraints.

Global investment also climbed to a new record level, in spite of the plunge in fossil fuel prices, the strength of the US dollar (which reduced the dollar value of non-dollar investments), the continued weakness of the European economy and further declines in per unit costs of wind and solar photovoltaics (PV). For the sixth consecutive year, renewables outpaced fossil fuels for net investment in power capacity additions.

Private investors stepped up their commitments to renewable energy significantly during 2015. The year witnessed both an increase in the number of large banks active in the renewables sector and an increase in loan size, with major new commitments from international investment firms to renewables and energy efficiency. New investment vehicles – including green bonds, crowdfunding and yieldcos – expanded during the year. Mainstream financing and securitisation structures also continued to move into developing country markets as companies (particularly solar PV) and investors sought higher yield, even at the expense of higher risk.

In parallel with growth in markets and investments, 2015 saw continued advances in renewable energy technologies, ongoing energy efficiency improvements, increased use of smart grid technologies and significant progress in hardware and software to support the integration of renewable energy, as well as progress in energy storage development and commercialisation. The year also saw expanded use of heat pumps, which can be an energy-efficient solution for heating and cooling.

Employment in the renewable energy sector (not including large-scale hydropower) increased in 2015 to an estimated 8.1 million jobs (direct and indirect). Solar PV and biofuels provided the largest numbers of renewable energy jobs. Large-scale hydropower accounted for an additional 1.3 million direct jobs. Considering all renewable energy technologies, the leading employers in 2015 were China, Brazil, the United States and India.

POWER SECTOR

Record year for solar PV and wind, transformation accelerates

The power sector experienced its largest annual increase in capacity ever, with significant growth in all regions. Wind and solar PV had record additions for the second consecutive year, accounting for about 77% of new installations, and hydropower represented most of the remainder. The world now adds more renewable power capacity annually than it adds (net) capacity from all fossil fuels combined. By the end of 2015, renewable capacity in place was enough to supply an estimated 23.7% of global electricity, with hydropower providing about 16.6%.

Around the world, technical, economic and market transformation of the electric power sector continued to accelerate, and many countries have begun to respond to the challenge of grid integration. Technological advances, expansion into new markets with better resources, and improved financing conditions continued to reduce costs in 2015.

Electricity from hydro, geothermal and some biomass power sources has been broadly competitive with power from fossil fuels for some time; in favourable circumstances (i.e., with good resources and a secure regulatory framework), onshore wind and solar PV also are cost-competitive with new fossil capacity, even without accounting for externalities. In 2015 and early 2016, expectations of further cost improvements were made evident by record-low winning bids in power auctions in places ranging from Latin America, to the Middle East and North Africa region, to India.

Globally, renewable electricity production in 2015 continued to be dominated by large (e.g., megawatt-scale and up) generators that are owned by utilities or large investors. At the same time, there are markets where distributed, small-scale generation has taken off, or is starting to do so. Bangladesh is the world's largest market for solar home systems, and other developing countries (e.g., Kenya, Uganda and Tanzania in Africa; China, India and Nepal in Asia; Brazil and Guyana in Latin America) are seeing rapid expansion of small-scale renewable systems, including renewables-based mini-grids, to provide electricity for people living far from the grid. Developed countries and regions – including Australia, Europe, Japan and North America – have seen significant growth in numbers of residential and industrial electricity customers who produce their own power.

HEATING AND COOLING SECTOR

Increasing awareness, but challenges continue to inhibit growth rates

Modern renewable energy supplies approximately 8% of final energy for heating and cooling services worldwide in buildings and industry, the vast majority of which is provided by biomass, with smaller contributions from solar thermal and geothermal energy. However, approximately three-quarters of global energy use for heat is fossil fuel-based.

Although the total capacity and generation of renewable heating and cooling technologies continued to rise, 2015 saw global growth rates decline, due in part to low global oil prices. Trends differed substantially by region, however. Solar energy was integrated into a number of district heating systems in 2015, largely in Europe. While there is growing interest in district cooling systems, the use of renewable energy in these systems is as of yet rare.

Policy support for renewable heating and cooling remained far below support in other sectors. Overall, despite ongoing challenges to renewable heating and cooling markets in 2015, there were international signals that awareness and political support for related technologies may be growing.

TRANSPORT SECTOR

Advances in new markets, applications and infrastructure

Renewable energy accounted for an estimated 4% of global fuel for road transport in 2015. Liquid biofuels continued to represent the vast majority of the renewable energy contribution to the transport sector. The year saw advances in new markets and applications, such as aviation biofuels.

Infrastructure for compressed natural gas vehicles and fuelling stations continued to spread, creating further opportunities for integrating biomethane, particularly in Europe. Electric mobility research advanced, with a number of announcements regarding new developments in both light- and heavy-duty electric vehicles (EVs), while exploration of methods to integrate renewable energy into EV charging stations also continued to expand.

Policy support for renewable energy in the transport sector continues to lag behind such support in the power sector.

RENEWABLE ENERGY INDICATORS 2015

		2014	2015
INVESTMENT			
New investment (annual) in renewable power and fuels[1]	billion USD	273	**285.9**
POWER			
Renewable power capacity (total, not including hydro)	GW	665	**785**
Renewable power capacity (total, including hydro)	GW	1,701	**1,849**
Hydropower capacity[2]	GW	1,036	**1,064**
Bio-power capacity[3]	GW	101	**106**
Bio-power generation (annual)	TWh	429	**464**
Geothermal power capacity	GW	12.9	**13.2**
Solar PV capacity	GW	177	**227**
Concentrating solar thermal power capacity	GW	4.3	**4.8**
Wind power capacity	GW	370	**433**
HEAT			
Solar hot water capacity[4]	GW_{th}	409	**435**
TRANSPORT			
Ethanol production (annual)	billion litres	94.5	**98.3**
Biodiesel production (annual)	billion litres	30.4	**30.1**
POLICIES			
Countries with policy targets	#	164	**173**
States/provinces/countries with feed-in policies	#	110	**110**
States/provinces/countries with RPS/quota policies	#	98	**100**
Countries with tendering / public competitive bidding[5]	#	60	**64**
Countries with heat obligation/mandate	#	21	**21**
Countries with biofuel mandates[6]	#	64	**66**

[1] Investment data are from Bloomberg New Energy Finance and include all biomass, geothermal and wind power generation projects of more than 1 MW; all hydro projects of between 1 and 50 MW; all solar power projects, with those less than 1 MW estimated separately and referred to as small-scale projects or small distributed capacity; all ocean energy projects; and all biofuel projects with an annual production capacity of 1 million litres or more.

[2] The GSR 2015 reported a global total of 1,055 GW of hydropower capacity at end-2014. The value of 1,036 GW shown here reflects the full difference between end-2015 capacity (1,064 GW) and new installations in 2015 (28 GW). Capacity at end-2014 may have been greater than 1,036 GW considering an undetermined amount of capacity retirements and plant repowering during the year. Note also that the GSR strives to exclude pumped storage capacity from hydropower capacity data.

[3] Bio-power capacity for 2014 was adjusted upwards relative to data in GSR 2015 to reflect the most recent data available.

[4] Solar hot water capacity data include water collectors only. The number for 2015 is a preliminary estimate.

[5] Data for tendering / public competitive bidding reflect all countries that have held tenders at any time up to the year of focus.

[6] Biofuel policies include policies listed both under the biofuels obligation/mandate column in Table 4 (Renewable Energy Support Policies) and in Reference Table R25 (National and State/Provincial Biofuel Blend Mandates). Countries are considered to have policies when at least one national or state/provincial-level policy is in place.

Note: All values are rounded to whole numbers except for numbers <15, biofuels and investment, which are rounded to one decimal point.

POLICY LANDSCAPE

The vast majority of countries worldwide had renewable energy support policies in place by the end of 2015. These policies received increased interest during the year, due in large part to the global effort to mitigate global climate change during COP21 in Paris.

The total number of countries with renewable energy policies increased again in 2015. As of year-end 2015, at least 173 countries had renewable energy targets (not considering INDCs), and an estimated 146 countries had renewable energy support policies, at the national or state/provincial level. Several jurisdictions raised the ambition of their targets and strengthened their policies, although many weakened their support for renewables.

POLICIES FOR ELECTRICITY

Electricity continues to dominate policy makers' focus

Policy makers continued to focus predominantly on renewable power generation technologies, particularly solar PV and wind power. As of year-end 2015, 110 jurisdictions at the national or state/provincial level had enacted feed-in policies, making this the most widely adopted regulatory mechanism to promote renewable power.

Tendering has gained significant momentum in recent years and is preferred to feed-in policies in a growing number of countries. By the end of 2015, at least 64 countries had held renewable energy tenders, with record bids in terms of both low price and high volume seen across the world's developing and emerging countries. European countries also are transitioning to tendering, reflecting the shift in EU policy.

In addition, 52 countries had adopted net metering / net billing policies, including four new policies adopted at the national level and five added at the state/provincial level. Fiscal policies, including grants, loans and tax incentives, continued to be important tools for promoting the deployment of new projects and the advanced development of renewable energy technologies. Many countries use a combination of these policies to advance renewables in the power sector.

POLICIES FOR HEATING AND COOLING

Policy support remains well below other sectors

The slow pace of adoption of policies to support renewable heating and cooling technologies continued throughout 2015. Policies that have been adopted are directed mainly towards renewable heating technologies rather than renewable cooling, and they focus primarily on smaller-scale solar thermal heating options in residential and commercial buildings, such as solar water heaters.

An estimated 47 countries worldwide had targets for renewable heating or cooling in place by the end of 2015. Renewable heating targets were included in the INDCs submitted to the UNFCCC by Bosnia and Herzegovina, Jordan and Malawi. At least 21 countries had mandates for renewable heating and cooling technologies during the year, and no new ones were added at the national or state/provincial level. Due to the slow progress in adopting regulatory support, fiscal incentives remain the primary mechanism that policy makers use to support the renewable heating and cooling sectors.

RENEWABLE ENERGY TRANSPORT POLICIES

Slow development and shifting support to second-generation biofuels

Nearly all policies adopted in the renewable transport sector in 2015, as in past years, were directed at road transport through support for biofuels production and use. Policies to promote the integration of renewable energy and electric vehicles, as well as the use of renewables in aviation, rail or shipping, have been slow to develop.

As of year-end 2015, biofuel mandates were in place in 66 countries at the national or state/provincial level. Support has shifted increasingly towards the promotion of advanced biofuels, although, globally, most policies adopted to date focus primarily on first-generation biofuels.

CITY AND LOCAL GOVERNMENT RENEWABLE ENERGY POLICIES

Continuing to lead with innovative policies

Cities and municipalities continued to expand their influence as leaders in the global energy transition. The important role of municipal governments and local-level climate-based commitments in promoting deployment of renewable energy technologies on a large scale was highlighted as an important component of the COP21 climate negotiations in Paris.

Cities relied on a mix of regulatory policies, mandates and direct purchasing to support the deployment of renewable energy within their jurisdictions.

In 2015, some cities – such as Amsterdam (Netherlands) and Graz (Austria) – committed to developing their renewable heat sectors, while others – including Cape Town (South Africa) and Banff (Canada) – adopted regulatory measures to promote renewable power. In the transport sector, some national governments (including Kenya, Mexico and Vietnam) introduced biofuel blend mandates as pilot initiatives in cities.

The 100% Renewable Energy movement expanded in 2015 with new members including Byron Shire, Coffs Harbour and Uralla in Australia; Oxford County and Vancouver in Canada; and the US cities of Rochester (Minnesota) and San Diego (California). The list of cities around the world that have committed to achieving a 100% renewable electricity or energy (across all sectors) system is growing rapidly.

Cities continued to work together to advance their common renewable energy goals through their membership in several high-profile global and regional partnerships, such as the Covenant of Mayors and the Compact of Mayors.

TOP FIVE COUNTRIES

Annual investment / net capacity additions / biofuel production in 2015

	1	2	3	4	5
Investment in renewable power and fuels (not including hydro > 50 MW)	**China**	United States	Japan	United Kingdom	India
Investment in renewable power and fuels per unit GDP[1]	**Mauritania**	Honduras	Uruguay	Morocco	Jamaica
Geothermal power capacity	**Turkey**	United States	Mexico	Kenya	Germany/Japan
Hydropower capacity	**China**	Brazil	Turkey	India	Vietnam
Solar PV capacity	**China**	Japan	United States	United Kingdom	India
Concentrating solar thermal power (CSP) capacity[2]	**Morocco**	South Africa	United States	–	–
Wind power capacity	**China**	United States	Germany	Brazil	India
Solar water heating capacity	**China**	Turkey	Brazil	India	United States
Biodiesel production	**United States**	Brazil	Germany	Argentina	France
Fuel ethanol production	**United States**	Brazil	China	Canada	Thailand

Total capacity or generation as of end-2015

	1	2	3	4	5
POWER					
Renewable power (incl. hydro)	**China**	United States	Brazil	Germany	Canada
Renewable power (not incl. hydro)	**China**	United States	Germany	Japan	India
Renewable power capacity *per capita* (among top 20, not including hydro[3])	**Denmark**	Germany	Sweden	Spain	Portugal
Biopower generation	**United States**	China	Germany	Brazil	Japan
Geothermal power capacity	**United States**	Philippines	Indonesia	Mexico	New Zealand
Hydropower capacity[4]	**China**	Brazil	United States	Canada	Russian Federat.
Hydropower generation[4]	**China**	Brazil	Canada	United States	Russian Federat.
CSP	**Spain**	United States	India	Morocco	South Africa
Solar PV capacity	**China**	Germany	Japan	United States	Italy
Solar PV capacity *per capita*	**Germany**	Italy	Belgium	Japan	Greece
Wind power capacity	**China**	United States	Germany	India	Spain
Wind power capacity *per capita*	**Denmark**	Sweden	Germany	Ireland	Spain
HEAT					
Solar water heating collector capacity[5]	**China**	United States	Germany	Turkey	Brazil
Solar water heating collector capacity *per capita*[5]	**Austria**	Cyprus	Israel	Barbados	Greece
Geothermal heat capacity[6]	**China**	Turkey	Japan	Iceland	India
Geothermal heat capacity *per capita*[6]	**Iceland**	New Zealand	Hungary	Turkey	Japan

[1] Countries considered include only those covered by Bloomberg New Energy Finance (BNEF); GDP (at purchasers' prices) data for 2014 from World Bank. BNEF data include the following: all biomass, geothermal and wind generation projects of more than 1 MW; all hydropower projects of between 1 and 50 MW; all solar power projects, with those less than 1 MW estimated separately and referred to as small-scale projects or small distributed capacity; all ocean energy projects; and all biofuel projects with an annual production capacity of 1 million litres or more. Small-scale capacity data used to help calculate investment per unit of GDP cover only those countries investing USD 200 million or more.

[2] Only three countries brought concentrating solar thermal power (CSP) plants online in 2015, which is why no countries are listed in places 4 and 5.

[3] Per capita renewable power capacity ranking considers only those countries that place among the top 20 worldwide for total installed renewable power capacity, not including hydropower. Several other countries including Austria, Finland, Ireland and New Zealand also have high per capita levels of non-hydro renewable power capacity, with Iceland likely the leader among all countries. Population data are for 2014 and are from the World Bank.

[4] Country rankings for hydropower capacity and generation differ because some countries rely on hydropower for baseload supply whereas others use it more to follow the electric load and to match peaks in demand.

[5] Solar water heating collector rankings for total capacity and per capita are for year-end 2014 and are based on capacity of water (glazed and unglazed) collectors only. Data from IEA SHC. Total capacity rankings are estimated to remain unchanged for year-end 2015.

[6] Not including heat pumps.

Note: Most rankings are based on absolute amounts of investment, power generation capacity or output, or biofuels production; if done on a per capita, national GDP or other basis, the rankings would be different for many categories (as seen with per capita rankings for renewable power, solar PV, wind power and solar water collector capacity).

MARKET AND INDUSTRY TRENDS

BIOMASS ENERGY:
Continued growth but challenges remain

Bioenergy production continued to increase in 2015, helping to meet rising energy demand in some countries and contributing to environmental objectives. However, the sector also faced a number of challenges, in particular from low oil prices and policy uncertainty in some markets.

Bio-heat production for buildings and industrial uses grew slowly in 2015, with modern uses of bio-heat rising by approximately 3% from 2014 levels. There has been marked growth in the use of biomass for district heating in the Baltic and Eastern European regions. The use of bio-power has increased more quickly – averaging some 8% annually – with rapid growth in generation notable in China, Japan, Germany and the United Kingdom.

Ethanol production increased by 4% globally, with record production levels in the United States and Brazil. Global production of biodiesel fell slightly due to constrained production in some Asian markets, although growth continued in the major producing countries (the United States and Brazil). Blend mandates sheltered demand for biofuels from falling fossil fuels prices, but uncertainty about future markets constrained investment in new production capacity during the year.

2015 saw continuing progress in the commercialisation and development of advanced biofuels, with expansion in the capacity and production of fuels by both thermal and biological routes.

GEOTHERMAL POWER AND HEAT:
Steady growth hampered by low fossil fuel prices and high development risk

About 315 MW of new geothermal power capacity came online in 2015, bringing the global total to 13.2 GW. Geothermal power generated an estimated 75 terawatt-hours (TWh) during the year. Low fossil fuel prices, coupled with perpetually high project development risk, created unfavourable conditions for geothermal power. Turkey led the market, commanding about half of new global capacity additions.

Geothermal direct use amounted to an estimated 272 petajoules (75 TWh) of heat energy in 2015. An estimated 1.2 GW_{th} was added in 2015 for a total capacity of 21.7 GW_{th}. The average annualised growth rate in direct use geothermal heat consumption has been a little over 3% in recent years.

HYDROPOWER:
Industry responds to climate risk and rising shares of variable renewables

Approximately 28 GW of new hydropower capacity (excluding pumped storage) was commissioned in 2015, increasing total global capacity to about 1,064 GW. It is estimated that global generation rose to about 3,940 TWh. Persistent droughts continued to adversely affect hydropower output in many regions, including the Americas and Southeast Asia. China's domestic market continued to contract, but the country retained the global lead by a wide margin, with 16 GW added. Significant capacity also was added in Brazil, Turkey, India, Vietnam, Malaysia, Canada, Colombia and Lao PDR.

Climate risk and growing shares of variable renewable power are driving further adaptation in the hydropower industry. Modernisation, retrofits and expansion of existing facilities continued in many markets to improve efficiency, flexibility and system resilience. Responses to rising shares of variable renewables have included an increased emphasis on pumped storage and co-implementation of hydropower with solar and wind power.

OCEAN ENERGY:
Development continues in wave and tidal current technologies

Ocean energy capacity, mostly tidal power, remained at about 530 megawatts (MW) in 2015. The year presented a mixture of tail- and headwinds for the ocean energy industry. A number of companies continued to successfully advance their technologies and to deploy new or improved devices, mostly in European waters. However, at least one company had to declare bankruptcy, and the industry as a whole continued to face a constrained financial landscape beyond public funding. As in most years, ocean energy technology deployments in 2015 were predominantly demonstration projects, with most activity concentrated in tidal energy technologies, followed by wave energy conversion devices.

SOLAR PV:
Record deployment and rapid expansion into new markets

The solar PV market was up 25% over 2014 to a record 50 GW, lifting the global total to 227 GW. The annual market in 2015 was nearly 10 times the world's cumulative solar PV capacity of a decade earlier. China, Japan and the United States again accounted for the majority of capacity added, but emerging markets on all continents contributed significantly to global growth, driven largely by the increasing cost-competitiveness of solar PV.

An estimated 22 countries had enough capacity at end-2015 to meet more than 1% of their electricity demand, with far higher shares in some countries (e.g., Italy 7.8%, Greece 6.5% and Germany 6.4%). China achieved 100% electrification, in part because of significant off-grid solar PV installed since 2012; on-grid, however, curtailment of solar generation started to become a serious challenge for China's solar PV sector.

The industry recovery of recent years strengthened further due to the rise of new markets and strong global demand, and most top-tier companies were back on their feet in 2015. Record-low bids for large-scale solar PV projects were seen in tenders from Latin America to the Middle East to India. Distributed rooftop solar PV remains more expensive than large-scale projects but has followed similar price trajectories and is competitive with retail prices in many locations.

SOLAR THERMAL HEATING AND COOLING:
Continued slowdown in China and Europe, but increased deployment of large-scale projects

Global capacity of glazed and unglazed solar thermal collectors rose by more than 6% in 2015, despite a market slowdown due primarily to the continued contraction of markets in China and Europe. China accounted for about 77% of newly installed solar water heater capacity, followed by Turkey, Brazil, India and the United States. Cumulative capacity of water collectors reached an estimated 435 GW_{th} by year's end (with air collectors adding another 1.6 GW_{th}), enough capacity to provide approximately 357 TWh of heat annually.

Market development varied widely from country to country. Denmark, Israel, Mexico, Poland and Turkey reported significant growth. By contrast, low oil and gas prices in Europe and the ongoing slowdown in housing construction in China dampened these markets. Even so, several European solar thermal manufacturers managed to increase their sales by developing new business models, offering heat supply contracts or energy service company (ESCO) contracts, or offering extended finance periods.

2015 saw increasing interest in and deployment of large-scale solar thermal systems in district heating networks and for industrial use. Large investments signalled a new era with the start of the construction of a 1 GW_{th} solar process heat plant in Oman.

CONCENTRATING SOLAR THERMAL POWER (CSP):
Marked shift to developing regions, increasing importance of thermal energy storage

Morocco (160 MW), South Africa (150 MW) and the United States (110 MW) all brought new CSP facilities online in 2015, raising total global capacity by about 10% to nearly 4.8 GW. The new facilities represent a mix of parabolic trough and tower technologies, and all incorporate thermal energy storage (TES). By year's end, additional CSP capacity was under construction in Morocco (350 MW), South Africa (200 MW), Israel (121 MW), Chile (110 MW), Saudi Arabia (100 MW), China (50 MW) and India (25 MW), reflecting a shift from traditional markets (Spain and the United States) to developing regions with high direct normal insolation levels.

Industrial capacity continued to expand in developing regions, supported in part by local content requirements associated with CSP procurement programmes. Large facilities (greater than 100 MW) are increasingly the norm, as is the incorporation of TES and dry cooling technologies. CSP bid prices in national tenders continued to decline, most notably in South Africa and Morocco. Cost reduction and increased thermal efficiency were key areas of focus in several research and development (R&D) programmes around the world.

WIND POWER:
Largest source of new renewable power capacity; growing role in meeting electricity demand

Wind power was the leading source of new power generating capacity in Europe and the United States in 2015, and the second largest in China. Globally, a record 63 GW was added for a total of about 433 GW. Non-OECD countries were responsible for the majority of installations, led by China, and new markets emerged across Africa, Asia and Latin America. Corporations and other private entities continued turning to wind energy for reliable and low-cost power, while many large investors were drawn by its stable returns.

The offshore sector had a strong year with an estimated 3.4 GW connected to grids, mostly in Europe, for a world total exceeding 12 GW.

Wind power is playing a major role in meeting electricity demand in an increasing number of countries, including Denmark (42% of demand in 2015), Germany (more than 60% in four states) and Uruguay (15.5%).

The industry had another strong year, and most top turbine manufacturers broke their own annual installation records. To meet rising demand, new factories opened or were under construction around the world. Challenges included lack of transmission infrastructure and curtailment of wind generation (particularly in China).

DISTRIBUTED RENEWABLE ENERGY FOR ENERGY ACCESS

Positive market trends, innovative business models, increased investment

Approximately 1.2 billion people (constituting 17% of the global population) live without electricity, with the vast majority in the Asia-Pacific region and sub-Saharan Africa. Distributed renewable energy (DRE) systems continue to play an increasing role in providing energy services to these populations.

Advances in technology, increased awareness of deforestation and enhanced government support enabled the expansion of DRE in the cooking and heating sector in 2015. By year's end, approximately 28 million households worldwide were using clean cook stoves.

DRE solar PV markets also continued to flourish. Roughly 44 million off-grid pico-solar products had been sold globally by mid-2015, representing an annual market of USD 300 million. About 70 countries worldwide either had some off-grid solar PV capacity installed or had programmes in place to support off-grid solar PV applications by the end of 2015. In addition, several thousand renewables-based mini-grids were in operation, with primary markets in Bangladesh, Cambodia, China, India, Morocco and Mali.

The year saw positive market trends and increased investment. Innovative business models also continued to mature, with expanding use of mobile payment systems and scratch cards, the "Powerhive" business model, pay-as-you-go micro-payment schemes and integrated service providers with products that range from simple solar lamps with radios and mobile phones, to aspirational items like televisions.

DRE deployment in 2015 was supported by a variety of policy types, such as auctions, dedicated electrification targets and initiatives related to clean renewable cooking. Fiscal and other incentives that focus on specific renewable energy technologies, such as exemptions on value-added tax (VAT) and import duties, also were in use to support DRE deployment.

Dozens of international actors, including at least 30 programmes and approximately 20 global networks, also were involved in deploying DRE in 2015. Many international programmes focus specifically on improving energy access with renewables, in Africa and elsewhere.

INVESTMENT FLOWS

A new record high; developing and emerging countries lead

Global new investment in renewable power and fuels climbed to a record USD 285.9 billion in 2015 (not including hydropower projects >50 MW[i]). This represents a rise of 5% compared to 2014 and exceeds the previous record (USD 278.5 billion) achieved in 2011. Including investments in hydropower projects larger than 50 MW, total new investment during 2015 in renewable power and fuels (not including renewable heating and cooling) was at least USD 328.9 billion.

In 2015, global investment in new renewable power capacity, at USD 265.8 billion[ii], was more than double the USD 130 billion allocated to new coal- and natural gas-fired power generation capacity. This difference in favour of renewables is the largest witnessed to date. If hydropower projects larger than 50 MW are considered, the spread between renewables and fossil fuel investment in new power capacity is even greater.

For the first time in history, total investment in renewable power and fuels in developing countries in 2015 exceeded that in developed economies. The developing world, including China, India and Brazil, committed a total of USD 156 billion (up 19% compared to 2014). China played a dominant role, increasing its investment by 17% to USD 102.9 billion, accounting for 36% of the global total. Renewable energy investment also increased significantly in India, South Africa, Mexico and Chile. Other developing countries investing more than USD 500 million in renewables in 2015 included Morocco, Uruguay, the Philippines, Pakistan and Honduras.

By contrast, renewable energy investment in developed countries as a group declined by 8% in 2015, to USD 130 billion. The most significant decrease was seen in Europe (down 21% to USD 48.8 billion), despite the region's record year of financing for offshore wind power (USD 17 billion, up 11% from 2014). In the United States, renewable energy investment (dominated largely by solar power) increased by 19% to USD 44.1 billion, the country's largest increase in dollar terms since 2011.

Investment in renewable energy has been weighted increasingly towards wind and solar power. Solar power was again the leading sector by far in terms of money committed during 2015, accounting for USD 161 billion (up 12% over 2014), or more than 56% of total new investment in renewable power and fuels. Wind power followed with USD 109.6 billion, or 38.3% of the total (up 4%). All technologies except solar and wind power saw investment decline relative to 2014: investment in biomass and waste-to-energy fell by 42% to USD 6 billion, small-scale hydropower fell by 29% to USD 3.9 billion, biofuels fell by 35% to USD 3.1 billion, geothermal energy fell by 23% to USD 2 billion, and ocean energy fell by 42% to USD 215 million.

ENERGY EFFICIENCY

Increased awareness, investment, policies and targets

Emphasis on activities to improve energy efficiency in all sectors increased during 2015 at all levels of government, as well as in the private sector. There is growing recognition worldwide that energy efficiency can play a key role in reducing energy-related emissions and that it can provide multiple economy-wide benefits – such as enhanced energy security, reduced fuel poverty and improved public health.

By the end of 2015, at least 146 countries had enacted some kind of energy efficiency policy, and at least 128 countries had one or more energy efficiency targets (not considering INDCs). Some policies attempt to harness the synergy between energy efficiency and renewable energy, as efficiency measures have the potential to enable a more rapid increase in renewable energy's share of global energy consumption.

Driven by structural changes and energy efficiency improvements among other factors, global primary energy intensity declined between 1990 and 2014 at an average annual rate of 1.5%, falling by more than 30% overall during this period. However, the global economy has expanded even more, and energy demand has risen steadily.

In the transport and industrial sectors, global energy intensity has declined over the past few decades. In the buildings sector, the relatively small but growing market for more-efficient building envelopes and materials is resulting in improved building energy performance, particularly in developed countries. Total energy demand for a number of appliance and equipment categories (e.g., computers, fans, motors) continues to rise, despite improvements in efficiency, due largely to a rapid increase in the use of electricity-consuming products.

Energy efficiency improvements reflect, in part, increasing investments. In 2013, global investment in energy efficiency totalled an estimated USD 130 billion, including the end-user categories of buildings, transport and industry as well as associated costs such as labour and taxes (but not fuel switching). In September 2015, 70 financial institutions from more than 20 countries – including national, regional and global banks – committed to increasing financing for energy efficiency investments.

Advancements also reflect increased use of support policies and programmes. A growing number of countries is setting energy efficiency targets and defining roadmaps; adopting new policies and updating existing legislation to advance energy efficiency; and expanding the coverage of standards and labelling programmes, with developing and emerging countries playing an increasing role in these trends. Several developed countries also have introduced new financial incentives to channel additional funding towards energy efficiency measures.

i Investment data do not include hydropower projects >50 MW, except where specified.

ii This number is for renewable power asset finance and small-scale projects. It differs from the overall total for renewable energy investment (USD 285.9 billion) provided elsewhere in the report because it excludes biofuels and some types of non-capacity investment, such as equity-raising on public markets and development R&D. In addition, it does not include investment in hydropower projects >50 MW.

01

Community energy for energy access and transportation

On the remote island of Fetlar, obtaining access to energy and fuel for transportation has been an ongoing challenge. Eager to reduce the costs of transporting and using imported fuel, residents brought the community-owned electric **Fetlar Minibus** to their island as a dial-a-ride service and installed three charging points. Since January 2016, two 25 kW wind turbines have been powering the minibus and providing power and heat to the local school and nursery.

Fetlar, Shetland Isles, United Kingdom | Created: 2013 | Members: 40-50
50 kW wind power capacity and charging stations for an electric minibus

01 GLOBAL OVERVIEW

The year 2015 was an extraordinary one for renewable energy, with the largest global capacity additions seen to date, although challenges remain, particularly beyond the power sector. The year saw several developments that all have a bearing on renewable energy, including a dramatic decline in global fossil fuel prices; a series of announcements regarding the lowest-ever prices for renewable power long-term contracts; a significant increase in attention to energy storage; and a historic climate agreement in Paris that brought together the global community.[1]

Renewables now are established around the world as mainstream sources of energy.[2] Rapid growth, particularly in the power sector, is driven by several factors including the improving cost-competitiveness of renewable technologies, dedicated policy initiatives, better access to financing, concerns about energy security and the environment, growing demand for energy in developing and emerging economies, and the need for access to modern energy.[3]

The year 2015 was one of firsts as well as of high-profile agreements and announcements related to renewable energy, including:

- In their Declaration on Climate Change, the G7 countries committed to strive "for a transformation of the energy sectors by 2050" and to "accelerate access to renewable energy in Africa and developing countries in other regions."[4]
- Renewables were on the G20[i] agenda for the first-ever G20 Energy Ministers meeting, where the high-level participants affirmed their commitment to renewable energy and energy efficiency.[5] The Ministers endorsed an 11-point Communiqué that included the adoption of a toolkit for a long-term sustainable and integrated approach to renewable energy deployment; the Communiqué was adopted by the full G20 summit in November.[6] Participants also agreed on a G20 Energy Access Action Plan for sub-Saharan Africa that highlights the huge renewable energy resources in the region and the importance of improving energy efficiency.[7]
- The United Nations (UN) General Assembly adopted 17 Sustainable Development Goals (SDGs) containing, for the first time, a dedicated goal on sustainable energy for all[ii].[8] This achievement was due in great part to the Sustainable Energy for All (SE4All) initiative[iii], which played a strong role in the SDG debate. Throughout 2015, SE4All continued its work to further global efforts to increase energy access and to implement the new SDG, working with numerous countries to develop pathways to promote its goals.[9]
- Twenty-five worldwide business networks representing more than 6.5 million companies from over 130 countries pledged in May to lead the global transition to a low-carbon, climate-resilient economy.[10] Late in the year, 409 investors representing more than USD 24 trillion in assets called on governments to provide stable, reliable and economically meaningful carbon pricing, to strengthen regulatory support for renewables and energy efficiency, and to develop plans to phase out fossil fuel subsidies.[11]
- A series of religious declarations released throughout the year – including the Pope's environmental encyclical, Laudato Si', as well as the Islamic, Hindu and Buddhist declarations on climate change – called on billions of people of faith to address climate change and to commit to a zero- or low-carbon future through renewable energy.[12]

The year's events culminated in December at the UN Climate Change Conference (COP21[iv]) in Paris, where 195 countries agreed to limit global warming to well below 2 degrees Celsius and a majority of countries committed to scaling up renewables and energy efficiency through their Intended Nationally Determined Contributions (INDCs).[13] (→ *See Sidebar 4 in Policy Landscape chapter.*) Although far more is needed to avoid the worst potential effects of climate change, there was a clear commitment from the global community to address the challenge, and many experts emerged with a sense that there is a strong international consensus to transition away from fossil fuels.[14]

Notable commitments included a US-China Joint Presidential Statement on Climate Change highlighting new domestic policy commitments involving renewables and energy efficiency, and a common vision for an ambitious global climate agreement in Paris.[15] The European Union (EU) committed to a binding regional target of at least 40% domestic reduction of greenhouse gas emissions by 2030 (from a 1990 baseline), complemented

i The UN-supported Group of 20 includes the world's 20 leading economies (19 individual countries plus the EU), which together account for more than 75% of global trade. The G20 was formed in 1999 to study, review and promote high-level discussion on policy issues relating to international financial stability.

ii SDG 7: "Ensure access to affordable, reliable, sustainable and modern energy for all" by 2030. This SDG (7.2) calls for increasing substantially the share of renewable energy in the energy mix and for doubling the global rate of improvement in energy efficiency. See http://sdgcompass.org/sdgs/sdg-7/.

iii SE4All aims to double the share of renewable energy in the global energy mix from a baseline share of 18% in 2010 to 36% in 2030. SE4All, "Tracking Progress," http://www.se4all.org/tracking-progress/.

iv The 21st annual session of the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC).

by renewable energy and energy efficiency targets.[16] The International Solar Alliance was launched by the presidents of France and India to unite more than 120 sun-drenched countries to accelerate solar energy deployment in order to enhance energy security and sustainable development, improve access to energy and advance living standards.[17]In parallel, precedent-setting, ambitious commitments to renewable energy were made at the regional, state and local levels in the lead-up to and during COP21 in Paris.[18] Heads of state of African nations launched the African Renewable Energy Initiative with the goal of achieving by 2030 as much as 300 gigawatts (GW) of renewable capacity (about twice the continent's total power capacity at end-2015).[19] The leaders of the Climate Vulnerable Forum, a broad global coalition of 30 nations (middle-income and least-developed nations, and small-island developing states), called for 100% renewable energy by 2050 in the Manila-Paris Declaration.[20]

The growing global movement for 100% renewables – driven by the imperative of addressing climate change, and the pursuit of local economic development and community-owned energy – also gained momentum from the Paris City Hall Declaration, which calls for 100% renewable energy or 80% reductions in greenhouse gas emissions by 2050. Nearly 1,000 city mayors from five continents signed the Declaration.[q21] Cities around the world have become important change makers in the renewable energy and climate arena, acting independently and collectively to share knowledge and achieve their goals.[22] (→ *See Policy Landscape chapter.*)

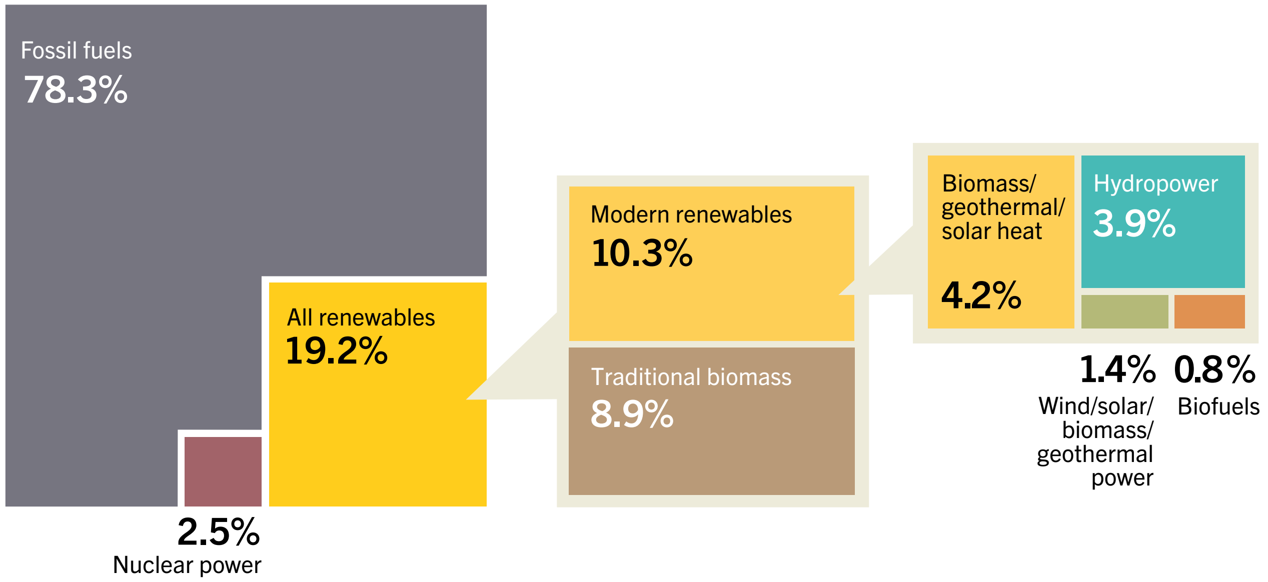
The private sector also strengthened its commitments to renewable energy in 2015.[23] As of December, 2,025 companies had publicly pledged to reduce their carbon emissions, many through the use of renewable energy and energy efficiency; this group includes 154 US companies, with nearly 11 million employees, that have committed to purchasing 100% renewable energy.[24] By year's end, more than 50 of the world's largest companies were participating in RE100, a global business initiative in which companies commit to getting 100% of their electricity from renewable sources.[25] Many companies are moving beyond the motivation of social responsibility to the view that renewables make good business sense.[26]

Although most of the initiatives announced in Paris and elsewhere did not start to affect renewable energy markets in 2015, there were already signs that a global energy transition is under way.[27] By some accounts, the annual growth in global carbon dioxide (CO_2) emissions stalled during 2014 and 2015, even as the global economy grew, due to industrial restructuring, improvements in energy efficiency and increased global deployment of renewable energy.[28] Further, per capita greenhouse gas emissions appear to be falling in 11 of the G20 economies, marking a possible shift in global trends.[29] Nonetheless, atmospheric concentrations of greenhouse gases continue to rise, due largely to increasing use of fossil fuels, and annual emissions are expected to continue climbing for some time in the developing world.[30]

As of 2014, renewable energy provided an estimated 19.2% of global final energy consumption. Of this total share, traditional biomass, used primarily for cooking and heating in remote and rural areas of developing countries, accounted for about 8.9%, and modern renewables (not including traditional biomass) increased their share slightly over 2013 to approximately 10.3%.[31] (→ *See Figure 1.*) In 2014, hydropower accounted for an estimated 3.9% of final energy consumption, other renewable power sources comprised 1.4%, renewable heat energy accounted for approximately 4.2% and transport biofuels provided about 0.8%.[32]Although the use of renewable energy is rising rapidly, the share of renewables

Figure 1. Estimated Renewable Energy Share of Global Final Energy Consumption, 2014

Source: See endnote 31 for this chapter.



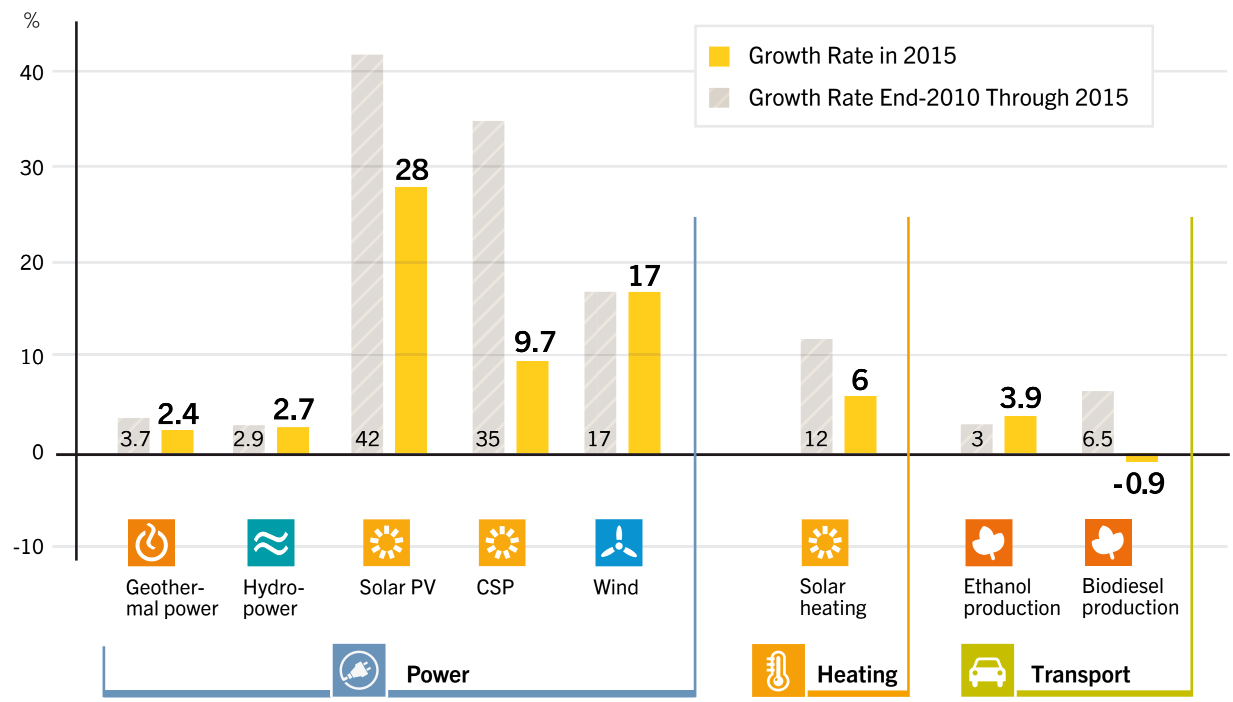
in total final energy consumption is not growing as quickly. In developed countries, energy demand growth is slow, and displacing the large stock of existing infrastructure and fuels takes time. In developing countries, energy demand growth is rapid, and fossil fuels play a significant part in meeting this rising demand. In addition, the shift away from traditional biomass for heating and cooking to modern, more-efficient renewables and fossil fuels, while in general a very positive transition, reduces overall renewable energy shares.[33] These "two worlds" into which modern renewables are making inroads present different political and policy challenges, economic structures, financial needs and availability, and other factors that delay or advance renewable energy deployment.[34]

Government policy continued to play an important role in renewable energy developments. The number of countries with renewable energy targets and support policies increased again in 2015, and several jurisdictions made their existing targets more ambitious. (→ *See Policy Landscape chapter.*) However, in some markets, policy changes and uncertainties (such as unexpected or retroactive changes, new taxes on renewable generators and uncertainties around the US federal Production Tax Credit for most of the year) undermined investor confidence and held up investment and deployment.[35] Despite the important contribution of the heating and transport sectors to energy demand and global emissions – together these sectors account for about two-thirds of final energy consumption and more than half of global greenhouse gas emissions – policy makers have focused predominantly on the power sector, a trend that has helped to shape the current landscape.[36]

Even in the face of ongoing fossil fuel subsidies and tumbling prices in 2015, renewable energy continued its rapid growth in both capacity added and energy produced. The power sector experienced the greatest increases in capacity, whereas growth of renewables in the heating and cooling and transport sectors was comparatively slow.[37] Solar photovoltaics (PV) and wind were the most dynamic markets, and hydropower continued to provide the majority of renewable power capacity and generation. Bioenergy remained the leader by far in the heat (buildings and industry) and transport sectors.[38]

Growth rates for various renewable energy technologies reflect a number of factors, including falling renewable energy technology costs and increasing competition for policy support and investment among different renewable technologies.[39] Low fossil fuel prices also affected growth rates, causing turbulence in some markets, particularly for renewable heating and cooling; biofuels were sheltered in many locations where mandates exist, although the low oil prices affected the appetite for new investment.[40] (→ *See Figure 2 and **Reference Table R1.***)

Figure 2. Average Annual Growth Rates of Renewable Energy Capacity and Biofuels Production, End-2010 to End-2015



Source: See endnote 40 for this chapter.

01

Global oil prices plummeted more than 70% between June 2014 and January 2016, due to oversupply and slowdown in economic growth in China and Europe.[41] Coal and natural gas prices were down as well.[42] While these trends affected markets for some renewables, they also highlighted the improving cost-competitiveness of solar and wind power.[43] Further, these trends reinforced concerns about the volatility of fossil fuel prices.[44]

The dramatic rise in global coal consumption that occurred over the past decade, due largely to China, appears to be slowing somewhat.[45] China's government announced plans to close more mines and to reduce coal's share of the energy mix in 2016, due in part to a virtual flat-lining in electricity demand; however, some countries – particularly in Asia – still have big plans for coal.[46] Other countries and regions have introduced regulations that could constrain coal use (e.g., the US Clean Power Plan), have announced plans to phase it out (including Austria, Finland, Portugal and the United Kingdom) or have already achieved phase-out targets (e.g., Ontario, Canada and Scotland).[47] In 2015, the United States (the world's second largest coal consumer after China) saw the acceleration of a downward trend in coal consumption.[48]

Low oil prices facilitated reductions in subsidies, but globally fossil fuel subsidies remained substantial – estimated at over USD 490 billion[i] (compared with USD 135 billion for renewables) in 2014 – and continued to temper renewable energy growth.[49] Other challenges faced by renewables in 2015 included the integration of rising shares of renewable generation, policy and political instability, regulatory barriers and fiscal constraints.[50] (→ *See, for example, Sidebar 1.)* In Europe, markets have slowed due in part to relatively high penetrations of renewables and to challenges related to their integration, but also to the ongoing shift in support policies that began during the financial crisis.[51] Elsewhere, national energy monopolies lack awareness of renewables or demonstrate resistance to their adoption, and in many economies concerns remain about how to integrate variable renewable generation.[52] In addition, in many developing countries, policy and political instability combined with corruption have made it difficult to access financing (particularly for energy access projects), which slows advances despite extensive renewable resources and positive technology developments.[53]Even so, markets continued their geographic spread, further establishing renewable energy as a mainstream energy source worldwide.[54] Although Europe remained an important regional market and a centre for innovation, activity continued to shift towards other regions. China again led the world in new renewable power capacity installations.[55] Many other countries – including Brazil, Chile, India, Mexico, Morocco and South Africa – accelerated their efforts in 2015, and the number of developing countries across Asia, Africa and Latin America that were manufacturing and deploying renewable technologies continued to expand.[56]

Employment and investment during 2015 followed the market expansion into new countries. The number of jobs in renewable energy rose again during 2015, reaching an estimated 8.1 direct and indirect jobs worldwide, plus an estimated 1.3 million direct jobs associated with large-scale hydropower.[57] (→ *See Sidebar 2.*)

Global investment climbed to a new record level. This occurred in spite of the plunge in fossil fuel prices, the strength of the US dollar (which reduced the dollar value of non-dollar investments), the continued weakness of the European economy and further declines in per unit costs of wind power and solar PV.[58] For the sixth consecutive year, renewables outpaced fossil fuels for net investment in power capacity additions.[59] However, the increase in investment was due entirely to increases in solar and wind power; investment in all other renewable power technologies, as well as biofuels, declined relative to 2014.[60]

Private investors stepped up their commitments to renewable energy significantly during 2015, and an increasing number of investors opted to divest from fossil fuels.[61] Some in the financial community backed away from coal due to its perceived high risk, and focused on clean energy.[62] The year witnessed both an increase in the number of large banks active in the renewables sector and an increase in loan size, with major new commitments from international investment firms to renewables and energy efficiency.[63]

New investment vehicles – including green bonds, crowdfunding and yieldcos – expanded during the year. Although their levels remained relatively small, green bonds supporting renewable energy (as well as energy efficiency) grew many-fold from 2012 to 2015 and have helped to address a major challenge for renewable energy financing: lack of liquidity.[64] Funding for emerging markets increased with the creation of innovative financial instruments for the African market and with the increase in financing of companies selling distributed energy products in Africa and India.[65] (→ *See Distributed Renewable Energy chapter.)* Mainstream financing and securitisation structures also continued to move into developing country markets as companies (particularly solar PV) and investors sought higher yield, even at the expense of higher risk.[66]

For the first time, developing countries, including China, were ahead of developed countries for total investment in renewable energy. Several developing countries saw substantial increases, due at least in part to rapidly expanding markets driven by falling solar and wind power technology costs, whereas developed countries as a group saw an 8% decline in investment. China alone accounted for more than one-third of the global total[ii] and was the first country to break the USD 100 billion threshold.[67] By dollars spent, the leading countries for investment were China, the United States, Japan, the United Kingdom, India, Germany, Brazil, South Africa, Mexico and Chile.[68] Considering investments made in new renewable power and fuels relative to annual GDP, top countries included Mauritania, Honduras, Uruguay, Morocco and Jamaica.[69] Among the leading countries for investment per inhabitant were Iceland, the United Kingdom, Uruguay, Japan and Ireland.[70] (→ *See Investment Flows chapter.*)

In parallel with growth in renewable energy markets and investments, 2015 saw continued advances in renewable energy technologies, including improvements in materials and efficiency

i International Energy Agency (IEA) estimates include subsidies to fossil fuels consumed by end-users and subsidies to consumption of electricity generated by fossil fuels. IEA, *World Energy Outlook 2015* (Paris: 2015), p. 96, http://www.worldenergyoutlook.org/weo2015/.

ii Note that this estimate does not include investment in hydropower projects >50 MW, which ranked third, behind solar and wind power, for total investment in 2015. See Frankfurt School–UNEP Collaborating Centre for Climate & Sustainable Energy Finance and Bloomberg New Energy Finance (BNEF), *Global Trends in Renewable Energy Investment 2016* (Frankfurt: March 2016), http://fs-unep-centre.org/publications/global-trends-renewable-energy-investment-2016. China was responsible for a large share of new large-scale hydropower capacity in 2015. (→ *See Hydropower section.*)

Sidebar 1. Regional Spotlight: South East Europe, Caucasus, Russian Federation and Central Asia

Over the past decade, 17 countries[i] in South East and Eastern Europe, the Caucasus, and Central Asia, as well as the Russian Federation – totalling over 300 million inhabitants – have started to leverage their considerable renewable energy potentials. Policies in most, but not all, of these countries have been driven by concerns about energy security and access to reliable, affordable, sustainable and modern energy. Moreover, numerous initiatives have been launched to promote energy efficiency improvements[ii]. It is worth noting, however, that renewable energy and efficiency initiatives in many of these countries were hampered by the impacts of the 2009 financial crisis on energy consumption and investments.

The economy-wide share of renewable energy used in these countries differs widely, ranging from 0% in Turkmenistan to 58% in Tajikistan (both based on 2012 data), with most countries in the 1-20% range. Where the shares are relatively high, this is due almost entirely to use of hydropower and/or biomass, with traditional use of biomass (for heating) still playing a significant role in several countries. In the power sector, Albania, Kyrgyzstan and Tajikistan rely almost exclusively on hydropower, whereas Georgia and Montenegro generate more than half of their electricity with hydropower. The Russian Federation produces more electricity from hydropower than any other country in the region, but hydropower's share of total generation is lower than that in some other countries due to the scale of the Russian Federation's total output.

Deployment of other renewable energy technologies for power generation in the region is nascent, with significant capacity only in Ukraine (mostly solar PV and onshore wind). However, sizable solar PV and onshore wind potential exists throughout the region, and large biomass resources exist in South East Europe, Eastern Europe and the Russian Federation. The potential for CSP and geothermal power (using high-temperature resources) is limited to a few areas, primarily in the Russian Federation.

The penetration of modern renewable technologies for heating and cooling is modest. While solar water heating could be deployed economically in all 17 countries, installations exist in only a few. The potential for biomass-based heat also is considerable, particularly through existing district heating networks. Despite the existence of biofuels targets (for heat and transport) in several countries, liquid biofuel production capacity currently is found only in Belarus (biodiesel), the former Yugoslav Republic of Macedonia (biodiesel) and Ukraine (ethanol).

On the policy front, some progress has been made in support of renewable energy and energy efficiency. For example, all countries but Turkmenistan have strategies outlining their priorities in at least one renewable energy technology, and all but Georgia and Turkmenistan have adopted renewable energy targets.

Most support policies in the region exist in the power sector, where feed-in tariffs are the most commonly used (in 12 countries), followed by tendering. Utility obligations and net metering have been adopted in four countries each. Montenegro is the only country among the 17 that has policies to support renewable heating and cooling. Although most renewable energy support policies in the region have been enacted at the national level, an increasing number of city and local governments are promoting renewable energy.

All 17 countries except Turkmenistan also have enacted regulatory policies to advance energy efficiency – most commonly in the building sector (including lighting and appliances), followed by transport and industry – and most have established efficiency targets. All but four countries have national energy efficiency awareness campaigns.

Despite these efforts, the 17 countries continue to represent only a small share – just 0.5% (USD 0.9 billion) in 2014 – of the world's total investment in renewable power capacity (not including hydropower >50 MW) and fuels. Investment in the region saw some positive developments during 2008-2011, driven by growth in Eastern Europe, followed by decline in 2013 and 2014. Numbers and trends might be quite different when large-scale hydropower (>50 MW) is included, but good data are not available.

From a global perspective, non-hydro renewable energy developments in the region remain marginal. Despite the great diversity in population size and economic, social and political characteristics, the energy systems of these countries all were developed in a similar manner, and renewables and energy efficiency face some common challenges across the region. These include considerable regulatory and investment barriers, as well as lack of awareness about renewable energy and energy efficiency. In many cases, legal frameworks are not considered stable and transparent enough to trigger large-scale private investment. Further, market entry remains challenging in countries that have not fully liberalised their energy markets. Large subsidies for fossil fuels and their abundance in some countries in the region continue to put renewable energy and energy efficiency projects at an economic disadvantage. Furthermore, entrenched interests in conventional energy resources in many countries represent a significant barrier to effective legislation and policy implementation.

Renewables and efficiency have advanced slowly in most of these countries over the past decade, and there is significant room for improvement. Across the region, policy implementation at all levels is hampered by the complexities of enforcing and monitoring the actions set out in supporting legislation, and local regulations often lack transparency and are unstable and inconsistent. The lack or incompleteness of statistical data on final energy production and use impedes the implementation of more-precise monitoring measures, as well as new investment in the region. In this regard, a critical look by legislators at the existing legal frameworks is necessary, in order to investigate if these structures create the stable investment conditions required by private investors.

Additional investment is required to enable the region to fully realise its renewable potential, particularly for efficient and sustainable heating, and for upgrades to ageing energy infrastructure. The need to replace ageing infrastructure also presents an opportunity to better integrate renewable energy and improve energy efficiency across the region's economies.

Source: See endnote 50 for this chapter.

i Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Montenegro, the Russian Federation, Serbia, Tajikistan, the former Yugoslav Republic of Macedonia, Turkmenistan, Ukraine and Uzbekistan.

ii The key messages of this sidebar are derived from REN21, *UNECE Renewable Energy Status Report* (Paris: December 2015), http://www.ren21.net/regional. Helpful illustrations of the content of this sidebar can be found in Figures 2, 5 and 13 and in Table 9.

of solar cells and modules, floating wind turbines, large-scale solar thermal district heating and cooling, and progress in pyrolysis and gasification of biomass. Ongoing energy efficiency advances, such as more-efficient lighting systems, are reducing the cost of providing energy services with renewable energy, whether on-grid or off-grid.[71] (→ *See Distributed Renewable Energy and Energy Efficiency chapters.*)

The year also brought advances in enabling technologies, such as hardware and software to support the integration of renewable energy. These included management systems that aim to optimise performance and energy storage.[72] The past few years have brought significant progress in the development and commercialisation of energy storage, driven largely by the growth in electric vehicle (EV) markets and in renewables (mainly solar and wind power). Development continued during 2015 in areas such as thermal storage for heating and refrigeration, and particularly for concentrating solar thermal power (CSP); conversion of electricity to heat or gas; compressed air; and batteries for EV propulsion and electricity storage.[73]

Batteries – including lithium-ion, graphene polymer and redox flow batteries – have been the main focus of investor and industry interest in storage.[74] Although cost remains a barrier to large-scale deployment, battery costs fell rapidly during 2010–2014, and their decline accelerated in 2015. For example, average costs for EV (lithium-ion) batteries fell 35% between the second half of 2014 and the second half of 2015.[75]

Modern renewable energy is being used increasingly in power generation, heating and cooling, and transport. The following sections discuss 2015 developments and trends in these sectors. For discussion of off-grid renewables for providing energy access in developing countries, see the Distributed Renewable Energy chapter.

POWER SECTOR

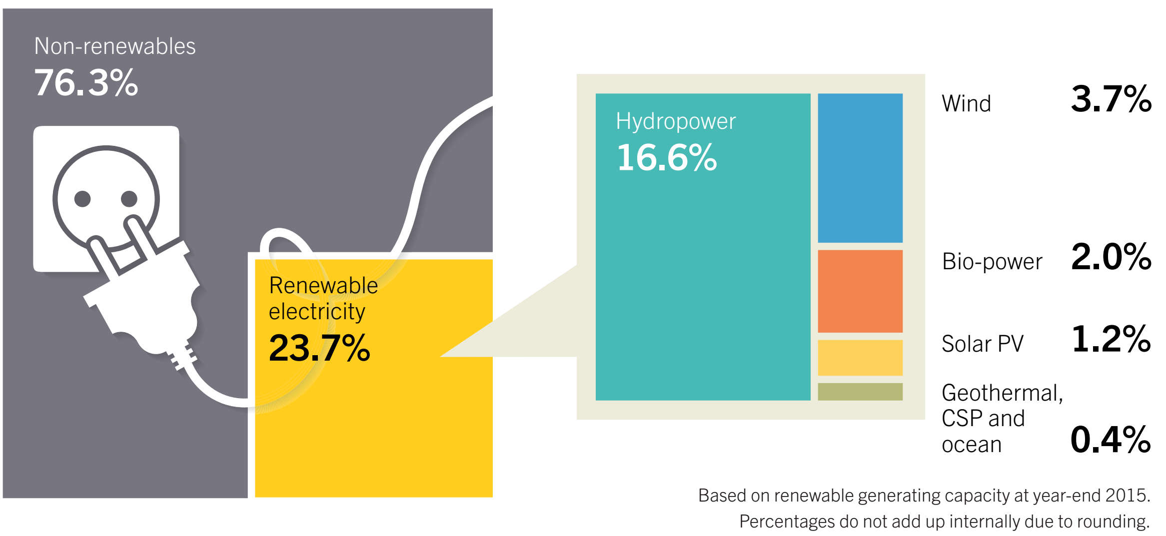
Renewable power generating capacity saw its largest annual increase ever in 2015, with an estimated 147 GW of renewable capacity added. Total global capacity was up almost 9% over 2014, to an estimated 1,849 GW at year's end.[76] Wind and solar PV both saw record additions for the second consecutive year, together making up about 77% of all renewable power capacity added in 2015.[77] Hydropower capacity rose by 2.7% to an estimated 1,064 GW, accounting for approximately 19% of additions.[78] (→ ***See Reference Table R1.***)

The world now adds more renewable power capacity annually than it adds (net) capacity from all fossil fuels combined.[79] In 2015, renewables accounted for an estimated more than 60% of net additions to global power generating capacity, and for far higher shares of capacity added in several countries around the world.[80] By year's end, renewables comprised an estimated 28.9% of the world's power generating capacity – enough to supply an estimated 23.7% of global electricity, with hydropower providing about 16.6%.[81] (→ *See Figure 3.*)

Technological advances, expansion into new markets with better resources, and improved financing conditions have reduced costs, particularly for wind and solar PV.[82] (→ *See Sidebar 3.)* Electricity from hydro, geothermal and some biomass power sources have been broadly competitive with fossil power for some time; in favourable circumstances (i.e., good resources and a secure regulatory framework), onshore wind and solar PV also are cost-competitive with new fossil capacity, even without accounting for externalities.[83] For example, wind power was the most cost-effective option for new grid-based power in 2015 in many markets, including Brazil, Canada, Mexico, New Zealand, South Africa, Turkey, and parts of Australia, China and the United States.[84]

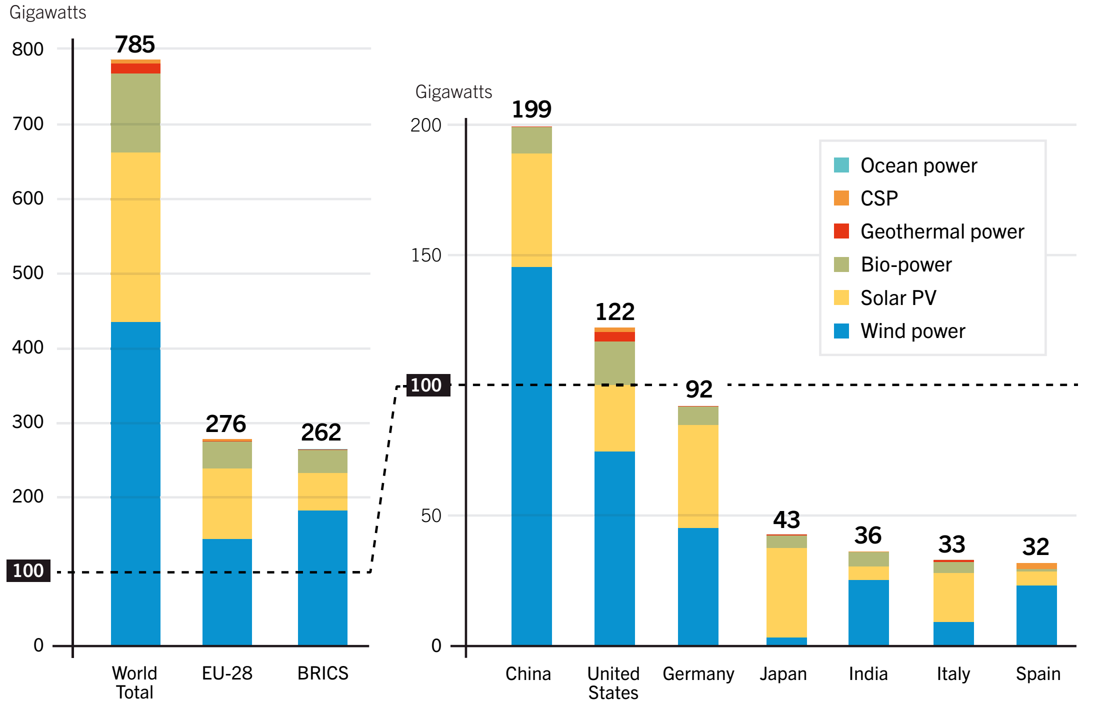
Expectations of further improvements were made evident in power auctions in 2015 and early 2016, with very low tender-generated prices for wind power in, for example, Egypt, Mexico, Morocco and Peru, and for solar PV in Chile, India, Mexico, Peru

Figure 3. Estimated Renewable Energy Share of Global Electricity Production, End–2015



Source: See endnote 81 for this chapter.

Figure 4. Renewable Power Capacities* in World, EU-28, BRICS and Top Seven Countries, End-2015



Source: See endnote 89 for this chapter.

* Not including hydropower (see Reference Table R2 for data including hydropower).

The five BRICS countries are Brazil, the Russian Federation, India, China and South Africa.

and the United Arab Emirates, rivalling new coal-fired capacity in these countries.[85] However, the economic competitiveness of renewable technologies still depends on regulatory framework and market design.[86]

By the end of 2015, the top countries for total installed renewable electric capacity continued to be China, the United States, Brazil, Germany and Canada.[87] China was home to more than one-quarter of the world's renewable power capacity – totalling approximately 495 GW, including about 296 GW of hydropower.[88] Considering only non-hydro[i] capacity, the top countries were China, the United States and Germany; they were followed by Japan, India, Italy and Spain.[89] (→ *See Figure 4 and* ***Reference Table R2.***) Among the world's top 20 countries for non-hydro renewable power capacity, those with the highest capacity amounts per inhabitant were Denmark, Germany, Sweden, Spain and Portugal[ii].[90]

Throughout the year, there were noteworthy developments in most regions:

- **Asia:** Of all regions, Asia installed the most renewable power generating capacity during 2015. China again led the world in additions of hydropower capacity, was a leader in bio-power capacity and set new world records for wind and solar power installations, although curtailment affected the potential for these assets to contribute to generation.[91] India also ranked among the top countries for solar PV, hydro and wind power capacity additions, and Japan was second only to China for new solar PV installations.[92] Turkey ranked first globally for new geothermal power capacity, third for new hydro and tenth for wind power capacity additions.[93] Other countries in the region – including Malaysia, Pakistan, the Philippines, the Republic of Korea, Thailand and Vietnam – have emerged as important markets for more than one renewable power technology.[94]
- **Europe:** Renewables accounted for the majority (77%) of new EU generating capacity for the eighth consecutive year, and the region continued to decommission more capacity from conventional sources than it installed.[95] Between 2000 and 2015, the share of renewables in the EU's total power capacity increased from 24% to 44%, and, as of 2015, renewables were Europe's largest source of electricity.[96] In Scotland, renewables met over half of electricity demand, a year ahead of an established target; throughout the United Kingdom, output from renewables hit a record high, passing coal for the first time in the fourth quarter of 2015.[97] In Germany, renewable power output increased by 20% in 2015, and the share of renewables in electricity consumption was 32.6% (up from 27.4% in 2014).[98] Even so, markets have slowed in most European countries due to reduced levels of financial support and to an increased focus on the integration of variable renewable generation.[99]

i Distinction of non-hydro capacity is made because hydropower remains the largest single component by far of renewable power capacity and output.

ii While there are other countries with high per capita amounts of renewable capacity and high shares of renewable electricity, the GSR focuses here on the top 20 countries for total installed capacity of non-hydro renewables. Several other countries, including Austria, Finland, Greece, Ireland and New Zealand, also have high per capita levels of non-hydro renewable power capacity, with Iceland likely the leader among all countries. (→ ***See Reference Table R17*** *for country shares of electricity from renewable sources.*)

- **North America:** In the United States, wind (8.6 GW) and solar (7.4 GW, solar PV and CSP) were the leading sources of new power capacity in 2015, exceeding natural gas capacity additions (about 6 GW).[100] Renewables accounted for nearly 13.7% of electricity generation (up from 13.4% in 2014), despite a 3.2% drop in hydropower output.[101] Canada continued to be a leader in hydropower development and ranked sixth globally for wind power capacity additions.[102]
- **Latin America and the Caribbean:** Countries across the region achieved high shares of their electricity generation with renewables: for example, Costa Rica generated 99% of its electricity with renewable sources, Uruguay generated 92.8% and Chile has quickly surpassed several long-term targets.[103] Latin America remained one of the fastest growing markets for wind energy and solar PV in 2015, albeit from a small base. Brazil was second globally for new hydropower and fourth for new wind power capacity (although the country has been challenged by lack of transmission capacity); Guatemala brought its first wind power plant online, and Mexico was one of the few countries worldwide to add geothermal power capacity in 2015.[104] Several countries – including Chile, Mexico and Peru – held successful tenders in 2015 and early 2016, resulting in some of the world's lowest bid prices, due in part to the region's vast renewable energy resources.[105]
- **Africa:** Many countries throughout Africa increased their policy commitments in the power sector during 2015. All renewable power generating technologies except ocean energy are being deployed across the continent, with significant markets on-grid as well as off-grid (for solar PV in particular). In 2015, several countries (including Ethiopia, Guinea and Zambia) brought new hydropower facilities online.[106] Morocco was the world's largest CSP market, South Africa was the first country on the continent to achieve 1 GW of solar PV and helped push the continent's wind power capacity above the 3 GW mark, and Kenya ranked fourth globally for new geothermal power capacity.[107] Across Africa, renewable power projects and technology manufacturing facilities were being planned or were under construction.[108]
- **Pacific:** Australia led the region in 2015 and was among the top 10 countries for newly installed solar PV, ending the year with the equivalent of one solar panel per inhabitant.[109] Renewables accounted for about 14.6% of Australia's electricity generation (up from 13.5% in 2014), despite a significant drop in hydropower generation.[110] Elsewhere in the region, Samoa installed its first wind farm, and Fiji saw the inauguration of some solar PV micro-grid projects.[111]
- **Middle East:** Relatively little renewable power capacity has been deployed in most countries of the region, but interest in CSP and solar PV, in particular, is growing rapidly.[112] Iraq, Jordan and the United Arab Emirates all held tenders for renewable power in 2015. Jordan brought its first utility-scale wind farm online, Israel led the region for solar PV capacity additions, and significant steps were taken towards domestic manufacturing of solar technologies in several countries, including Saudi Arabia.[113]

The rapid growth of renewable power generation created both challenges and opportunities in 2015. In countries where electricity consumption is expanding, both renewable energy and fossil fuel generation are being deployed to meet growing demand. In countries with slow or negative growth in electricity consumption (e.g., several OECD countries), renewable energy is increasingly displacing existing generation and disrupting traditional energy markets and business models.[114] In response to this competition, some incumbents are pushing back against supportive renewable power policies or adapting their business models by restructuring, consolidating or splitting.[115] Other utilities and electricity suppliers are repositioning by acquiring significant renewable energy assets, decreasing their fossil fuel investments, acquiring other utilities that already have significant amounts of renewable energy in their generation portfolios and moving into new markets.[116]

Around the world, technical, economic and market transformation of the electric power sector continued to accelerate in 2015.[117] Several factors are driving a transformation from centralised systems to more-complex systems that encompass a growing number of decentralised generating assets.[118] These factors include technological advances, social change, policy goals and, in particular, declining costs and increasing shares of variable wind and solar PV.[119] A key challenge is adapting the power grid to integrate rising shares of renewable generation, developing more-flexible systems to balance variable resources (on both the supply and demand sides) while minimising costs.[120]

Several jurisdictions – including Denmark, Germany, the state of South Australia and some US states – already have successfully integrated high shares of variable renewables.[121] Throughout 2015, variable renewables achieved high penetration levels in several countries: for example, wind power met 42% of electricity demand in Denmark, 23.2% in Portugal and 15.5% in Uruguay; and solar PV accounted for 7.8% of electricity demand in Italy, 6.5% in Greece and 6.4% in Germany.[122] Electric utilities also have successfully integrated very large shares over short time periods: for example, variable renewable generation reached new highs in Denmark, Germany and parts of the United States during the year.[123]

Many developed countries and some developing countries have begun to respond to the challenge of grid integration.[124] Strategies in 2015 included various combinations of: increased flexibility on the demand side and on the supply side (e.g., innovations in flexible fossil power plants; energy storage, particularly pumped storage; active power controls at wind and solar power plants); construction of new transmission networks; development of smarter grids; interconnection and co-ordination with neighbouring grids; advanced resource forecasting; integrated heating and cooling systems; and innovative market designs.[125]

Dispatchable renewable energy plants – including reservoir hydro, biomass and geothermal power (and CSP with storage) contributed to flexibility. System balancing also is served by new and upgraded transmission interconnections, such as the Skagerrak 4 interconnector between Norway and Denmark, which became operational in 2015. The interconnector was built to help balance Denmark's wind and thermal power and Norway's hydropower.[126] Innovative hybrid systems have emerged, such as the Longyangxia station in China, where 1,280 megawatts (MW) of hydropower is linked to a massive solar PV

facility (850 MW upon completion).[127] Further, advancements in inverter technologies are enabling solar and wind power to provide a range of balancing services.[128]

In addition, stationary battery storage continues to advance and costs are trending downwards.[129] Utility-scale storage in the power sector, not including pumped storage and lead-acid batteries, increased by a record 250 MW in 2015 (compared with an estimated 160 MW in 2014), and projects announced by the year's end totalled more than 1.2 GW.[130] Although tiny compared with up to 145 GW of pumped storage hydropower capacity – which accounts for about 97% of global storage capacity and continued to expand in 2015 – the market is growing quickly.[131] Most of the capacity is being installed in the developed world, but storage projects also are under way in developing countries, particularly in conjunction with mini-grids.[132]

The behind-the-meter storage (batteries) sector also took a great step forward in 2015 with some high-profile announcements and a host of companies competing for this small but rapidly growing market.[133] Such markets are developing in Australia, Germany, Japan, parts of the United States and elsewhere, particularly in combination with small-scale solar PV.[134] Innovative business and deployment models for integrating renewables and on-grid storage continued to emerge.[135]

Even so, in a growing number of regions and countries additional increases in variable renewable penetration will require changes to the grid system, regulations and market design.[136] To address such challenges in the EU, several initiatives are under way to advance grid integration in the region, including changes in electricity market designs.[137] In 2015, the German government issued a "white paper" proposing changes to the national electricity law and market.[138] In the United States, California continued development of a flexible ramping product (due to be launched in 2016), which aims to shift generation as-needed through a new market mechanism that allocates the extra costs of flexibility.[139]

Globally, renewable electricity production in 2015 continued to be dominated by large (e.g., megawatt-scale and up) generators that are owned by utilities or large investors.[140] Towards the end of 2015, more than half of global solar PV capacity was in projects of 4 MW and larger; the world's 50 largest solar PV plants in operation by early 2016 had a combined capacity exceeding 13.5 GW, and at least 33 of these facilities came online (or achieved full capacity) in 2015 and early 2016.[141] CSP and wind energy projects also are growing, as are wind turbines – the average-size turbine delivered to market in 2015 was 2 MW.[142] The hydropower industry is using ever-larger units; the single largest hydropower turbine under development by early 2016 has a capacity of 1 GW.[143]

At the same time, there are some markets where distributed, small-scale generation has taken off, or is starting to do so. Bangladesh is the world's largest market for solar home systems, and other developing countries (e.g., Kenya, Uganda and Tanzania in Africa; China, India and Nepal in Asia; Brazil and Guyana in Latin America) are seeing rapid expansion of small-scale renewable technologies for remote uses.[144] Developed countries and regions – including Australia, Europe, Japan and North America – have seen significant growth in numbers of residential electricity customers who produce their own power.[145]

Industrial auto-producers in developed and developing countries also generated significant amounts of renewable electricity (and heat) on site in 2015, particularly with waste biomass associated with forestry and agriculture.[146] A European Commission-funded effort was launched in 2015 to develop innovative business models and regulations to increase the flexibility of electricity demand by energy-intensive industries in order to facilitate the growth and integration of variable renewable energy, while reducing industrial electricity costs.[147]

In addition, mini- and micro-grids, increasingly driven by renewable systems, are being employed in island and other remote communities to replace diesel generators or to provide electricity access for the first time (e.g., in the US state of Alaska and parts of Australia, island communities in Malaysia, remote areas of India and southern Africa) or to achieve energy independence and a more-secure and -resilient electricity supply (e.g., in the US northeast in the wake of natural disasters such as Hurricane Sandy).[148] These may be isolated or connected to a wider grid.

Community and co-operative ownership of renewable power capacity also expanded in 2015.[149] Japan has seen a significant increase in community power projects since March 2011, interest in Australia is patchy but growing rapidly, and, in the United States, Community Choice Aggregation (which enables communities to contract with producers to tailor their own energy supply) is spreading beyond California.[150] In Europe, citizens in Croatia, France, Greece and Spain have started to invest in renewable energy co-operatives, but they lag behind northern European countries due to different legal contexts and lack of support mechanisms.[151] Denmark and Germany, in particular, have long traditions of community and local ownership of renewable energy systems, although Germany experienced a significant slowdown in 2015 due to policy revisions.[152] (→ *See Feature.*)

Major corporations and institutions around the world made large commitments in 2015 to purchase renewable electricity.[153] It was a record-setting year in the United States, where large corporate buyers are helping to drive the market for renewable power and represent a rising share of renewable energy power purchase agreements (PPAs).[154] In addition to PPAs and leases, some major companies are developing their own large-scale projects in the United States, Europe, Asia and elsewhere.[155] In early 2016, the world's biggest government contractor concluded a deal to buy solar power, joining a growing list of leading corporations (now also including industrial and manufacturing companies) signing deals for the first time in 2015 and early 2016.[156] Other big purchasers included municipalities (→ *See Policy Landscape chapter*), the US military and mining companies from Australia to Chile to South Africa.[157]

Voluntary purchases of renewable energy from traditional utilities also continued in some countries, including several countries in Europe as well as Australia and the United States.[158] In 2014 (latest available data), US voluntary retail green power sales totalled 74 terawatt-hours (TWh), up 10% over 2013, and represented about 2% of total US electricity sales.[159]

Through green purchasing, local ownership, and other means, increasing numbers of jurisdictions around the world aim to meet all of their electricity demand with renewable sources (the most common 100% target).[160] Several cities, states and countries made new commitments to 100% renewable power in 2015, while others reached their targets.[161] (→ *See Policy Landscape chapter.*) For example, Austria's largest state, Lower Austria, achieved its 100% goal, providing electricity for 1.65 million people with hydro, wind, biomass and solar power.[162] The German state of Schleswig-Holstein reached 100% net electricity from renewables during the year, as did several communities around the world.[163]

HEATING AND COOLING SECTOR

Energy use for heat accounted for about half of total world final energy consumption in 2015.[164] Global consumption of heat energy grew at an average annual rate of less than 1% in recent years.[165] Cooling demand also continued to increase in 2015 as a result of improved energy access and rising average global temperatures.[166]

Renewable energy is used to meet heating and cooling demands by means of solar, geothermal, aerothermal or hydrothermal[i], or biomass resources in solid, liquid and gaseous forms. Renewable technologies also can supply electricity that can be converted to heat. Because of an oversupply of electricity on the market at peak renewable energy production times, electrification of heat has received increasing attention, especially in Europe, although there were few concrete steps in this direction in 2015.[167]

In 2015, renewable energy's share of final energy use in the heat sector was 25%; of this share, more than two-thirds was traditional biomass, predominantly in the developing world.[168] Modern renewable energy supplied the remaining third – or approximately 8%.[169] Although the total amount of deployed renewable heating and cooling technologies is growing worldwide, annual growth rates are falling.[170] Low global oil prices resulted in a slowdown in investment in renewable energy heating and cooling during 2015.[171]

In the buildings sector, biomass and solar thermal energy account for the vast majority of modern renewable heat (with most recent estimates ranging from 7% to 10% of total heat demand combined). In the industry sector, bioenergy dominates renewable heat production (accounting for roughly 10% of total heat demand).[172]Trends in the use of renewable energy for heating vary by technology, although relative shares have remained stable in the past few years.

- Bioenergy accounted for over 90% of modern renewable heat generation in 2015.[173] In some regions – especially in European countries that import solid biomass – an ongoing discussion on the use of biomass for heat was spurred by the sustainability debate in the transport sector.[174]
- Solar thermal accounted for roughly 8% of modern renewable energy heat output. The year 2015 saw increasing interest in and deployment of large-scale solar systems in district heating networks; markets also expanded for solar process heat in industry (such as food and beverage as well as the copper industry, which has substantial demand for low-temperature heat).[175] However, most residential-scale solar thermal markets stagnated or declined due to low oil prices, a comparative dip in building construction in some regions and the low price of solar PV systems; exceptions included Denmark, Israel, Mexico, Poland and Turkey.[176]
- Geothermal heat represented the remaining 2% share of modern renewable heat generation. Over the past few years, direct use of geothermal heat, excluding heat pumps, has grown by over 3% annually on average, with geothermal space heating growing around 7% annually. China, Turkey, Japan and Iceland lead in terms of heat energy generated by direct use of geothermal.[177]

i Heat pumps utilise the ground, ambient air or water bodies for heating and cooling. The total share of renewable energy delivered by a heat pump on a primary energy basis depends not only on the efficiency of the heat pump and its operating conditions, but also on the composition of the energy used to drive the heat pump. (→ *See Sidebar 4 in GSR 2014.*)

There are important differences in renewable heating trends at the regional level:

- **Asia:** China continued to lead the world in installed capacity of solar thermal, geothermal and biogas-fuelled heating systems in 2015. The country saw declining investment in solar thermal collectors for the second consecutive year, although demand increased in some market segments (e.g., multi-family residences).[178] Elsewhere in Asia, modern biomass for residential heat markets has grown, especially in Japan and the Republic of Korea, where strict efficiency requirements have influenced the development of globally competitive biomass boilers.[179] Some Asian countries, such as India, continued to use substantial shares of bioenergy for heat production in industry.[180] Renewable energy use in clean cook stoves – dominated by biogas – also has been on the rise, in particular in China and India and to a lesser extent in Bangladesh and Cambodia.[181]

- **Europe:** Renewable energy accounted for an estimated 18% of the EU's total heating and cooling consumption; in industry, the overall share was 13%.[182] Europe has experienced the strongest growth in renewable energy use for heat of any region, with average annual increases of almost 5% since 2008.[183] Nonetheless, market growth slowed in 2015 due to the economic crisis, a downturn in the building sector and low oil prices.[184] Despite the slowdown for some renewable heat technologies, residential-scale biomass boilers began to show signs of recovery in 2015, and geothermal-based district heat has expanded, especially where resources are optimal and where building construction has continued – as in Paris, Munich (Germany) and Gyor (Hungary).[185] The market for heat pumps has continued to grow, especially in France and Finland (both with supportive government policies) and in Poland.[186]

- **North America:** Renewable energy accounted for roughly 13% of final energy for heat in North America. Much of this was used in industry: in the United States, biomass contributes approximately 17% of industrial heat production.[187] Growth rates in renewable energy use for heat have been comparatively slow (0.6%), due in part to reduced industrial output.[188] Residential heating with wood pellets declined in 2015 as low oil prices reduced the cost-competitiveness of renewable heat, and solar thermal markets also continued to stall.[189]

- **Latin America:** Biomass-based heat accounts for almost a third of industrial heat production in Latin America.[190] Solar thermal markets are growing in Brazil's residential sector, where demand for domestic hot water is accompanied by a lack of sufficient gas infrastructure and an over-burdened electric grid, and the technology is supported by social housing programmes.[191] In Mexico, solar thermal installations increased 8% in 2015, thanks in part to mandates at the state and city level.[192] Several countries throughout the region – including Argentina, Brazil, Costa Rica, Mexico and Uruguay – are working together to implement standards for solar hot water equipment that would support market development.[193]

- **Africa:** Biomass supplies a substantial share (roughly a third) of Africa's industrial-based heat.[194] South Africa's solar thermal market has grown relatively quickly, although it dropped in 2015 due to a delay in government tenders linked to an improved solar hot water programme.[195] During the year Lesotho, Mozambique and Zimbabwe formulated new policies to support solar hot water.[196] Countries in the Great Rift Valley, where there are significant geothermal resources (as in Kenya), have begun to tap direct geothermal heat for use in greenhouses, for example (as well as for electricity).[197] Clean cook stoves, many of which use biogas as a source, are used increasingly in Africa, notably in Ethiopia, Kenya and, to a lesser extent, in Nigeria and Rwanda.[198]

- **Middle East:** Counter to global trends, solar thermal markets grew in the Middle East during 2015.[199] Oman, for example, announced plans to host the world's largest solar thermal facility (>1 GW), which will produce steam for the oil industry.[200] In addition, mandatory green building certifications (in the United Arab Emirates, for example) have helped spur solar cooling markets in the region.[201]

In 2015, several trends continued that facilitate increases in renewable energy in the heating and cooling sector: the number of net-zero-energy buildings continued to rise, and improvements continued in the efficiency of industrial processes, building materials and heating and cooling systems. (→ *See Energy Efficiency chapter.*) In addition, although policies supporting energy efficiency and renewable energy generally are treated as separate policy pillars, there were examples in 2015 of policies that worked towards their integration. Notable are the EU labelling requirements for heating devices, which permit only those space and water heating systems that include renewable energy to achieve the best efficiency class rating.[202]

The expansion of district heating systems also may provide increased opportunities for renewable heating. The year 2015 saw an increasing use of solar heat for district heating systems, in both new and expanded systems, with Denmark (which now supplies 53% of its heat in district heating systems with renewables, waste incineration or industrial surplus heat) as an especially noteworthy mover.[203] There also were a number of announcements to expand or develop biomass- and geothermal-based district heating systems – for example, in Scotland (biomass), Sweden (biomass) and France (geothermal).[204] In China's Inner Mongolia Autonomous Region, progress continued on the implementation of a district heating system that will be powered by surplus wind energy.[205]

Seasonal storage of heat generated by renewable energy for district heating systems (heat is fed in the summer, taken out in winter) also has been deployed in a number of cases.[206] Borehole thermal storage from solar collectors has been implemented in Canada, Germany, Italy, the Netherlands and Sweden, and a number of demonstration projects have been implemented in Australia, China and France.[207] On a smaller scale, solar PV is being combined with heat pump systems, which provide storage and enable increased on-site consumption of the renewable energy generated.[208]

Solar technologies have accounted for the majority of renewable energy used to meet cooling demand in recent years. The growth rate of the global solar cooling market has fluctuated, averaging approximately 6% between 2010 and 2014.[209] Although there is a niche market for medium-sized capacity installations (e.g., in hotels and hospitals, especially on islands where fuel must be imported), widespread deployment has stagnated due to relatively high system costs, space requirements and the complexity of solar thermal-based cooling, especially for small-capacity systems.[210] Solar-based cooling discussions are shifting increasingly to integrated solar PV-driven systems, as the technology progresses in the research and development (R&D) stage.[211] Bioenergy-based cooling – for example, via connection to adsorption chillers – remains in the R&D stage, with very little practical implementation due to high comparative cost.[212]

There also is growing interest in district cooling systems, spurred by an increasing demand for cooling.[213] Growth in district cooling in the Middle East, namely in the United Arab Emirates, Qatar and Saudi Arabia, has surpassed other world regions. There was, however, also noteworthy development in Australia, the Republic of Korea and Singapore in 2015.[214] Such systems offer opportunities for integration of renewable energy, although their deployment is as yet rare.[215]

In general, deployment of renewable technologies in the heating and cooling markets continued to be constrained by a limited awareness of the technologies, the distributed nature of consumption and fragmentation of the heating market, comparatively low fossil fuel prices, ongoing fossil fuel subsidies and a comparative lack of policy support.[216]

Despite challenges to renewable heating and cooling markets in 2015, there were international signals that awareness and political support for related technologies may be growing. A number of INDCs delivered to the UNFCCC for COP21 specifically mention goals to expand the use and manufacture of renewable heating technologies.[217] In addition, the European Commission continued to develop its first strategy for heating and cooling in 2015 (launched in early 2016) with plans to boost energy efficiency in buildings and increase the use of renewable energy in the heating and cooling sector.[218] The development of this strategy – one of the first of its kind – demonstrates a growing awareness of the potential of renewable heating and cooling.

TRANSPORT SECTOR

Global consumption of energy in transport has increased by an average of 2% annually since 2000 and accounts for about 28% of overall energy consumption.[219] Most of the total transport energy demand (around 60%) is for passenger transport, a majority of which is for passenger cars.[220] Road transport also accounts for a majority (around 67%) of freight transport, with shipping (23%) and rail (4%) accounting for smaller shares.[221] Renewable energy accounted for an estimated 4% of global road transport fuel in 2015.[222]

There are three main entry points for renewable energy in the transport sector: the use of 100% liquid biofuels or biofuels blended with conventional fuels; the growing role of natural gas vehicles and infrastructure that can be fuelled with gaseous biofuels; and the increasing electrification of transportation.

Renewable energy use in transport received increasing international attention in 2015. Many countries pledged in their INDCs to "decarbonise fuel", focusing largely on passenger transport.[223] (→ *See Sidebar 4 in Policy Landscape chapter.*) The Partnership for Sustainable Low Carbon Transport, a multi-stakeholder partnership of more than 90 organisations, and the Global Fuel Economy Initiative continued work towards low-carbon (including renewable), efficient transport in 2015.[224]

Liquid biofuels (ethanol and biodiesel) represent the vast majority of the renewable share of global energy demand for transport. In 2015, ethanol production increased 4%, whereas global biodiesel production fell slightly (less than 1%).[225] Although low oil prices negatively affected some sectors in 2015 (particularly heating and cooling), liquid biofuel markets were somewhat sheltered in many countries thanks to blending mandates.[226] (→***See Reference Table R3.***) Regional trends include:

- **North America:** In the United States, the world's largest biofuel producer, after long delays and lapses the biofuel industry received positive signals from policy makers in 2015. Ethanol production (based largely on maize) rose, and biodiesel production (based largely on soya oil) decreased slightly relative to 2014 levels.[227] To the north, Canada, a leader in fuel ethanol production in past years, saw production fall in 2015.
- **Latin America:** Brazil, the world's second largest biofuel producer, increased both ethanol and biodiesel production during 2015, due to good sugarcane harvests and blending mandates. However, in Argentina, a leading producer in years past, output fell by 20% due to constrained export markets. Colombia, the region's third largest biofuel producer, raised its ethanol production by almost 12% over 2014 levels, but its biodiesel production decreased slightly.[228]
- **Europe:** In the EU, new rules came into force, amending existing legislation to limit to 7% the share of biofuels in transport from crops grown on agricultural land.[229] Against this background, biofuel production in the region remained largely stable.
- **Asia:** As fuel ethanol continued to grow in Asia, led by increases in China and Thailand, biodiesel production fell sharply. Indonesia, previously one of the top biodiesel producers worldwide, saw production decrease by roughly 60%. China's biodiesel production increased, almost overtaking Indonesia's 2015 levels.

- **Africa:** Although biofuel production levels in Africa remained comparatively very low, the continent saw substantial growth in ethanol production in 2015.

Biofuels saw continued advances in new markets and applications during 2015. In Egypt, Japan, Mexico, the Netherlands and the United States, there were announcements of aviation biofuel supply agreements or plans to integrate aviation biofuel into future flights.[230] United Airlines became the first US airline to move beyond demonstration to regular operations using biofuels.[231] In addition, 2015 brought announcements of several feedstock-related innovations for aviation fuels, including drop-in fuels produced with woody biomass and efforts to convert municipal solid waste (MSW) into jet fuel.[232] There also were announcements of fully renewable transatlantic flights based on a combination of algae-based biomass and solar energy, as well as an around-the-world flight powered solely by solar PV.[233]

Developments associated with gaseous fuels and electricity continued to create pathways for integrating renewables into transportation. The number of compressed natural gas (CNG) vehicles and fuelling stations continued to expand in 2015 – with notable development in the United States (which had reached more than 900 CNG stations in early 2016), India, Iran and the Netherlands – creating parallel opportunities for gaseous biofuels such as biomethane.[234] Although biomethane production is concentrated primarily in Europe, early steps were taken to introduce the fuel in Latin America in 2015. For example, Brazil set new specifications for the production and sale of biomethane and launched its first biomethane-powered city bus.[235]

Electrification of the transport sector expanded during the year, enabling greater integration of renewable energy in the form of electricity for trains, light rail, trams as well as two- and four-wheeled electric vehicles.

The number of electric passenger vehicles (EVs) on the road increased again in 2015; key markets are in China, Northern Europe and the United States. Manufacturers announced several new models of light-duty EVs with longer ranges (300 kilometres) that are expected to be available at more-affordable prices in the coming years.[236] The year 2015 also saw substantial developments in R&D for electrification of heavy-duty vehicles, broadening the scope beyond a focus almost exclusively on light-duty vehicles.[237]

Exploration of methods to integrate renewable energy into charging stations for electric cars expanded in 2015, although many projects are pilot or demonstration and integration remains relatively small-scale. Some companies also worked to expand charging networks worldwide, including stations powered by solar PV.[238] China launched its largest solar PV charging station in 2015 (capable of charging 80 EVs per day) and launched a pilot project in Shanghai to test the ability of EVs to support the integration of renewable energy into the electric grid.[239] Japan also announced implementation of solar-powered recharging stations in 2015.[240] In the United States, innovators began demonstration of off-grid 100% solar carports for charging EVs – mobile charging stations that fit in standard parking spaces.[241] For more-traditional, grid-tied charging stations, utilities in southern California began to explore innovative incentives to encourage customers to charge their vehicles when renewable energy is plentiful.[242]

The year 2015 also brought progress towards integrating renewable energy into EV charging infrastructure where markets are smaller or nascent. In the Middle East, for example, Jordanian officials signed letters of commitment to build 3,000 solar-powered electric charging stations over the next decade.[243] In the Pacific, plans were announced to test the concept of solar-powered charging stations for a small fleet of electric cars in the Marshall Islands.[244]

In the shipping sector, integration of renewable energy stagnated in 2015, inhibited by low oil prices, a lack of supportive policies (very few national policies exist for renewables in shipping – the Marshall Islands is one noteworthy exception) and international regulation, and lock-in of shipping fleets.[245]Despite the lack of progress in renewable energy deployment, R&D continued in 2015, with Korean innovation in wind energy-supported ships; German developments of a 60-metre renewable-powered research freighter; and several pilot projects of biomethane application in ships that operate on liquefied natural gas (LNG).[246] In addition, developments in battery-powered ferries in Northern Europe may enable further integration of renewable energy in the form of electricity.[247]

Several concrete strides were taken in the rail sector towards achieving existing goals to supply increasing shares of electricity demand with renewable energy, and new goals were announced during the year. In the Netherlands, to build on its goals established in 2014, the Dutch rail network completed a contract to source wind energy to meet up to 100% of the power needed to propel its trains by 2018; nearly half of the power for the network was supplied by wind power in 2015.[248] In Australia, Canberra announced a new light rail project that requires an initial minimum of 10% renewables use, with a target to increase the share to 90% by 2020 and New South Wales announced a tender to supply the Sydney metro with renewable energy.[249]

Sidebar 2. Jobs in Renewable Energy

Employment in the renewable energy sector increased by 5% in 2015, to 8.1 million jobs (direct and indirect), as estimated by IRENA[i]. (→ *See Table 1 and Figure 5.*) Solar PV and wind power remained the most dynamic markets, while solar PV and biofuels provided the largest numbers of jobs. In addition, large-scale hydropower accounted for another 1.3 million direct jobs in 2015.

Renewable energy markets and employment were characterised by favourable policy frameworks in several countries, regional shifts in investment and increased labour productivity. Enabling policy frameworks remained a key driver of employment, as illustrated by the ambitious solar targets in India and the wind energy auctions, coupled with financing rules to encourage local content, in Brazil. Greater renewable energy deployment, particularly in Asia, and sluggish markets in Europe continued to drive regional shifts in employment numbers. Meanwhile, increasing labour productivity and automation have negatively affected employment in certain technologies, such as solar PV and bioenergy. Although growth in jobs was slower in 2015 than in previous years, the total number of jobs worldwide continued to rise, in stark contrast with depressed labour markets in the broader energy sector.

Record solar PV deployment enhanced job creation, with the number of jobs up 11% over the 2014 estimate. China was the undisputed leader in solar PV employment in 2015, with 1.7 million jobs, followed by Japan and the United States. India continued to emerge as a major market, and the number of jobs in the sector increased accordingly. In the EU, however, solar PV employment decreased by 13% in 2014, the most recent year for which data are available.

Employment in liquid biofuels declined by an estimated 6% in 2015, even as global production rose relative to 2014, due mainly to increasing mechanisation in some countries. The United States and Brazil, for example, saw minor job losses even as biofuel production rose. In the EU, biofuel employment was up 8% in 2014. In Southeast Asia, Malaysia and Thailand increased production to meet growing domestic demand in 2015, creating new job opportunities. Indonesia, however, suffered job losses as exports declined.

Wind power witnessed a record year with strong market growth in several countries. As result, global employment was up 5%, with close to half of all wind power jobs in China. Germany and the United States also were top players in 2015, followed by India and Brazil.

In solar heating and cooling, China continued to lead but suffered job losses for the second year running due to the economic slowdown, the reduced demand in the real estate industry and the removal of subsidies in 2013. Turkey, India, Brazil, the United States and the EU also are major employers in solar heating and cooling.

Employment in the small-scale hydropower industry decreased by 5% in 2015, due largely to job retrenchments in China. IRENA's estimates indicate that global employment in large-scale hydropower[ii] totalled 1.3 million direct jobs, dominated by positions in operation and maintenance. China, Brazil and India were the leading employers.

Considering all renewable energy technologies, the leading employers in 2015 were China, Brazil, the United States and India. The global top 10 employers include four countries from Asia, compared with only three in 2013.

China accounted for more than one-third of global renewable energy installations in 2015 and led employment with 3.5 million jobs. Marginal gains in solar PV and wind power were offset somewhat by losses in the solar heating and cooling and small-scale hydropower sectors. In addition, employment in large-scale hydropower in China supported around 440,000 direct jobs, most of which were in construction.

For the fourth year in a row, the EU registered renewable energy job losses in 2014 (the latest available data). Employment fell by 3% due to decreasing investments and adverse policy conditions in some countries. Europe's wind industry provided most of the jobs. As of 2014, employment in the solar PV industry was just one-third of its 2011 peak. Despite a 32% decline in solar PV employment, in 2014 Germany remained the leading renewable energy employer by far – with almost as many jobs as the next three countries combined (France, the United Kingdom and Italy).

Renewable energy employment in the United States increased by 6% in 2015. All solar (solar PV, CSP and solar heating and cooling) employment rose by 22%, with most of these jobs in installation of residential solar PV rooftop systems. Women represented 24% of the solar workforce, up from 19% in 2013. Wind power employment also increased, and prospects for future growth improved with the multi-year extension of the Production Tax Credit in December.

In Brazil, most renewables employment was found in bioenergy and large-scale hydropower. Jobs in the wind sector are increasing due to rising deployment and local manufacturing. Elsewhere in Latin America, jobs also are increasing in the wind and solar sectors.

The Indian solar and wind power markets have seen substantial activity as the ambitious renewable energy targets are translated into concrete policy frameworks. Central and state auctions for solar PV contributed to the installation of 2 GW in 2015 and to an impressive pipeline of 23 GW. Employment in solar PV expanded by 23% in 2015, and jobs in the wind sector also rose.

Japan experienced notable gains in solar PV deployment in recent years, resulting in a 28% increase in employment in 2014. It is likely that there was additional job growth in 2015; however, recent reductions in feed-in-tariffs may change the upward trend.

Africa presents specific data challenges, but it is clear that a number of solar PV, wind and geothermal power projects in Egypt, Kenya, Morocco and South Africa created new jobs. IRENA estimates that the continent had more than 60,000 renewable energy jobs (not including large-scale hydropower) in 2015. Close to one-half of these jobs are in South Africa and about one-fourth are in northern Africa.

[i] This sidebar is drawn from IRENA, *Renewable Energy and Jobs – Annual Review 2016*. Data are principally for 2014–2015, with dates varying by country and technology, including some instances where only dated information is available.

[ii] IRENA defines large-scale hydropower as projects above 10 MW. Definitions may vary across IRENA member countries. Projects below 10 MW are considered as small-scale hydropower.

JOBS IN RENEWABLE ENERGY

Table 1. Estimated Direct and Indirect Jobs in Renewable Energy Worldwide, by Industry

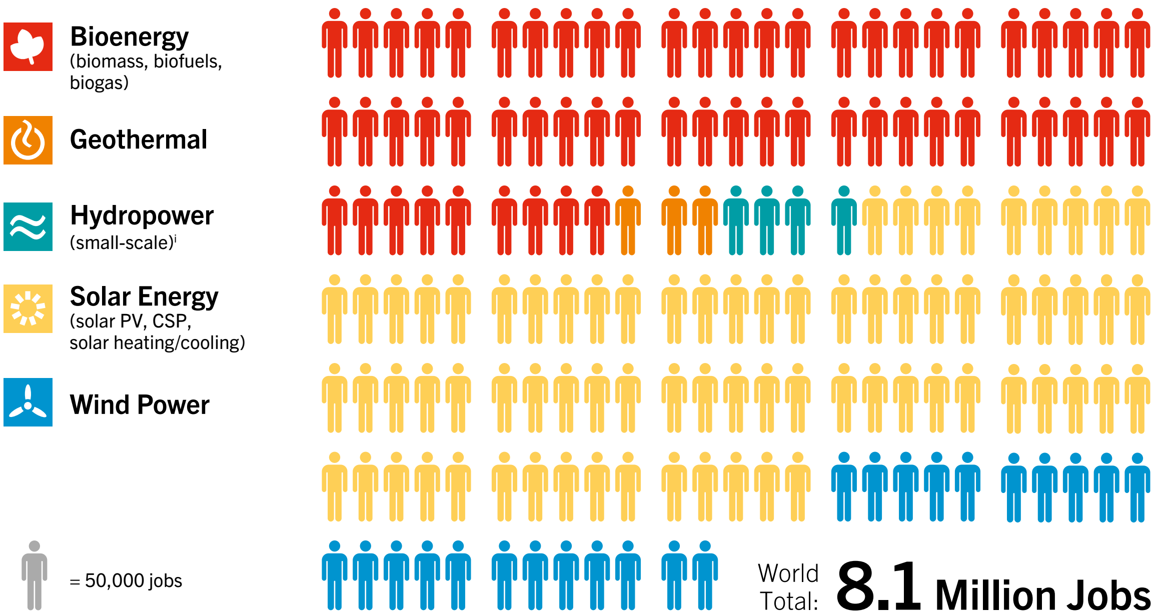
	World	China	Brazil	United States	India	Japan	Bangladesh	European Union[i]		
								Germany	France	Rest of EU
	THOUSAND JOBS									
Solar PV	**2,772**	1,652	4	194	103	377	127	38	21	84
Liquid biofuels	**1,678**	71	821[c]	277[f]	35	3		23	35	47
Wind power	**1,081**	507	41	88	48	5	0.1	149	20	162
Solar heating/ cooling	**939**	743	41[d]	10	75	0.7		10	6	19
Solid biomass[a,g]	**822**	241		152[e]	58			49	48	214
Biogas	**382**	209			85		9	48	4	14
Hydropower (small-scale)[b]	**204**	100	12	8	12		5	12	4	31
Geothermal energy[a]	**160**			35		2		17	31	55
CSP	**14**			4				0.7		5
Total	**8,052[h]**	**3,523**	**918**	**769**	**416**	**388**	**141**	**355[j]**	**170**	**644[k]**

Note: Figures provided in the table are the result of a comprehensive review of primary (national entities such as ministries, statistical agencies, etc.) and secondary (regional and global studies) data sources and represent an ongoing effort to update and refine available knowledge. Data do not include large-scale hydropower. Totals may not add up due to rounding.

[a] Power and heat applications (including heat pumps in the case of the EU). [b] Although 10 MW is often used as a threshold, definitions are inconsistent across countries. [c] About 268,400 jobs in sugar cane and 190,000 in ethanol processing in 2014; also includes 200,000 indirect jobs in equipment manufacturing and 162,600 jobs in biodiesel in 2015. [d] Equipment manufacturing and installation jobs. [e] Biomass power direct jobs run to only 15,500. [f] Includes 227,562 jobs for ethanol and 49,486 jobs for biodiesel in 2015. [g] Traditional biomass is not included. [h] The total for 'World' is calculated by adding the individual totals of the technologies, with 3,700 jobs in ocean energy, 11,000 jobs in renewable municipal and industrial waste and 14,000 jobs in others (jobs that cannot be broken down by technology). [i] All EU data are from 2014, and the two major EU countries are represented individually. [j] Includes 8,300 jobs in publicly funded R&D and administration; not broken down by technology. [k] Includes 8,000 jobs in renewable municipal and industrial waste and 3,700 jobs in ocean energy.

Source: IRENA

Figure 5. Jobs in Renewable Energy

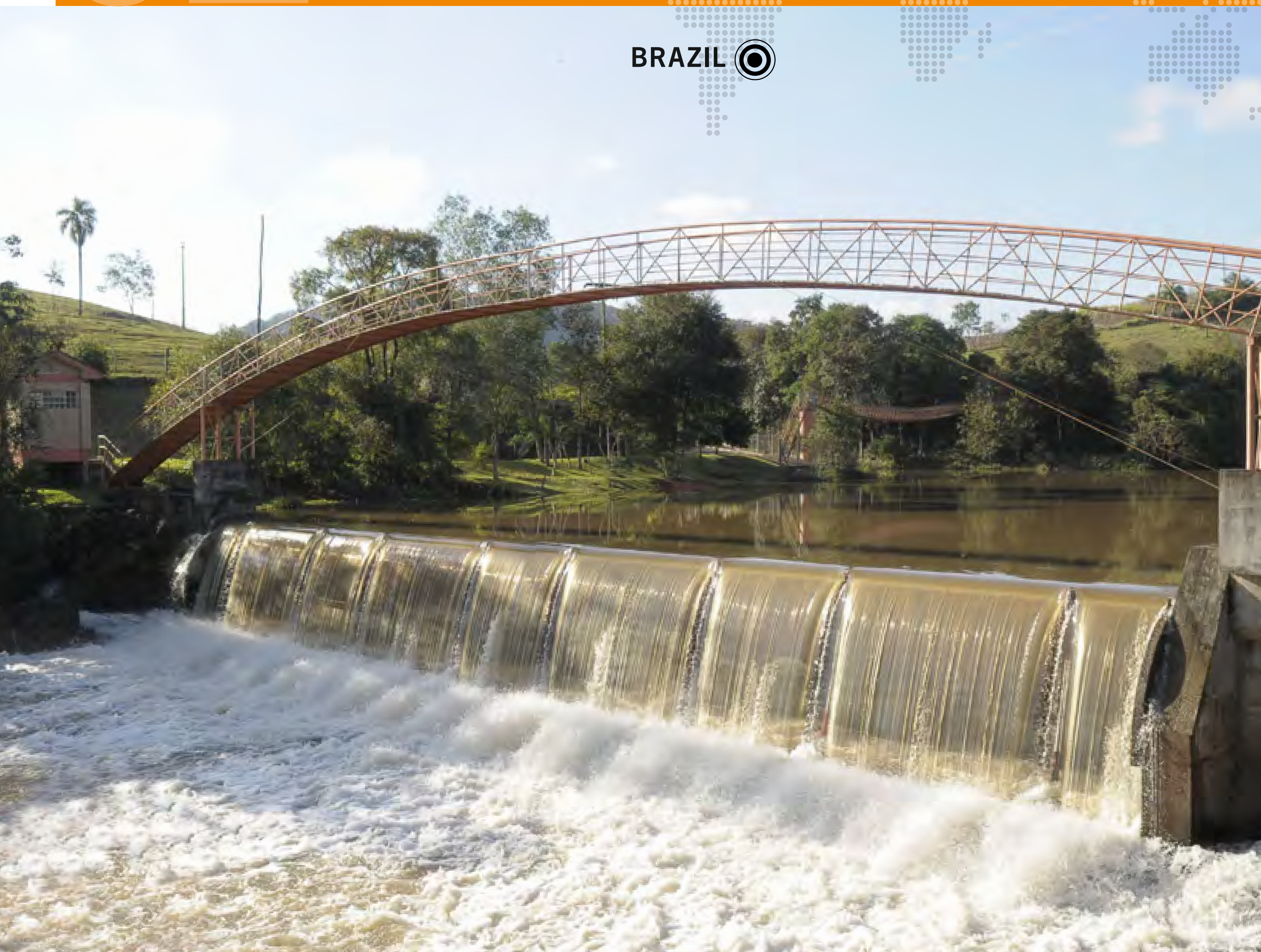


Source: IRENA

i Employment for large-scale hydropower not included.

01

02



Community-based electrification - power generation and distribution

Reliable electricity supply is critical for the sustainable development of rural communities. The member-run co-operative **CRELUZ** started its activities with the objective of extending the electric grid to rural homes within an area of 13,000 km2. CRELUZ invested in six local run of river mini-hydropower plants as well as in wind to provide a reliable power supply, overcoming power cuts in the national electric grid.

Rio Grande do Sul, Brazil | Created: 1966 | Members: 20,000 families in 36 municipalities
4500 km of power lines, 3.96 MW of run of river mini-hydropower capacity

02 MARKET AND INDUSTRY TRENDS

BIOMASS ENERGY

Bioenergy draws on a wide range of potential feedstock materials: forestry and agricultural residues and wastes of many sorts, as well as material grown specifically for energy purposes. The raw materials can be converted to heat for use in buildings and industry, to electricity, or into gaseous or liquid fuels, which can be used in transport, for example. This degree of flexibility is unique amongst the different forms of renewable energy.[1]

The most commonly used conversion methods – combustion of fuels to produce heat or electricity; anaerobic digestion to produce methane for heat or power production; and the conversion of sugary and starchy raw materials to ethanol, or of vegetable oils to biodiesel – all are well-established and commercial technologies.[2] A further set of conversion processes – for example, the production of liquid fuels from cellulosic materials by biological or thermochemical conversion processes, such as pyrolysis – are at earlier stages of commercialisation or still under development.[3]

In 2015, drivers for the production and use of biomass energy included rapidly rising energy demand in many countries and local and global environmental concerns and goals. Challenges to bioenergy deployment included low fossil fuel prices and rapidly falling energy prices of some other renewable energy sources, especially wind and solar PV.[4] Ongoing debate about the sustainability of bioenergy, including indirect land-use change and carbon balance, also affected development in the sector.[5] Given these challenges, national policy frameworks continue to have a large influence on deployment.

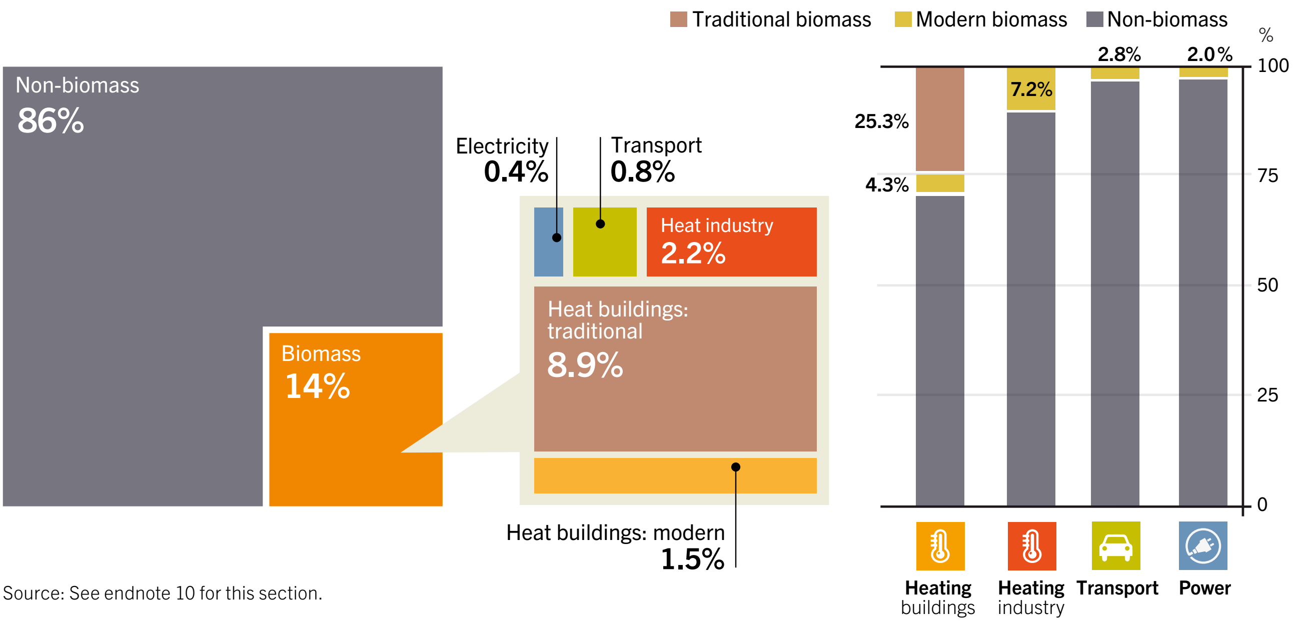
BIOENERGY MARKETS

Bioenergy contributes more to primary global energy supply than any other renewable energy source.[6] Total energy demand supplied from biomass in 2015 was approximately 60 exajoules (EJ).[7] The use of biomass for energy has been growing at around 2% per year since 2010.[8] The bioenergy share in total global primary energy consumption has remained relatively steady since 2005, at around 10%[i], despite a 24% increase in overall global energy demand between 2005 and 2015.[9]

Bioenergy plays a role in all three main energy-use sectors: heat (and cooling), electricity and transport. The contribution of bioenergy to final energy demand for heat (traditional and modern) far outweighs its use in either electricity or transport.[10] (→ *See Figure 6.*)

Solid biomass represents the largest share of biomass used for heat and electricity generation, whereas liquid biofuel represents the largest source in the transport sector.[11] (→ *See Figure 7.*)

Figure 6. Shares of Biomass in Total Final Energy Consumption and in Final Energy Consumption by End-use Sector, 2014



Source: See endnote 10 for this section.

i The final energy share is about 14%, as seen in Figure 6.

Bio-heat Markets

Biomass in many forms – as solids, liquids or gases – can be burned directly to produce heat for cooking and heating in the residential sector by means of the traditional use of biomass or in modern appliances. It also can be used at a larger scale to heat larger institutional and commercial buildings, or in industry to produce high-temperature process heat and/or lower-grade heat for heating or drying. The heat can be produced directly or co-produced with electricity via combined heat and power (CHP) systems and distributed from larger production facilities by district heating systems to provide heating (and in some case cooling) to residential, commercial and industrial customers.

The traditional use of biomass for heat involves primarily the use of simple and inefficient devices to burn woody biomass, in the form of fuelwood or charcoal.[12] Biomass energy use in 2015 is estimated at 31 EJ, although it is difficult to quantify the volume consumed given the informal nature of the supply and uncertainty regarding the use of these biomass materials.[13] Consumption of fuelwood for traditional energy uses remained stable in 2015 compared to previous years, at an estimated 1.9 billion cubic metres (m^3); the largest shares of fuelwood (as well as other fuels such as dung and agricultural residues) are consumed in Asia, South America and Africa.[14] The use of charcoal for cooking in many developing countries, especially in urban areas, has been increasing by an average of around 3% a year since 2010, reaching an estimated 55 million tonnes in 2015.[15]

Modern bioenergy applications provided some 14.4 EJ of heat in 2015, of which an estimated 8.4 EJ was for industrial uses and 6.3 EJ was consumed in the residential and commercial sectors (used principally for heating buildings and cooking).[16] Modern biomass heat capacity in 2015 increased by an estimated 10 GW_{th} to reach approximately 315 GW_{th}.[17]

Bioenergy accounts for around 10% of all industrial heat consumption, and its use in industry has been growing at about 1.3% annually over the past 15 years, principally from solid biomass.[18] The use of biomass residues to produce heat, often via CHP, is particularly important in bio-based industries. The pulp and paper sector was the largest industrial consumer of bioenergy for heat, sourcing some 43% of its heat requirements from biomass process residues such as bark and pulping liquors.[19] The food and tobacco industries also meet a considerable share of their energy needs with biomass. Heat is required to manufacture biofuels as well: for example, bagasse is used to generate heat and power in facilities that produce sugarcane-based ethanol.

The principal regions that rely on biomass for industrial heat are Asia and South America (particularly Brazil, where bagasse is used in sugar production).[20] North America is the next largest user; however, the region's use of bioenergy for heat is declining due to changes in the structure of the forestry and paper industries.[21]

In the buildings sector, the largest consumers of modern biomass for heat by country include the United States, Germany, France, Sweden, Italy and Finland.[22] Europe is the largest consumer by region, due largely to efforts of EU Member States to meet mandatory targets under the Renewable Energy Directive.[23]

Europe (primarily Italy, Germany, Sweden and France) also was the largest market for wood pellets for heating in 2015, although the region's second consecutive mild winter reduced demand somewhat during the year.[24]

Several countries in the Baltic and Eastern European regions have seen an increase in the use of wood fuels in recent years. Rising demand is driven by the countries' ample biomass resources, widespread use of district heating and desire to reduce quantities of imported natural gas. In Lithuania, for example, 61% of energy used in district heating in 2015 was derived from local forestry industry residues. Lithuania's biomass-based heat capacity tripled between 2011 and 2015, to 1,530 MW_{th}.[25]

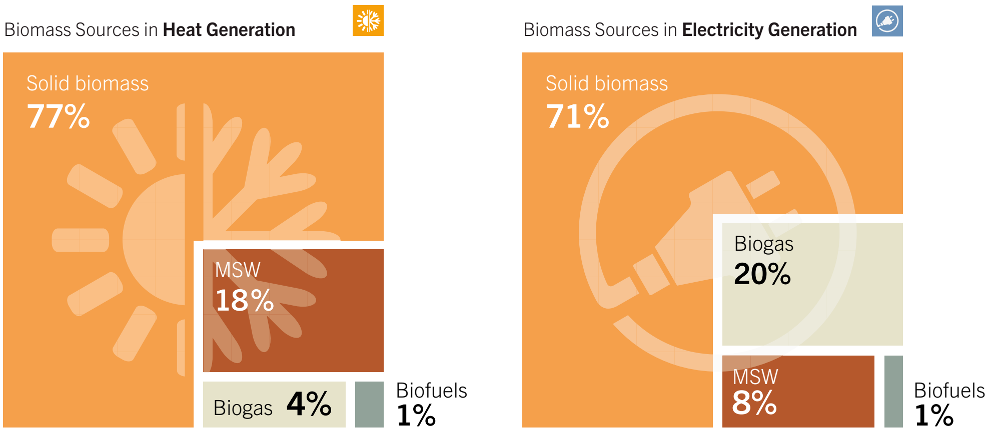
The United States and Canada have strong traditions of using wood as a fuel for residential heating. As of 2014, some 2.5 million US households used fuelwood as their principal household heating fuel, and another 9 million homes used it as a secondary fuel.[26] Use of wood pellets also increased in these markets, although growth was constrained by low oil prices during 2015.[27]

In China, a programme launched in 2008 to encourage the use of pelletised agricultural residues for heating and to reduce coal use in local district heating schemes has stimulated the growth of a national market and industry. The policy provides support to farmers to collect and process residues and so provides a useful rural economic incentive. It is estimated that more than 6 million tonnes of pellets, with an energy content of some 96 petajoules (PJ), were produced and used in China during 2015.[28]

Biogas also is used in industrial and residential heating applications. In Europe, it is used increasingly to provide heat for both buildings (space) and industry (processes), often in conjunction with electricity production via CHP.[29] Asia leads the world in the use of small-scale biogas digesters to produce gas for cooking and space heating. More than 100 million people in rural China and 4.83 million people in India have access to digester gas.[30]

BIOMASS ENERGY

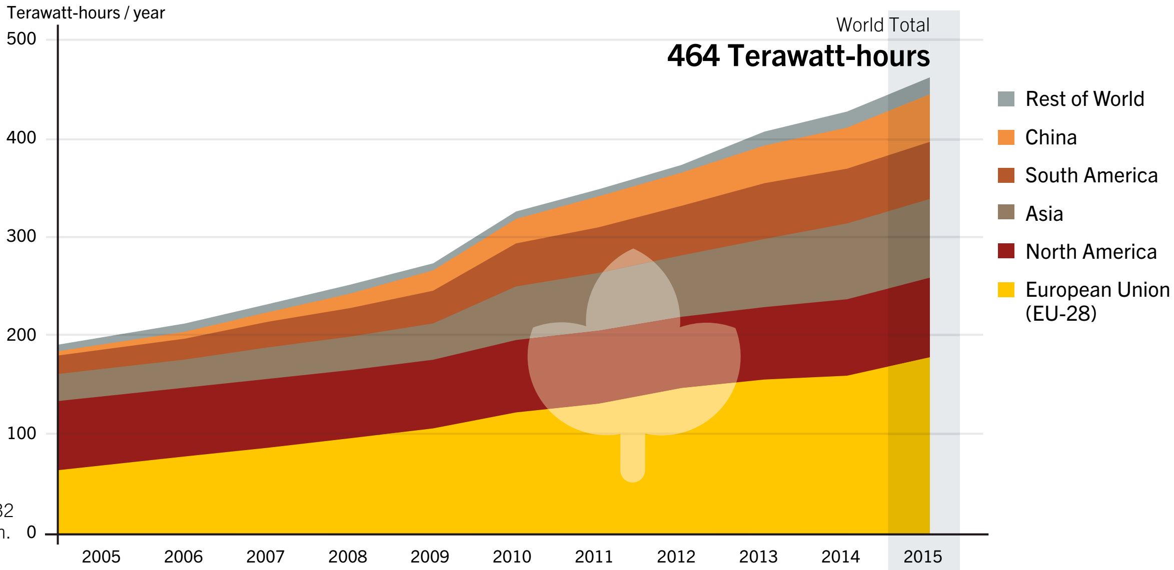
Figure 7. Shares of Biomass Sources in Global Heat and Electricity Generation, 2015



Source: See endnote 11 for this section.

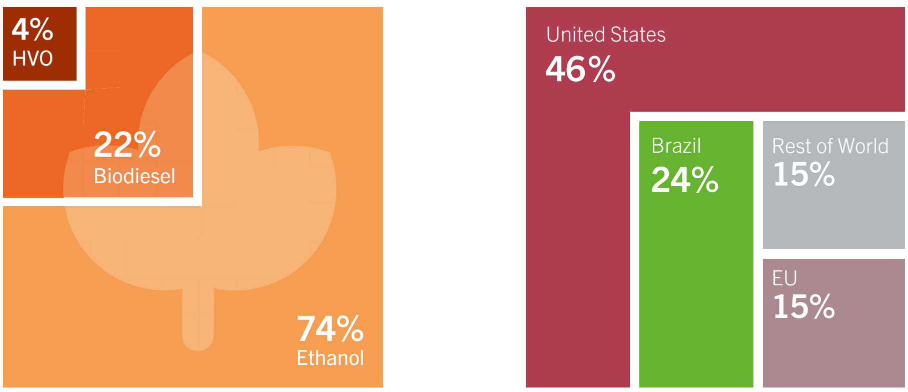
Municipal solid waste (MSW) includes the renewable portion only.

Figure 8. Bio-power Global Generation, by Country/Region, 2005–2015



Source: See endnote 32 for this section.

Figure 9. Biofuels Global Production, Shares by Type and by Country/Region, 2015



Source: See endnote 48 for this section.

02

Bio-power Markets

Bio-power capacity increased by an estimated 5% in 2015, to 106.4 GW, and generation rose by 8% to 464 TWh; the rise in generation was due in part to increased use of existing capacity.[31] The leading countries for electricity generation from biomass in 2015 were the United States (69 TWh), Germany (50 TWh), China (48 TWh), Brazil (40 TWh) and Japan (36 TWh) followed by the United Kingdom and India.[32] (→ *See Figure 8.)*

By country, the United States is the largest producer of electricity from biomass sources. In 2015, US biopower capacity in operation increased by 4% to 16.7 GW; generation in 2015 was close to the 2014 level of 69.3 TWh.[33] There are signs that some existing bio-electricity in the United States is not financially competitive with low-cost generation from natural gas and with generation from other lower-cost renewables.[34]

Bio-power production, from both solid biomass and biogas, continued to grow in Europe.[35] Germany remains Europe's largest producer, and total bio-power capacity in the country remained constant at 7.1 GW in 2015. Much of this capacity (4.8 GW) relates to biogas-fuelled installations based on energy crops. Germany has the largest biogas-powered generation capacity in Europe.[36] However, biogas power capacity growth was limited in 2015 due to reductions in financial support for biogas plants.[37] Bioelectricity production was up by 2% over 2014, to 50 TWh.

Elsewhere in Europe, both bio-power capacity and generation increased significantly in the United Kingdom during 2015 (by 12% and 27%, respectively), making the country the world's sixth largest user of biomass for electricity generation.[38] These increases were due largely to activities at Drax, previously the United Kingdom's largest coal-fired power station, where two large generation units have been converted to biomass firing, with a third currently undergoing conversion.[39] Around 4% of UK electricity is generated from biomass at the site. The biogas market also grew strongly in the United Kingdom, with the fastest growth of any country in Europe, stimulated by an attractive feed-in-tariff rate.[40]

In China, bio-power capacity reached 10.3 GW in 2015, an increase of 0.8 GW over the year.[41] Generation was up 16% over 2014, to an estimated 48.3 TWh.[42] The country's 2010–2015 Five-Year Plan aimed to reach 13 GW by 2015, with a target of 30 GW by 2030. Factors that have restricted progress include high feedstock prices, poor co-ordination among projects and technical operating difficulties.[43]

Elsewhere in Asia, Japan's efforts to stimulate growth in renewables following the Fukushima nuclear disaster have led to increased use of bio-power. Capacity reached a total of 4.8 GW in 2015, and generation reached some 36 TWh. The growing market is based largely on imported fuels such as wood pellets (principally from Canada), wood chips and palm kernel shells.[44] In India, bio-power capacity saw relatively small gains in 2015: on-grid capacity increased by 144 MW (up 0.3%) to 4.67 GW, and off-grid capacity rose by 18.9 MW (up 2%) to 927 MW.[45]

In Brazil, bio-power production relies primarily on sugarcane residues, such as bagasse, as fuel. Capacity increased 250 MW over the period 2013–2015, to 9.7 GW at end-2015. Growth was relatively slow because wind power dominated the country's renewable energy auctions over this period. Even so, some bio-power projects were selected in the three auctions held in 2013 and 2015, and several PPAs were awarded during 2015 for new and existing bio-power plants.[46]

Transport Biofuel Markets

In 2015, global biofuels production increased by around 3% compared to 2014, reaching 133 billion litres.[47] This increase was due to good harvests in key ethanol-producing countries – maize in the United States and sugar cane in Brazil – but was abated by a slight reduction in biodiesel production. Demand was consistent due to blending mandates, which sheltered markets from the potential impacts of comparatively low global gasoline and diesel fuel prices.

Global production of biofuels was dominated by the United States and Brazil – these two countries produce 72% of all biofuels – followed by Germany, Argentina and Indonesia. An estimated 67% of biofuel production (in energy terms) was fuel ethanol, 33% was biodiesel, and a small but increasing share was hydrogenated vegetable oils (HVO) and other advanced biofuels (with existing capacity of around 0.5 billion litres/year).[48] (→ *See Figure 9.)*

Global production of fuel ethanol increased by some 4% between 2014 and 2015, to 98.3 billion litres. The United States and Brazil accounted for 86% of global ethanol production in 2015. China, Canada and Thailand were the next largest producers.[49]

US ethanol production rose 3.8% to 56.1 billion litres during the year.[50] Domestic demand was supported by the US Environmental Production Agency's (US EPA) final Renewable Fuel Standard (RFS 2) allocations for annual volume requirements. A 2% increase in gasoline demand also increased the amount of ethanol that could be blended while avoiding the 10% "blend wall".[51] Ethanol production in Brazil also increased by 10%, to a record output of 28.2 billion litres, due to a good harvest.[52] The other major producer in the Americas, Canada, ranked fourth globally in 2015, producing 1.7 billion litres (down 1% compared to 2014).[53]

China, the third largest ethanol producer, produced an estimated 2.8 billion litres in 2015, a decline of 14%. China increased ethanol imports during the year but added no new production capacity, in part because of a moratorium on maize-based ethanol production.[54] Asia's other major producer, Thailand, saw ethanol production rise by 10%, from 1.1 billion litres in 2014 to 1.2 billion litres in 2015.[55]

In the EU, key producers include France, Germany, Spain, Belgium and the United Kingdom.[56] EU ethanol production was down by about 7% in 2015 to some 4.1 billion litres, particularly because of reduced production in the United Kingdom.[57]

Ethanol production in Africa increased substantially, from 0.10 billion litres in 2014 to 0.13 billion litres in 2015, due largely to increases in production in South Africa.[58]

Leading countries in biodiesel production worldwide were the United States, Brazil, Germany and Argentina. Following a significant increase in 2014 (up 13% to 30.4 billion litres), global production of biodiesel fell slightly in 2015 to 30.1 billion litres.[59] The decline was due to constrained production in Argentina and Indonesia, in particular.

US biodiesel production rose by 2% in 2015, reaching close to 4.8 billion litres.[60] In Brazil, output was up 20% to 4.1 billion litres.[61] Growth in Brazilian demand for biodiesel was stimulated by an increase in the biodiesel blending mandate to 7%.[62] By contrast, biodiesel production in Argentina declined by 30% in 2015, to 2.1 billion litres.[63] Output was reduced due to a reduction in export markets, which resulted from a tax increase by the EU on Argentinian biodiesel imports.[64]

European biodiesel production rose by 5% to 11.5 billion litres.[65] Germany was again the largest European producer (2.8 billion litres), followed by France (2.4 billion litres).[66]

The year 2015 saw significant changes in biodiesel production patterns in Asia. In Indonesia, the region's largest producer, biodiesel production dropped by over 40% – from 2.9 billion litres in 2014 to 1.7 billion litres – due to delays in fully implementing the B15 biodiesel programme.[67] In Malaysia, the introduction of a B7 blend mandate increased demand and resulted in a 40% jump in production to around 0.7 billion litres.[68] China's biodiesel production is estimated to have increased substantially – by an estimated 24% – to 0.35 billion litres in 2015.[69]

Global production of HVO grew by some 20% to 4.9 billion litres, with the Netherlands, the United States, Singapore and Finland as major producers.[70]

The use of biomethane as a transport fuel also continued to increase during the year.[71] The largest markets are all in Europe, where Sweden, Germany and Finland lead, using a combined 119,000 tonnes (4.7 PJ) of biomethane fuel.[72]

BIOENERGY INDUSTRY

The bioenergy industry includes feedstock suppliers and processors; firms that deliver biomass to end-users; manufacturers and distributors of specialist biomass harvesting, handling and storage equipment; and manufacturers of appliances and hardware components designed to convert biomass to useful energy carriers and energy services. Industry, with support from academia and governments, also is making progress in bringing a number of new technologies and fuels to the market.

Solid Biomass Industry

The industries involved in producing solid biomass and manufacturing-related technologies are very diverse. The production and supply of traditional biomass is usually informal and local, although there are signs of increasingly industrial approaches to the production and marketing of systems such as biomass-based cook stoves.[73]

The industry for manufacturing modern biomass heating appliances is well-developed in Europe and North America, where regional players generally focus on local markets and can tailor their products to specific customer and regulatory requirements. Large-scale systems used for district heating and industrial applications typically are provided by global players.

Fuelwood and other biomass feedstock supply for heat or power production tends to be based locally in order to constrain transport costs and associated emissions. For example, straw used to fuel power generation plants usually is collected within a radius of around 50 kilometres.[74]

In contrast, wood pellets (which have a relatively high energy density) are traded globally.[75] Wood pellets are supplied primarily from Europe (Germany, Sweden and Latvia), North America (the United States and Canada) and the Russian Federation.[76] The pattern of trade varies year to year as the demand for pellets for power generation is affected by changes in regulations and levels of financial support. Historically the EU region has been the major importer, but since 2014, Japan and the Republic of Korea also have become important markets.[77]

The United States exported more than 4.5 million metric tonnes of wood pellets in 2015, 84% of which went to the United Kingdom and 14% to Benelux countries.[78] Drax (United Kingdom) has invested more than USD 350 million in fuel production plants in the US states of Louisiana and Mississippi, and in 2015 the company opened biomass pellet storage, handling and loading facilities at Louisiana's Port of Greater Baton Rouge that are capable of handling 3 million tonnes of pellets a year.[79]

In Canada, pellet exports remained close to 2014 levels, at 1.63 million tonnes. Rising sales to the United Kingdom (up 23%) and Japan (up 30%) were offset by reductions in exports to Italy and the Republic of Korea.[80] Canadian exports to the Republic of Korea fell by 68% because of short-term contracting issues and new regulations that aim to improve sustainability of supply.[81]

The year 2015 saw growth and developments in industry quality standards and sustainability certifications. ENplus, an industry quality standard, covered 7.7 million tonnes of product in 2015, a rise of 1.7 million tonnes over 2014.[82] In addition, in 2015 the Sustainable Biomass Partnership (SBP), an industry-led initiative, developed and published a framework of standards and independent certification procedures that enable companies using biomass at a large scale to demonstrate compliance with legal, regulatory and sustainability requirements that relate to woody biomass.[83]

The production of torrefied wood/pellets, which increases the energy density of biomass-based fuels and results in a product compatible with systems designed for coal, also saw some expansion during 2015. For example, In the United States, Vega Biofuels entered into a joint-venture agreement to construct a bio-coal manufacturing plant in the state of Georgia, which will be operated by Agri-Tech Producers and Vencor International.[84]

Liquid Biofuels Industry

In contrast to solid biomass, production of liquid biofuels is focused around a number of large industrial players with dominant market shares. These include ethanol producers Archer Daniels Midland (ADM), POET and Valero in the United States, and Copersucar, Oderbrecht (ETH Bioenergia) and Raizen in Brazil.[85]

In 2015, there was limited development of new conventional biofuels production capacity in the principal producer markets – the United States, Brazil and Europe – largely because existing plants were not operating at full capacity. Total global biofuels capacity is some 209 billion litres a year.[86] With current production of 133 billion litres, there is some 35% spare capacity. Future demand patterns remained unclear due to regulatory and market uncertainty, so there is little motivation for large-scale new capacity investment.

However, new developments occurred in a number of new and emerging markets in Asia and Africa. In Nigeria, for example, an international funding partnership was announced with the country's cassava growers association to produce ethanol in 10 distilleries in different states around the country.[87]

Ethanol is traded internationally, and trade patterns showed some significant variations in 2015. US net exports of ethanol increased by 28% compared with 2014, to 2.5 billion litres; shipments were to Brazil, the Philippines, India and the Republic of Korea.[88] The Chinese market for ethanol imports (particularly from the United States) has grown rapidly, influencing global trade patterns.[89]

Biodiesel production is more geographically diverse than ethanol, with production spread among a number of countries. The top producers are the United States, Brazil, Germany, Argentina, France, the Netherlands, Indonesia and Thailand.[90] The biodiesel industry has been affected to a significant degree by policy and regulatory changes and by shifting patterns in international trade. In the United States, for example, industry developments have been subject to uncertainty about the biodiesel tax credit and an expectation that Argentina may become a major exporter to the country.[91] In Europe, biodiesel sales are constrained by the 7% limit introduced in 2015 on the contribution of starch-rich, sugar and oil crops to the EU's 2020 biofuel target.[92]

In 2015, there was active progress in demonstrating the reliable production of a range of advanced biofuels. These fuels offer alternatives to conventional biofuels (produced with sugar, starch and oils) and thereby offer the prospect of lower life-cycle greenhouse gas emissions and reduced competition with food production.[93] A number of routes are being investigated including the production of HVO, the use of biological processes to produce fuels from cellulosic materials (such as crop residues), and thermochemical processes including gasification and pyrolysis.[94]

During 2015, activity related to advanced biofuels was concentrated largely in the United States, Brazil and Europe. Key players in the ethanol, biodiesel and other bio-based industries (as well as fossil fuel suppliers) are playing major roles in this sector, working with

technology providers, research groups and academia to develop and bring novel processes into full-scale production.

Capacity for producing fuels by hydrogenating vegetable oils (including used cooking oil (UCO), tall oil[i] and others) increased significantly in 2015.[95] UPM (Sweden), for example, invested USD 150 million to develop a plant in Finland on the same site as the company's Kaukas pulp and paper mill, which produces 100,000 tonnes of diesel fuel from tall oil annually.[96] In April 2015, Total (France) announced an investment of some USD 220 million to convert the La Mède oil refinery in southern France into a biorefinery that will produce renewable diesel from UCO and other feedstocks.[97]

Several additional cellulosic ethanol manufacturing plants began production or were announced in 2015, including DuPont's plant in the US state of Iowa, which is designed to produce 140 million litres of ethanol per year, the largest such output in the world.[98] In Brazil, Raizen's large-scale cellulose ethanol plant in São Paulo began operations in 2015 and is expected to produce 42 million litres of cellulosic ethanol annually.[99]

Progress also was made in the production of fuels through pyrolysis and gasification of biomass during 2015. Biomass Technology Group (Netherlands) opened a 25 MW_{th} pyrolysis plant to generate electricity and process steam and to produce fuel oil from woody biomass.[100] In Sweden, the GoBiGas plant in Gothenburg became fully operational in early 2015 and is one of the first successful large-scale examples of the production of methane through the thermal gasification of forest biomass.[101] The process is able to run continuously thanks to developments that avoid the build-up of tars, a persistent problem in previous attempts to deploy this technology.

Aviation biofuels took strong strides forward in 2015. By mid-2015, 22 airlines based in Europe, North America and Asia had performed more than 2,000 commercial passenger flights with blends of up to 50% biojet fuel made from used cooking oil, jatropha, camelina, algae and sugar cane. Several airlines concluded long-term offtake agreements with biofuel suppliers, most of which are reported as price-competitive.[102] In the United States, United Airlines began using advanced biofuels for its regular operations – the first airline in the country to move beyond demonstration flights and test programmes.[103]

In the marine sector, Sweden's Stena Line launched the world's first methanol-fuelled ferry in March 2015.[104] Also in 2015, the US Navy launched an initiative to deploy alternative fuels in its operations. This includes a Carrier Strike Group (CSG) that uses alternative fuels, a contract for 300 million litres of fuel between October 2015 and September 2016 with AltAir Fuels, and a grant of USD 210 million to support three firms in the building of refineries to make biofuels using woody biomass, municipal solid waste (MSW) and used cooking grease and oil.[105] A portion of the CSG fuels consists of biofuel made from beef fat, which is certified as a "drop-in" replacement and requires no engine modifications or changes to operational procedures.[106]

The development and scale-up of biorefineries – facilities that can produce several products from biomass, including energy, chemicals and other valuable products – continued in 2015 with growing efforts in the United States, Europe, China and, most recently, India. For example, Godavari Biorefineries (India) raised more than USD 14 million during the year to increase ethanol production, while also adding specialty chemical production capacity.[107]

Gaseous Biomass Industry

The biogas sector continued to expand in 2015. Most biogas production is in the United States and Europe, although other regions increasingly are deploying the technology as well.[108] In Europe, the first biogas plant in Macedonia was constructed in 2015. The plant digests cattle waste and has a power generating capacity of 3 MW. Also during the year, the European Bank for Reconstruction and Development (EBRD) agreed to provide USD 32 million for a biogas plant in Ukraine.[109]

Anaerobic digestion plants are being deployed more widely to treat liquid effluents and wastes in Asia, notably in Thailand and Indonesia, where a range of waste materials – including effluents from cassava starch production, palm oil processing and ethanol production, as well as MSW – are being used as feedstocks.[110] For example, in early 2016, the Krabi waste-to-energy project began operation in Thailand, processing palm oil mill effluent and producing 12,300 MWh annually, which is exported to the neighbouring electricity grid.[111]

There are signs in Africa of increasing activity in biogas production, particularly waste-based projects that involve landfill gas, MSW and agricultural residues. The year 2015 saw the launch of the Bronkhurstspruit project in South Africa, which produces 4.4 MW of electricity from the digestion of cattle waste and sells the electricity to a neighbouring industrial plant – the first such project in the region.[112] In Kenya, a 2.2 MW grid-connected digester system that uses local crop residues opened in Nakuru Country.[113] In Dakar, Senegal, animal waste at a slaughterhouse is digested and used in a CHP system to generate electricity and heat; it produces 800 MWh of electricity and 1,600 MWh of thermal energy annually for internal use.[114]

i Tall oil is a mixture of compounds found in pine trees and is obtained as a byproduct of the pulp and paper industry.

GEOTHERMAL POWER AND HEAT

GEOTHERMAL MARKETS

Geothermal resources provide energy in the form of electricity and direct heating and cooling, totalling an estimated 543 PJ (151 TWh) in 2015.[1] Geothermal direct use and electricity generation each are estimated to account for one-half of total final geothermal output (75 TWh each)[i].[2] Some geothermal plants produce both electricity and thermal output for various heat applications.

About 315 MW of new *geothermal power* generating capacity was completed in 2015, bringing the global total to an estimated 13.2 GW.[3] Countries that added capacity during the year were (in order of new capacity brought online) Turkey, the United States, Mexico, Kenya, Japan and Germany.[4] (→ *See Figure 10.)* Turkey accounted for about half of new installations.

At the end of 2015, the countries with the largest amounts of geothermal power generating capacity were the United States (3.6 GW), the Philippines (1.9 GW), Indonesia (1.4 GW), Mexico (1.1 GW), New Zealand (1.0 GW), Italy (0.9 GW), Iceland (0.7 GW), Turkey (0.6 GW), Kenya (0.6 GW) and Japan (0.5 GW).[5] (→ *See Figure 11.)*

Capacity additions in 2015 were somewhat lower in total than in recent years. As many as 11 binary[ii] power plants were completed, totalling 129 MW, and another 8 single-flash plants were completed, totalling 186 MW.[6]

Turkey continued its relatively rapid build-up of geothermal power capacity, with 10 units completed in 2015, adding 159 MW for a total of at least 624 MW.[7] Among the plants completed was a 4 MW binary Organic Rankine Cycle (ORC) unit by Exergy (Italy) that is claimed to be the world's first to operate at two pressure levels, which increases energy recovery and overall efficiency from low-temperature resources.[8] Turkey is well on its way to meeting its goal of having 1 GW of geothermal power capacity in place by 2023.[9] In 2015, the country generated 3.37 TWh with geothermal energy, up 50% over 2014.[10]

The United States added 71 MW with two binary plants (by Ormat, United States) coming online in Nevada, bringing total operating capacity to nearly 3.6 GW (2.5 GW_{net}).[11] Generation in 2015 was 16.8 TWh, representing a 5.6% increase relative to 2014.[12] There are some indications that significant new growth could be unleashed if economic and regulatory conditions improved; about 500 MW of projects are languishing in late-stage development in the United States.[13]

Mexico brought online a 53 MW unit at the Los Azufres field in early 2015 and retired four ageing wellhead units (5 MW each) in the same location. In addition, two 5 MW wellhead plants were installed in the Domo San Pedro field, which is Mexico's first privately owned geothermal project.[14] The total net increase for the year was 43 MW, bringing Mexico's installed capacity to 1.1 GW.[15] During 2015, Mexico's energy authorities provided additional concessions for the government's power producer (CFE) in fields where the company already has developed geothermal resources. However, most of the country's remaining geothermal potential was opened for private investment and development.[16]

Kenya added at least 20 MW of new capacity in 2015 for a total of about 600 MW.[17] Drilling commenced on the first phase of the Akiira Geothermal 140 MW plant after Kenya Power signed a PPA for its output. It is expected that the plant will be sub-Saharan Africa's first private sector greenfield geothermal development.[18] Exploration risk insurance was secured for this project; in many cases, however, risk mitigation remains a hurdle for geothermal development, especially in developing countries.[19]

In late 2015, another binary plant was completed in Bavaria in Germany, supplying 5.5 MW of power generating capability in addition to 12 MW of thermal output.[20] As of early 2016, Germany had a concentration of several small geothermal plants around Munich that take advantage of local low-temperature geothermal resources to provide both heat and power.[21]

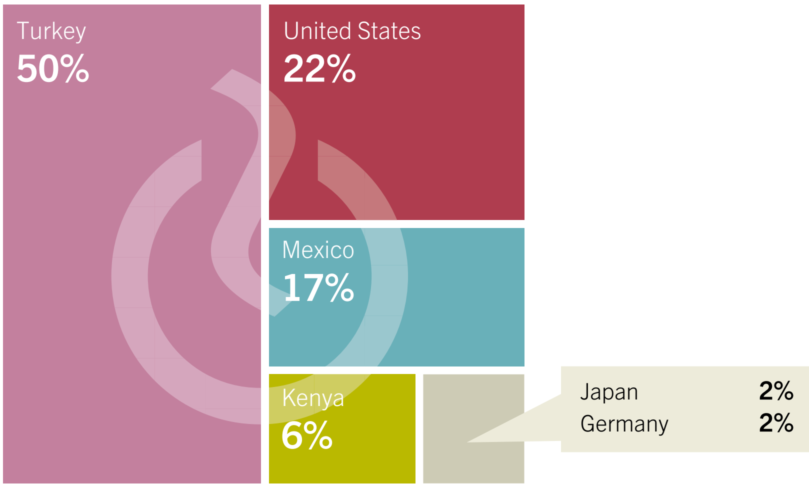
Japan also added several facilities (altogether 6.8 MW) in 2015, bringing its total capacity to 535 MW. The new plants included

i This does not include the renewable final energy output of ground-source heat pumps, which was estimated at 358 PJ (99 TWh) in 2015. See endnote 1 for this section.

ii In a binary plant, the geothermal fluid heats and vaporises a separate working fluid with a lower boiling point than water, which drives a turbine for power generation. Each fluid cycle is closed, and the geothermal fluid is re-injected into the heat reservoir. The binary cycle allows an effective and efficient extraction of heat for power generation from relatively low-temperature geothermal fluids. Organic Rankine Cycle (ORC) binary geothermal plants use an organic working fluid, and the Kalina cycle uses a non-organic working fluid. In conventional geothermal power plants, geothermal steam is used directly to drive the turbine, whereas in a conventional thermal power plant, fuelled by nuclear reaction or fossil fuels, the working fluid is pure water.

GEOTHERMAL POWER

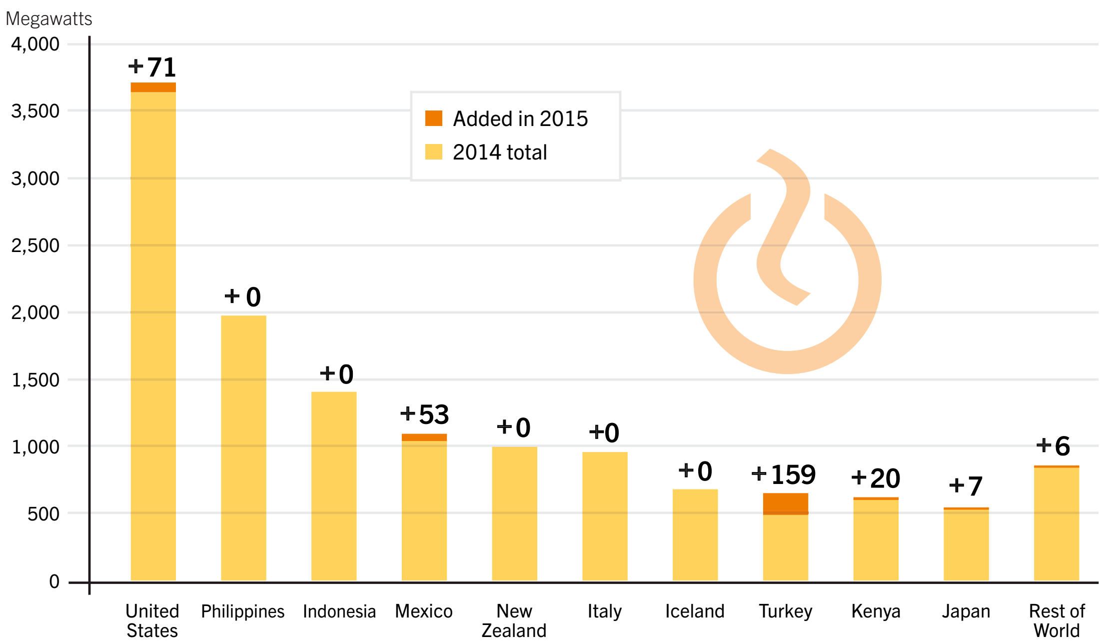
Figure 10. Geothermal Power Capacity Global Additions, Share by Country, 2015



Source: See endnote 4 for this section.

Global output:
Power 75 TWh
Heat 75 TWh

Figure 11. Geothermal Power Capacity and Additions, Top 10 Countries and Rest of World, 2015



Source: See endnote 5 for this section.

three binary units; a 5 MW plant, installed by Turboden (Italy) in co-operation with its parent company, Mitsubishi; and a 1.4 MW plant installed at a medical facility in Kagoshima prefecture.[22] In Tsuchiyu, Fukushima prefecture, a 400 kW unit was completed as part of revitalisation plans following the loss of tourism to the community's hot springs following the 2011 nuclear disaster.[23] By year's end, construction also was under way for a 42 MW plant in Akita prefecture.[24]

In Tuscany, Italy, the hybridisation of Enel Green Power's plant, Cornia 2, was completed, with biomass combustion (using local forest biomass) added to an existing facility to raise geothermal steam temperatures from about 150°C to as high as 380°C. Hybridisation of the plant is expected to improve power output and efficiency by providing steam that is drier and of higher temperature. This change added 5 MW of capacity to the plant, and output is expected to increase by 30 GWh per year.[25]

As geothermal technologies advance and as projects are brought online in new locations, interest in the potential for future geothermal developments continues to spread. For example, plans appear to be gathering steam on the volcanic island of Nevis in the Lesser Antilles. Construction was expected to begin in 2016 on a 9 MW binary plant that could meet the power needs of the island's 12,000 inhabitants while displacing diesel imports of 19 million litres (4.2 million gallons) per year.[26] The neighbouring St. Kitts also is pursuing geothermal exploration.[27]

Canada does not generate power from geothermal resources, but a recent estimation suggests that there is substantial potential in Alberta, Yukon and British Columbia, with sufficient resources in British Columbia to meet the province's entire power demand.[28] In response to a large expected rise in industrial electricity demand, geothermal power (including binary plants) has been proposed as a cost-competitive alternative to the province's proposed 1.1 GW "Site C" hydropower project.[29]

Geothermal direct use – direct thermal extraction for heating and cooling, excluding heat pumps[i] – was estimated at 272 PJ (75.5 TWh) in 2015. An estimated 1.2 GW_{th} of capacity was added in 2015, for a total of 21.7 GW_{th}.[30] Direct use capacity has grown by an annual average of 5.9% in recent years, while direct heat consumption has grown by an annual average of 3.3%.[31] The data suggest that the average global capacity factor (utilisation) for direct geothermal heat plants was 41% in 2014, down from about 46% five years earlier.[32] This decline is explained largely by a significant drop in indicated capacity utilisation for swimming and bathing (subject to great uncertainty due to differences in methods of operation), and to rapid growth in geothermal space heating (7% annually), which exhibits below-average capacity utilisation at 37%.[33]

The single largest direct use sector is estimated to be swimming pools and other public baths, which together accounted for nearly 45% of total geothermal heat capacity in 2015 and a similar share of heat use (9.7 GW_{th}; 33.7 TWh); however, these numbers are subject to uncertainty.[34] The second largest sector is space heating (including district heat networks), which was estimated at 8.1 GW_{th} in 2015 (26.2 TWh).[35] These two broad

markets command around 80% of both direct use capacity and consumption. The remaining 20% of direct use capacity and heat output is for applications that include domestic hot water supply, greenhouse heating, industrial process heat, aquaculture, snow melting and agricultural drying.[36]

Geothermal district heating continued its relatively dynamic growth in Europe, with several new systems completed in 2015. Eight systems were brought online in France and one in the Netherlands, with a combined installed capacity of nearly 100 MW_{th}.[37] As of early 2016, more than 200 additional projects were under development in Europe.[38]

Many of the geothermal district heat systems being developed in Europe are located in the Paris and Munich areas, where low-temperature geothermal aquifers coincide with population centres that together provide ideal conditions for geothermal district heat development.[39] Among a string of new projects in the Paris region is the new 10 MW YGéo project on the outskirts of the city, which is expected to be completed in 2016. These Paris projects tap into the Dogger aquifer that runs between Tours and Colmar. The operating temperature is relatively low, at around 66°C, but the YGéo system will be supplemented with heat pumps for an additional 7 MW.[40]

Interest in geothermal heat in Europe has expanded in recent years. In the Netherlands, geothermal heat use commenced in 2008. Initially, it was used primarily to serve greenhouses, but use of geothermal heat has grown notably since, rising to 100 MW_{th} as of 2014, with expansion into district heating.[41]

The countries with the largest geothermal direct use capacity are China (6.1 GW_{th}), Turkey (2.9 GW_{th}), Japan (2.1 GW_{th}), Iceland (2.0 GW_{th}), India (1.0 GW_{th}), Hungary (0.9 GW_{th}), Italy (0.8 GW_{th}) and the United States (0.6 GW_{th}). Together, these eight countries accounted for about 80% of total global capacity in 2015.[42]

In line with installed capacity, China utilised the most direct geothermal heat (20.6 TWh). Other top users of direct geothermal heat are Turkey (12.2 TWh), Iceland (7.4 TWh), Japan (7.1 TWh), Hungary (2.7 TWh), the United States (2.6 TWh) and New Zealand (2.4 TWh). These countries accounted for approximately 70% of direct geothermal in 2015. On a per capita basis, direct use is by far most significant in Iceland, at 22 MWh per person each year, followed by New Zealand, Hungary, Turkey and Japan, all at 0.5 MWh per person or less.[43]

i Direct use refers here to deep geothermal resources, irrespective of scale, as distinct from shallow geothermal resource utilisation, specifically ground-source heat pumps. (See heat pumps discussed in Sidebar 4 of GSR2014.)

GEOTHERMAL INDUSTRY

Low natural gas prices in 2015 created unfavourable conditions for geothermal energy. However, the relatively low oil prices also reduced global demand for drilling rigs, making more rigs available and reducing the associated costs of geothermal exploration and development of new fields.[44]

In Europe, renewed calls were made to policy makers to support geothermal energy development, primarily through technology-neutral policy measures such as improved data collection in the heat sector; the provision of financing that is directed towards renewable heat and cooling; and a formal examination of the potential for dispatchable renewable energy resources to complement rising shares of variable renewables. Another requirement that is specific to geothermal energy is public risk insurance to mitigate geologic risk.[45] In that context, the French government announced a new USD 54.6 million (EUR 50 million) geothermal risk fund in 2015 that will facilitate the initiation of new exploration efforts that carry the greatest risk profiles.[46]

The industry continued to work towards broader recognition of geothermal power as a valuable ally in the effort to integrate larger shares of variable renewable power. In addition to serving baseload demand, geothermal power also can balance variable grid supply, provide system inertia[i], regulate voltage when needed and assist in overall system stability.[47]

Some important partnerships were launched during 2015. In October, Ormat Technologies and Toshiba Corporation signed a strategic collaboration agreement to offer their customers more competitive solutions, drawing on both Ormat's binary technology and Toshiba's flash technology in a combined-cycle configuration. The first project expected under this collaboration is the Menengai plant, under development in Kenya.[48]

In addition, Engie (formerly GDF-Suez) and Reykjavik Geothermal (RG) announced that Storengy (Engie's subsidiary) and RG will pursue geothermal energy projects in Mexico, where RG was awarded one of the first two private geothermal exploration permits in the Ceboruco region and expects to complete a new plant by 2018.[49]

Following the launch of the Global Geothermal Alliance at the UN Climate Summit in 2014, the Alliance issued a joint statement at COP21 in Paris regarding its mission to consolidate government, industry and other stakeholder efforts in order to significantly increase global use of geothermal energy. The Allliance's goal is to achieve a five-fold increase in geothermal power capacity and a more than two-fold increase in geothermal heating, all by 2030 (relative to 2014 levels).[50]

i System inertia refers to the aggregate stored kinetic energy in power generators that acts as a short-term buffer in the event of loss of power by slowing down the frequency decline on the grid.

ii Unless otherwise specified, all capacity numbers exclude pumped storage capacity if possible. Pure pumped hydro plants are not energy sources but means of energy storage. As such, they involve conversion losses and are powered by renewable and/or non-renewable electricity. Pumped storage plays an important role in balancing power, in particular for variable renewable resources.

iii Despite slightly lower total capacity, Canada's baseloaded output exceeds the more load-following output in the United States.

HYDROPOWER

HYDROPOWER MARKETS

An estimated 28 GW of new hydropower capacity was commissioned in 2015, with total global capacity reaching approximately 1,064 GW[ii],[1] The top countries for hydropower capacity remained China, Brazil, the United States, Canada[iii], the Russian Federation, India and Norway, which together accounted for about 63% of global installed capacity at the end of 2015.[2] (→*See Figure 12 and* ***Reference Table R5.***) Global hydropower generation, which varies each year with hydrological conditions, was estimated in 2015 at 3,940 TWh.[3] Global pumped storage capacity (which is counted separately) was estimated to be as high as 145 GW at year's end, with approximately 2.5 GW added in 2015.[4]

As in the past several years, the most significant share of new hydropower capacity was commissioned in China, which accounted for about one-half of the global total. Other countries with substantial additions in 2015 included Brazil, Turkey, India, Vietnam, Malaysia, Canada, Colombia and Lao PDR.[5] (→ *See Figure 13.)*

China commissioned 16 GW of new hydropower projects (a 26% decline relative to 2014) for a year-end total of 296 GW; in addition, the country has 23 GW of pumped storage capacity.[6] Hydropower generation in China increased for the second consecutive year, up by more than 5% in 2015 (at 1,126 TWh).[7] Hydropower infrastructure investment declined sharply for the second year in a row, down 17% to USD 12 billion (CNY 78 billion), following a 21.5% drop in 2014.[8] China is pursuing large-scale projects including the 10.2 GW Wudongde plant, which is targeted for completion by 2020, as well as smaller projects in more remote regions, such as Tibet. At the same time, however, some potential projects have not advanced because Chinese authorities have refused construction permits for some untapped resources on ecological grounds.[9]

Hydropower capacity in Brazil increased in 2015 by 2.5 GW (2.8%), including 2.3 GW of large-scale[i] hydro (>30 MW) capacity, for a year-end total of 91.7 GW.[10] Despite the increase in capacity, hydropower output, at 382 TWh, dropped again (2.7% relative to 2014) due to continuing drought conditions. Between 2011 and 2015, Brazil's hydropower output declined about 15%, even as capacity expanded by about 11%.[11] New capacity is being built in a manner to improve the power system's resilience to drought.[12]

In 2015, 17 additional 75 MW turbines (1,275 MW) became operational at Brazil's Jirau plant, with just over 3 GW in place by year's end.[13] Jirau's sister plant, Santo Antonio (3.57 GW when completed), also along the Madeira River, added three units (212 MW) for a total of 2.5 GW.[14] Two units (728 MW) came online at the Teles Pires plant, which will yield 1.82 GW when completed.[15] The 11.2 GW Belo Monte was partially commissioned in early 2016, with full commissioning to follow when new transmission infrastructure is in place. Transmission lines continue to be one of the main bottlenecks for development of renewable energy projects in Brazil, with the majority of the country's transmission projects behind schedule.[16]

Turkey appears to be on track to achieve its target of 34 GW of hydropower capacity by 2023; this target is part of the country's plan to pursue all available resources to meet rapidly growing electricity demand.[17] Turkey added 2.2 GW in 2015, bringing the total to 25.9 GW.[18] Hydropower production has been affected by severe fluctuations in rainfall: following a particularly dry period and sharp drop in output in 2014, production rebounded in 2015 by nearly 66%, to 66.9 TWh.[19]

India ranked fourth for new installations. In 2015, the country brought online approximately 1.9 GW of new hydropower capacity, most (1.8 GW) of which was in the category of large-scale hydro (>25 MW per facility), and ended the year with a total of 47 GW. Generation in 2015 was an estimated 135 TWh; output of large-scale facilities was 123 TWh, a drop of 5.7% from 2014.[20] Completed facilities included the 800 MW Koldam project; this plant in the lap of the Himalayas in the northern state of Himachal Pradesh was long-delayed due to ecological and geological concerns.[21] In the state of Uttarakhand, the 330 MW Shrinagar run-of-river project started operation, with a portion of the plant's output designated for local consumption at no charge.[22]

Neighbouring Bhutan completed the 126 MW Dagachhu run-of-river station, the first transboundary Clean Development Mechanism (CDM) project registered with the UNFCCC.[23] All of the plant's output is destined for the Indian power market.[24] In Nepal, construction of new plants, such as the 111 MW Rasuwagadi and the 456 MW Upper Tamakoshi, suffered severe setbacks due to damage from the April 2015 earthquake and its aftershocks.[25] Nepal temporarily lost 150 MW of hydropower capability (about 30% of total), exacerbating an already severe electricity shortfall.[26]

Vietnam, which ranked fifth for installations, added a little over 1 GW of capacity in 2015. New capacity included the first of three 400 MW units at the Lai Chau plant; when completed, it will be Vietnam's third largest hydropower facility.[27] The country also commissioned the first of two 260 MW units at the Huoi Quang plant, with the second to follow in 2016.[28] Serious drought conditions have depleted Vietnam's reservoirs and strained hydropower production.[29]

Several other countries in the region completed projects during the year, including: Malaysia brought online the remaining 708 MW of the 944 MW Murun plant; Lao PDR finalised about 600 MW, including the 180 MW Nam Ngiep 2 plant, which has specially designed turbines for its head height of 495 metres; and Cambodia bolstered its inadequate electricity supply with the 338 MW Russei Chrum River dam (financed and built by Chinese corporations).[30] Myanmar completed a 140 MW plant on the Paunglaung River, which the government considered a major success in dealing with challenges posed by rapidly increasing power demand and very limited access to electricity, while overcoming significant population resettlement challenges.[31]

In March 2016, on the eve of the bi-annual meeting of the Mekong River Commission, China announced plans to release additional water into the downstream portions of the Mekong River, continuing into early April 2016 to help alleviate severe water shortages in the drought-stricken downstream countries of Lao PDR, Myanmar, Thailand, Cambodia and Vietnam.[32]

In North America, the United States continued to rank third globally for installed hydropower capacity but added only 70 MW to its grid in 2015, for a year-end total of 79.7 GW.[33] The country experienced a fourth consecutive year of decline in output due to unfavourable hydrological conditions, with generation of 251 TWh, 7.6% below the average for the preceding decade.[34]

Canada completed 0.7 GW of new facilities and expansions in 2015, raising total installed capacity to 79 GW, while maintaining output at 376 TWh for the year.[35] British Columbia's Waneta expansion project added 335 MW to an existing facility, cost-effectively capturing power from flow that otherwise would be spilled.[36] Also in 2015, the 270 MW Romaine-1 project – the second of four planned cascading plants – was completed in Québec.[37]

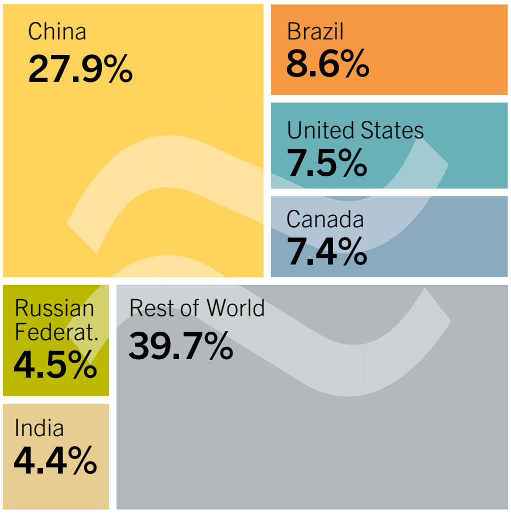
The Russian Federation continued to rank fifth globally for total installed capacity, adding a net of 143 MW in 2015 for a year-end total of 47.9 GW.[38] Hydropower generation (160 TWh) was down 4.1% relative to 2014.[39] RusHydro completed several refurbishment projects in 2015 and had plans to continue modernisation efforts for improved reliability, efficiency and security.[40] The Russian Federation's Boguchanskaya plant, which saw completion of the last of nine 333 MW units in late 2014, achieved an effective capacity of 3 GW when its vast reservoir finally reached design capacity in June 2015.[41] Following transmission and other plant upgrades, the effective capacity of the restored Sayano-Shushenskaya plant (6.4 GW) increased by another 700 MW, for a total of 5.1 GW.[42]

In Africa, Ethiopia neared completion of its 1.87 GW Gibe III plant, after nine years of construction, bringing 2 of the project's 10 turbines into service. Gibe III has one of the tallest concrete dams (246 metres) of its type in the world.[43] As of early 2016, UNESCO's World Heritage Centre continued to monitor the project's social and ecological impacts.[44] Once completed, the plant is expected to increase Ethiopia's electricity supply significantly and to pave the way for the country to become a major power exporter.[45]

i Brazil reports hydropower capacity separately by size category, at the thresholds of 1 MW (very small) and 30 MW (small). India reports hydropower above a threshold of 25 MW, separately from smaller facilities.

HYDROPOWER

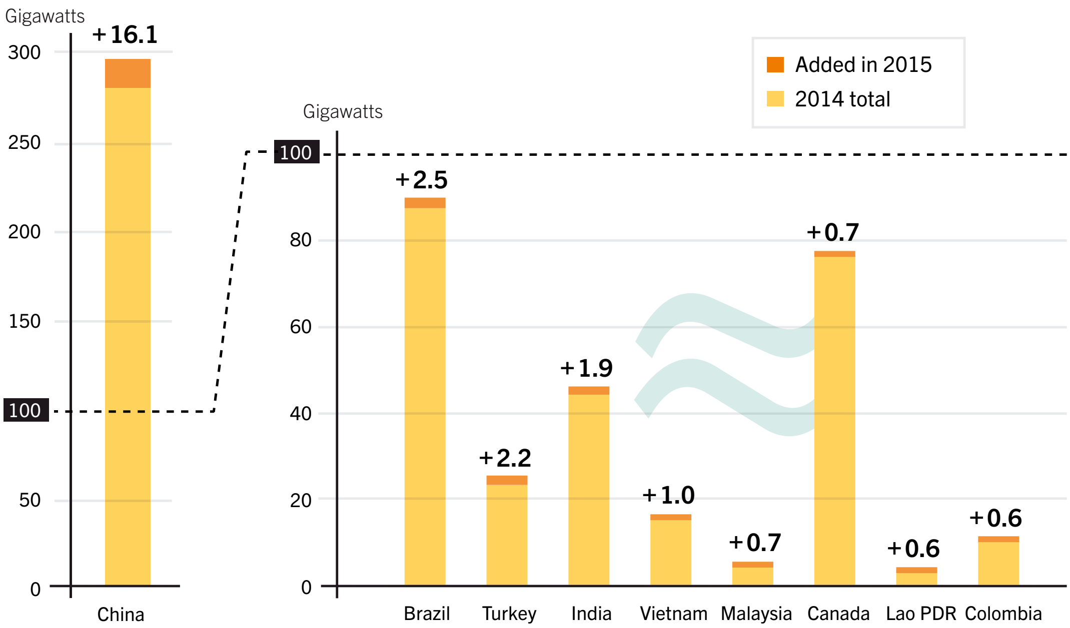
Figure 12. Hydropower Global Capacity, Shares of Top Six Countriesand Rest of World, 2015



Source: See endnote 2 for this section.

Global capacity reached 1,064 GW

Figure 13. Hydropower Capacity and Additions, Top Nine Countries for Capacity Added, 2015



Source: See endnote 5 for this section.

Other countries in Africa to add hydropower capacity included Guinea, which tripled its capacity with the completion of the 240 MW Kaleta facility in 2015 (it is anticipated that the plant will alleviate the country's energy shortage and also benefit neighbours in West Africa), and Zambia, where the 120 MW Itezhi Tezhi plant was completed.[46]

Numerous small-scale hydropower projects were completed in Brazil, India and elsewhere, including Scotland. The Isle of Mull saw the commissioning of a 400 kW community-owned run-of-river hydropower project in 2015. About half of the project cost was raised through a community share offer; the expected net return of as much as USD 3.6 million (GBP 2.4 million) over 20 years will serve the needs of the community through a local charity.[47] (For more on community energy projects, see Feature.)

The World Bank remains committed to continuing its support for well-designed and well-implemented hydropower projects of all sizes for both local development and climate mitigation.[48] In 2015, the World Bank announced its new action plan to improve its resettlement policy, drawing on lessons learned, with the intention of significantly improving the protection of people and businesses that may be resettled as a result of World Bank-funded development projects.[49]

Global pumped storage capacity rose by 2.5 GW, with the year-end total estimated to be as high as 145 GW.[50] China added 1.2 GW of new capacity, and Iran completed the first pumped storage plant in the Middle East, the 1,040 MW Siah Bishe.[51] Japan added storage with the completion of the second 200 MW variable-speed unit at Kyogoku plant, on the island of Hokkaido.[52] In Europe, Austria completed construction of the 430 MW Reisseck II pumped storage facility in 2015, but commissioning was delayed into 2016.[53]

Opportunities for growth in pumped storage may be hampered in some markets by regulatory restrictions. In China, however, an estimated 27 GW of new capacity is under construction to help reduce curtailment of solar and wind power and to accommodate further growth in variable renewable energy.[54]

HYDROPOWER INDUSTRY

Climate-related risk and rising shares of variable renewable power are driving adaptation in the hydropower industry. During 2015, the industry continued to adapt to manifestations of climate change – including increased glacial run-off and variability of rainfall – through operational changes, modifications to existing plants, and changes to the design of new hydropower plants.[55] Responses to rising shares of variable renewables have included an increased emphasis on pumped storage and coimplementation of hydropower with solar and wind power plants in order to both maximise the efficient utilisation of variable resources and conserve water resources.[56]

Modernisation, retrofitting and expansion of existing facilities continued in many locations. These developments reflect several pressing needs across the industry, including the needs to refurbish ageing infrastructure in many countries; maximise resource utilisation to increase efficiency of operations; shift from baseload operations to cycling and peak operations in many instances; and increase storage capacity for system back-up, reduced vulnerability to hydrological variation and improved overall system resilience.[57]

The industry approach to project financing continued to evolve in 2015 with a trend towards risk-sharing among partners. Examples include developers taking equity shares in new projects, and public and private parties sharing responsibility for each stage of project development. Refinancing upon successful completion of projects, which reduces long-term costs and frees public funds for further development, is also becoming more common. Although they are not yet subject to any common standards, green bonds have become very important to the hydropower industry because they help lower the risk profiles of projects. Finally, the alchemy of blended finance – leveraging development funding with private capital – has created opportunities to meet varied development goals, such as irrigation and flood control, while tying the objectives into the revenue-generating aspect of hydropower development.[58]

The most significant providers of hydropower equipment are GE (United States), Andritz Hydro (Austria) and Voith Hydro (Germany), each with about equal market shares. Together they account for about one half of the global industry.[59] Other notable manufacturers include Harbin (China), Dongfang (China) and Power Machines (Russian Federation).

Among notable events in the industry in 2015 was the completion of GE's USD 10.6 billion (EUR 9.7 billion) acquisition of Alstom's energy activities.[60] Andritz Hydro reported unchanged, difficult market conditions with a continued decline (-5.4%) in new orders, although sales were up slightly (+4.7%) for 2015. The company noted that relatively low electricity prices (and low energy prices in general) led to the postponement of many modernisation and refurbishment projects, especially in Europe.[61]

Voith noted strong sales in North and South America – in Brazil in particular, despite political instability and weak economic conditions in that country.[62] The company's 2015 sales were unchanged relative to 2014. Despite favourable currency developments (due to the weak euro), however, the high orders booked in 2014 could not be sustained, and declined by 5%.[63] Voith considers the North American market promising for both new plants and refurbishment, even though plentiful shale gas has depressed electricity prices.[64] The Asian market – including Indonesia, the Philippines and Vietnam – gained importance during the year.[65]

With a slowdown in domestic contracts, Chinese corporations have been increasing their involvement in hydropower-related projects around the world. Their involvement has included both construction and operations, and they have focused particularly in Africa, South Asia and South America.[66] In early 2016, China Three Gorges Corporation acquired two hydropower plants in Brazil, becoming Brazil's second largest private power producer. The State Grid Corporation of China has committed to building and operating new transmission lines in Brazil, including a long-range conduit for output from the large Belo Monte project.[67]

OCEAN ENERGY

OCEAN ENERGY MARKETS

Ocean energy refers to any energy harnessed from the ocean by means of ocean waves, tidal range (rise and fall), tidal streams, ocean (permanent) currents, temperature gradients and salinity gradients.[1] At the end of 2015, global ocean energy capacity remained at approximately 530 MW[i], mostly in the form of tidal power and, specifically, tidal barrages across bays and estuaries.

A commercial market for ocean energy technology has not really developed to date because most technologies are still in various prototype and demonstration stages. The one exception is the application of established in-stream turbine technology in tidal barrages. The two largest ocean energy projects are the 254 MW Sihwa plant in the Republic of Korea (completed in 2011) and the 240 MW La Rance tidal power station in France (1966), both tidal barrages.[2]

In 2015, it appeared that the proposed 320 MW Swansea Bay Tidal Lagoon in Wales would move forward when the UK government issued planning consent in June.[3] However, in February 2016, UK authorities announced an independent review into the feasibility and practicality of tidal lagoon energy in the United Kingdom. The review will consider the cost-effectiveness of such projects, potential impacts, financing options and opportunities for competitive frameworks for project delivery.[4]

Most of the recent development efforts in ocean power technologies are focused on tidal stream and wave energy in open waters. Several new projects were launched around the world in 2015, with most activity concentrated in Europe. As in most years, ocean energy technology deployments were predominantly demonstration projects.

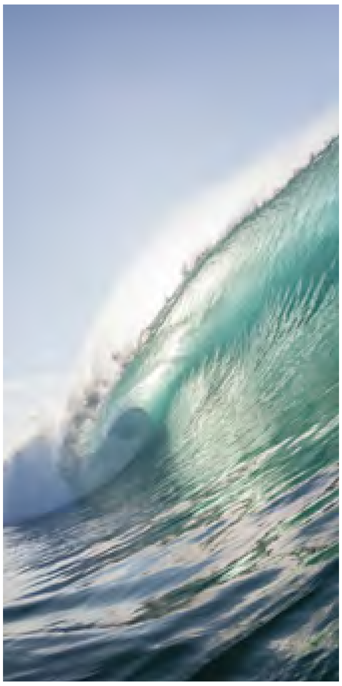
OCEAN ENERGY INDUSTRY

The year 2015 presented a mixture of tail- and headwinds for the ocean energy industry. A number of companies continued to successfully advance their ocean energy technologies and to deploy new or improved devices, but at least one company had to declare bankruptcy.

The tidal industry experienced a number of advances in 2015 with the launch of numerous projects around the world. The Netherlands, for example, saw the completion of two notable projects. In early 2015, Tocardo (Netherlands) installed three grid-connected tidal turbines in a Dutch sea defense dike, in co-operation with the Dutch Tidal Testing Center, and the company plans to expand this 300 kW installation to 2 MW upon further evaluation.[5] Later in the year, with the support of Huisman (provider of the turbine suspension structure), Tocardo successfully installed a five-turbine array in the Dutch Eastern Scheldt storm surge barrier.[6] The project has a power output of 1.2 MW, which is adequate to supply electricity to approximately 1,000 local households. Also in Dutch waters, the BlueTEC Texel tidal partnership launched a floating platform that carries a Tocardo turbine and supplies power to the grid.[7]

Atlantis Resources (UK/Singapore) commenced construction at the site of the MeyGen tidal stream project in Scotland in early 2015.[8] Later in the year, Atlantis completed cable deployment to the MeyGen site, where the first four 1.5 MW turbines were to be installed in 2016.[9] By early 2016, Atlantis was advancing on construction in Scotland of one of the four turbines – a single Lockheed Martin-designed AR1500 – while Andritz Hydro Hammerfest was completing the other three 1.5 MW turbines in Germany. Both turbine designs have an 18-metre rotor diameter and are configured for both active pitch and full yaw capability.[10]

Tidal Energy Ltd (UK) reached a milestone when its 400 kW DeltaStream tidal demonstration device became the first full-scale tidal device installed in Wales, in Ramsey Sound.[11] Also in



i This does not include all pilot and demonstration projects currently deployed, which may amount to several additional megawatts of capacity.

Wales, the Swedish tidal stream technology company Minesto secured USD 14.2 million (EUR 13 million) of EU funds to support development of its Deep Green device, which operates as an underwater kite.[12] Minesto partnered with Schottel Hydro, a German turbine manufacturer that will supply turbine components for upcoming deployments of Deep Green devices.[13]

Also in the United Kingdom, Sustainable Marine Energy Ltd. (UK) installed its PLAT-O turbine platform, which the company hopes will drive down the cost of tidal energy. The platform was fitted with two Schottel instream turbines and installed off the Isle of Wight, where it met all expectations.[14] Schottel notes that there is synergy in the combination of turbine and platform because both are designed to be lightweight, robust and simple.[15]

Nova Innovation (Scotland) and its partner ELSA (Belgium) secured additional funding from the Scottish government for a 500 kW tidal array in Shetland's (Scotland) Bluemull Sound. The project uses Nova's 100 kW M100 direct-drive turbine, and the first unit delivered power to the grid in early 2016.[16]

To the south, Sabella SAS (France) launched its full-scale, grid-connected 1 MW D10 tidal turbine off the coast of Brittany, in the Fromveur Strait, where it supplies electricity to the Ushant Island.[17]

OpenHydro (a subsidiary of DCNS, France) continued its work off the French coast, deploying the first of two new turbines at EDF's (France) site at Paimpol-Bréhat, following a few years of testing.[18] Across the Atlantic, OpenHydro also advanced a project at Canada's Fundy Ocean Research Center for Energy (FORCE) in the Bay of Fundy, where the company was awarded USD 4.5 million (CAD 6.3 million) to support its deployment of two 2 MW tidal turbines with local partner Emera.[19] The joint venture anticipated turbine deployment in 2016.[20]

Wave energy also saw progress during the year, with the deployment of several devices in pilot and demonstration projects in Europe, Australia, the United States and elsewhere. AW-Energy of Finland continued to refine its WaveRoller device in 2015, with plans to deploy 350 kW commercial units in a 5.6 MW array in Portugal in the near future.[21] In neighbouring Sweden, the 1 MW Sotenäs Wave Power Plant by Seabased (Sweden) started generating power in early 2016. The Sotenäs plant couples linear generators on the sea floor to surface buoys (point absorbers) and is said to be the world's first array of multiple wave energy converters in operation.[22]

Off the coast of Tuscany in Italy, 40South Energy (UK) launched its new 50 kW H24 wave energy converter, a fully submerged machine that is optimised to convert wave and tidal energy in shallow waters.[23]

Also in 2015, Eco Wave Power (Israel) deployed its second-generation wave energy conversion device in the Jaffa Port of Israel.[24] The company also advanced on the first 100 kW phase of a 5 MW EU-funded plant across the Mediterranean Sea in Gibraltar; the plant is expected to meet 15% of local electricity demand when it is completed.[25]

In Australia, BioPower Systems (Australia) deployed its 250 kW bioWAVE pilot demonstration unit off the coast of Port Fairy, Victoria. The device is a 26-metre-tall oscillating structure that was inspired by undersea plants; it is designed to sway back and forth beneath the ocean swell, capturing energy.[26] Another Australian firm, Carnegie Wave Energy Ltd, moved towards deployment of its 1 MW CETO 6 device in early 2016, a scaled-up version of the CETO 5 deployed in 2014.[27]

Across the South Pacific, the US state of Hawaii, home to the US Navy's Wave Energy Test Site (WETS), saw some progress during the year. Northwest Energy Innovations was chosen by the US Department of Energy to demonstrate its half-scale Azura wave energy device for one year of grid-connected testing at WETS, where the company implemented various improvements that were based on previous (2012) trials.[28] Other wave energy technology developers are scheduled to test their devices at WETS in coming years.[29]

The global wave energy industry received significant support from the Scottish Government in 2015. The government-funded Wave Energy Scotland, which was established in late 2014 to support development of wave energy technology, awarded over USD 13 million (over GBP 9 million) in 2015 to multiple developers in several countries for the advancement of innovative wave energy technologies at various stages of development.[30]

Among the most notable success stories in wave energy conversion has been the 296 kW Mutriku plant in the Basque

Country of Spain, the first commercial wave energy plant in Europe. Since its installation in 2011, the plant has operated continuously and, as of early 2016, it had generated more than 1 GWh of electricity by harnessing wave-driven compressed air (oscillating water column).[31]

Ocean energy technologies – both tidal and wave energy – also are being developed actively in East Asia. Japan has established several demonstration sites for ocean energy development with two projects coming online in 2015, a 5 kW tidal stream unit at Shiogama and a 43 kW wave energy project at Kuji.[32] China also is engaged in the development of both wave and tidal energy technologies and, in 2015, had 10.7 MW of capacity installed, including several development projects.[33] The Jiangxia tidal power plant was upgraded in 2015, from 3.9 MW to 4.1 MW.[34] Among new development projects is the 100 kW Sharp Eagle wave energy converter, which was deployed in 2015.[35] China's experience to date indicates that the country's tidal current technologies exhibit significantly lower-cost structures than its wave energy projects, but all are limited by immature technology and lack of experience and supporting infrastructure.[36]

Although the vast majority of demonstration and pilot projects focus on extracting useful energy from the tides and waves, the year 2015 also saw advances in the area of ocean thermal energy conversion (OTEC). Makai Ocean Engineering (United States) connected a new 100 kW OTEC plant – believed to be the world's largest – to Hawaii's electric grid in August.[37] Makai's research and evaluation OTEC plant uses the temperature difference between deep ocean water (at 670 metres) and surface water to generate electricity, where a closed-cycle working fluid of ammonia drives a turbine for power generation.[38]

As more projects are tested around the world, it is increasingly important to understand the potential effects of ocean energy development on marine life. A report on the status of scientific knowledge in this area, released in early 2016, found that the main potential interactions between ocean energy devices and marine animals that present ongoing concern include: risk of animals colliding with moving components; various potential impacts of sound propagation from ocean energy devices; and any biological effect of electromagnetic fields generated from underwater cables.[39] Many of the perceived risks associated with such interactions are driven by uncertainty, due to lack of data, which continues to confound differentiation between real and perceived risks.[40]

The industry continues to face a variety of challenges that were explored by the European Commission's Ocean Energy Forum in its 2015 draft Strategic Roadmap on ocean energy. The document outlines the main imperatives for overcoming the hurdles to realising commercial success for the various ocean energy technologies. These imperatives include infrastructure and logistical needs of the industry for technology advancement; overcoming financing obstacles in an industry characterised by relatively high risk and high upfront costs; and the need for improved planning, consenting and licensing procedures.[41]

The relatively high development risk of ocean energy technologies has proven the need for well-equipped test centres and other risk-mitigating innovations. In combination with competitive financial incentives from the US Department of Energy, the US Navy's recently renovated Carderock Maneuvering and Seakeeping Basin wave simulator will be used in a government effort to stimulate innovation, establish new companies and drive down costs in the development of new wave energy devices in the United States.[42]

Across the Atlantic, the FloWave ocean simulation test tank that opened at the University of Edinburgh in 2014 is intended to mitigate project risk by allowing testing of ocean energy devices before committing to the cost of trials at sea.[43] In 2015, Canadian and UK parties launched a collaboration to develop a new sensor system to increase understanding of the impact of turbulence on tidal devices, and thus reduce development risk.[44] The European Marine Energy Centre (EMEC) and FloWave joined forces to simulate actual sea conditions around Orkney based on EMEC's monitoring data, with the aim of improving test results.[45]

Due to difficult market conditions that include limited funding for R&D and a constrained financial landscape in general, EMEC characterised the year as turbulent, but noted also that new developers were signed up for tests at the Centre.[46]

Despite the many encouraging developments in ocean energy in 2015, the industry's challenges took their toll, and the year witnessed consolidation in the industry as well as one closure.

Aquamarine Power (UK) announced the successful demonstration of its wave energy converter (Oyster 800) in early 2015, but only a few months later the company was placed in administration due to lack of private sector backing that was required to supplement public funding support; subsequently, the company was dissolved.[47]

Atlantis acquired from Siemens AG the UK-based company Marine Current Turbines (MCT) – the manufacturer of the world's first utility-scale tidal stream project (the 1.2 MW SeaGen system). In late 2015, ScottishPower Renewables joined Atlantis as a shareholder in the Tidal Power Scotland Limited (TPSL) project portfolio, folding into TPSL its development projects in Scotland.[48]

SOLAR PHOTOVOLTAICS (PV)

SOLAR PV MARKETS

Solar PV experienced another year of record growth in 2015, with the annual market for new capacity up 25% over 2014.[1] More than 50 GW was added – equivalent to an estimated 185 million solar panels – bringing total global capacity to about 227 GW.[2] The annual market was nearly 10 times the size of cumulative world capacity just a decade earlier.[3] (→ *See Figure 14 and* ***Reference Table R6.***) Although the top three markets in 2015 were responsible for the majority of capacity added, globalisation continued with new markets on all continents.[4]

Until recently, demand was concentrated in rich countries; now, emerging markets on all continents have begun to contribute significantly to global growth, with solar PV taking off where electricity is needed most: in the developing world.[5] At the same time, however, many former gigawatt-sized markets in Europe installed little to no capacity in 2015.[6] Market expansion in most of the world is due largely to the increasing competitiveness of solar PV, as well as to new government programmes, rising demand for electricity and improving awareness of solar PV's potential as countries seek to alleviate pollution and CO_2 emissions.[7]

Asia eclipsed all other markets for the third consecutive year, accounting for about 60% of global additions.[8] Once again, China, Japan and the United States were the top three markets, followed by the United Kingdom.[9] (→ *See Figure 15.)* Others in the top 10 for additions were India, Germany, the Republic of Korea, Australia, France and Canada.[10] By end-2015, every continent (except Antarctica) had installed at least 1 GW, and at least 22 countries had 1 GW or more of capacity.[11] The leaders for solar PV per inhabitant were Germany, Italy, Belgium, Japan and Greece.[12]

China's central government continued to raise installation targets to increase renewable generation, address the country's severe pollution problems and prop up the domestic manufacturing industry.[13] In 2015, China added an estimated 15.2 GW for a total approaching 44 GW, overtaking long-time leader Germany to become the top country for cumulative solar PV capacity, with about 19% of the world total.[14] (→ *See Figure 16.)* The provinces of Xinjiang (2.1 GW), Inner Mongolia (1.9 GW) and Jiangsu (1.7 GW) were the top markets for the year, with much of this capacity far from the country's population centres.[15] However, six provinces in east and central regions each had more than 1 GW of solar PV capacity at year's end.[16] Large-scale power plants accounted for 86% of total capacity, with the remainder in distributed rooftop systems and other small-scale installations.[17]

The rapid increase in solar PV capacity in China, up from only 7 GW at the end of 2012, has caused grid congestion problems and interconnection delays in the country.[18] Curtailment started to become a serious challenge in 2015, with particularly high rates in the northwest provinces of Gansu (31% over the year) and Xingjiang Autonomous Region (26%), and a national average of 12%.[19] By year's end, insufficient grid capacity was a significant hurdle for new plants, and investors were growing wary of the sector due to delays in subsidy collection and problems with solar panel quality.[20] To address challenges related to curtailment, China has urged top solar-producing provinces to prioritise transmission of renewable energy, build more transmission capacity and attract more energy-intensive industries to increase local consumption.[21] Against these transmission and curtailment challenges, solar PV generated 39.2 TWh of electricity in China during 2015, up about 57% over 2014.[22]

In Japan, the boom continued with as much as 11 GW added to the grid, bringing total capacity to an estimated 34.4 GW.[23] Despite another year of record growth, the residential market was relatively low for the second consecutive year, with 0.9 GW connected to the grid. Commercial and utility-scale projects again drove the market.[24] Due to limited availability of land, developers turned to abandoned farmland and golf courses to site large-scale plants (an idea spreading to the United States as well).[25] Solar PV accounted for 10% of Japan's electricity demand on some of the hottest summer days, and represented 3% of total power generation in 2015.[26]

In only three years, Japan doubled its renewable energy capacity, with solar PV making up the vast majority of the total. The large volume of solar PV projects and their output has exceeded the capacity of the grid, leading the government to revise regulations and causing some utilities to refuse new interconnections and to curtail output from existing plants without compensation.[27] However, many other entities, both domestic and foreign – including telecommunications and gas companies, home builders and others – scrambled to set up renewable energy infrastructure and to begin buying solar PV-generated electricity from homeowners in anticipation of the liberalisation of Japan's electricity market in April 2016.[28]

Elsewhere in Asia, the largest annual market was India (2 GW), ranking fifth globally for additions and tenth for total capacity.[29] India's year-end capacity was over 5 GW, led by Rajasthan (1,264 MW), Gujarat (1,024 MW) and Madhya Pradesh (679 MW).[30] Additions were well above 2014 but below expectations for 2015, due to project delays in several states. Even so, the utility-scale pipeline grew rapidly, driven by the improving cost-competitiveness of solar PV and by rising electricity demand.[31] While most added capacity was in large-scale ground-mounted projects, India's rooftop sector also expanded thanks to high consumer awareness and favourable commercial tariffs in some states.[32] The most immediate challenge for India's solar sector, and for scaling up solar power capacity to achieve the country's ambitious goals (100 GW by 2022), is congestion in the grid.[33]

India was followed by the Republic of Korea, which added 1 GW to end the year with 3.4 GW.[34] Pakistan's market (an estimated 500 MW) took off in response to national FIT payments and other incentives enacted to help alleviate chronic power shortages and increase reliability.[35] Companies flocked to Pakistan, and China played an increasingly important role in the country's renewable energy expansion, including solar PV.[36] Other Asian countries with growing markets include the Philippines and Thailand (both adding more than 100 MW).[37]

Most of the approximately 20 GW installed outside of Asia was added in North America and the EU.[38] North America added 7.9 GW in 2015.[39] Canada accounted for about 0.6 GW, for a year-end total of 2.5 GW, with the rest brought online in the United States.[40]

The United States also had a record year, with solar PV installations exceeding new natural gas capacity for the first time.[41] Nearly

7.3 GW was installed, for a total of 25.6 GW.[42] The market was driven by a race to complete as many projects as possible before expiration of the federal Investment Tax Credit (ITC), which in late 2015 was extended through 2021.[43] The residential sector saw the fastest growth, and direct ownership continued to increase thanks in part to new loan products.[44] The utility-scale sector remained the largest, with more than 4 GW added and almost 20 GW under development at year's end.[45] Again, California led for capacity added (3,266 MW), followed by North Carolina (1,134 MW), with Hawaii well ahead for solar penetration.[46]

Solar PV is proving to be an economically competitive option for meeting US peak power needs, with utility interest going beyond the demand driven by state-based Renewable Portfolio Standards (RPS).[47] An estimated 39% of utility capacity added in 2015 was outside of state RPS mandates.[48] The success of distributed solar and falling costs has led some US utilities to establish their own solar programmes – including residential and community projects – and has led other utilities to fight for revisions or elimination of supportive policies.[49] Net metering has driven most US customer-sited solar PV capacity and has been at the centre of regulatory disputes in more than 20 states.[50] With extension of the ITC, the biggest challenges facing solar PV in the United States are ongoing battles over net metering and rate design.[51]

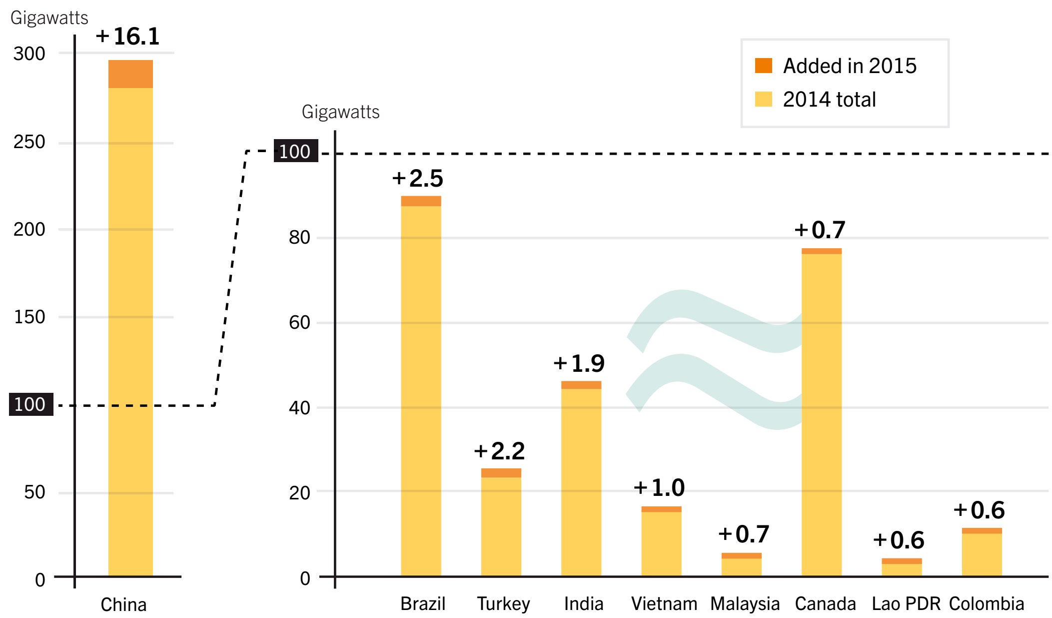
The EU market picked up in 2015 after three years of decline, but was still far below its 2011 peak (22 GW), restrained by a shift away from FITs and by general policy uncertainty.[52] (→ *See Policy Landscape chapter.)* About 7.5 GW was added, bringing the region's total to almost 95 GW of operating solar PV capacity, well ahead of all other regions.[53] Three countries – the United Kingdom (3.7 GW), Germany (1.5 GW) and France (0.9 GW) – were responsible for more than 75% of the EU's new grid-connected capacity.[54] Others adding capacity included the Netherlands (450 MW) and Italy (300 MW), where the market was down dramatically despite the low generating costs and supportive policies.[55] Spain, which drove the global market in 2008, has virtually disappeared from the solar PV picture due to retroactive policy changes and a new tax on self-consumption.[56]

The UK rush was in anticipation of subsidy expirations and FIT cuts, and brought total capacity to 9.1 GW.[57] Solar PV generation surpassed hydropower output in 2015 and reached levels that were not expected in the country for several more years.[58] Germany's annual market fell again (23% relative to 2014) to levels of about a decade ago, and well below the Renewable Energy Law (EEG) annual target of 2.5 GW.[59] Germany ranked second, after China, for total operating capacity, with 39.7 GW at year's end.[60]

Europe has become a challenging market for several reasons. The region is transitioning from FIT incentives to tenders and feed-in premiums for large-scale systems, and to the use of solar PV for self-consumption in residential, commercial and industrial sectors.[61] Further, the more that solar PV penetrates the electricity system, the harder it is to recoup project costs. So an important shift is under way: from the race to be cost-competitive with fossil fuels to being able to adequately remunerate solar PV in the market.[62] In addition, electricity demand is stagnating and conventional utilities are lobbying simply to maintain their position. Thus, electricity market design is increasingly important, and there is a need for new business models.[63]

SOLAR PV

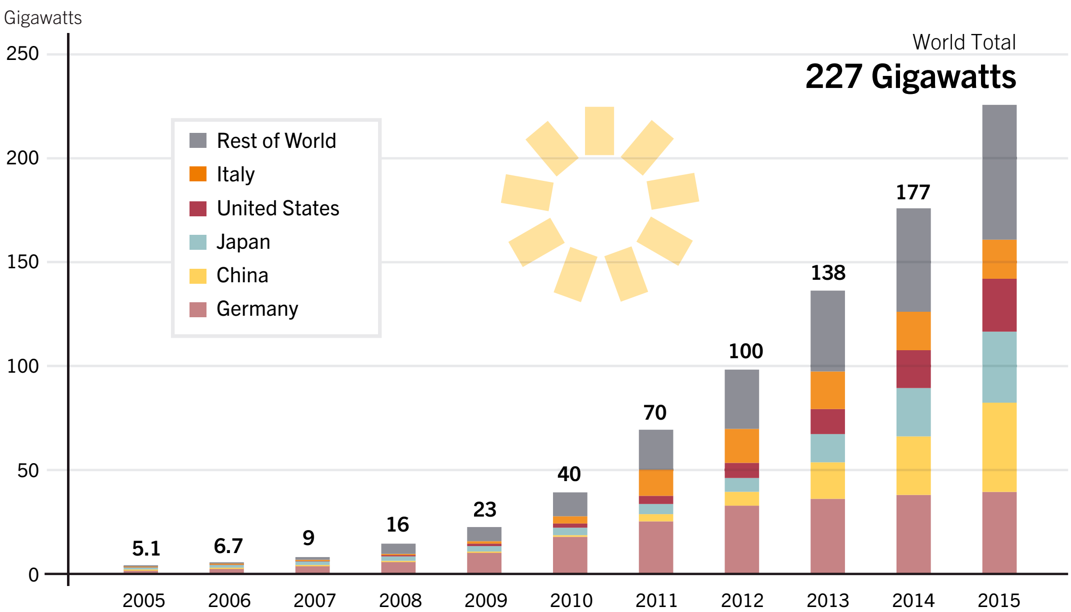
Figure 14. Solar PV Global Capacity and Annual Additions, 2005–2015



Source: See endnote 3 for this section.

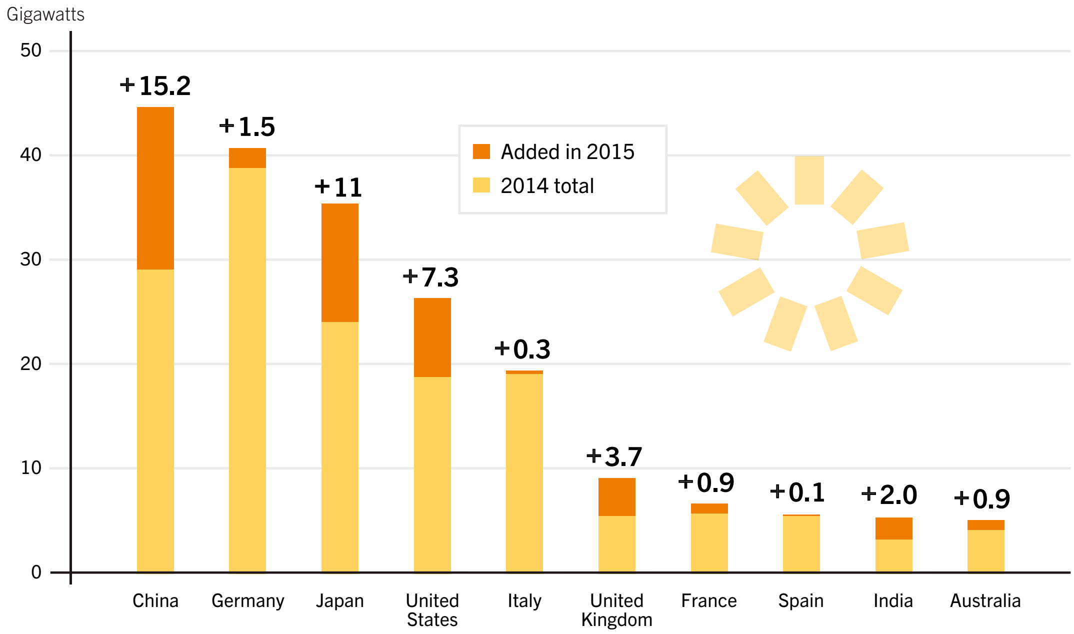
50 GW added in 2015

Figure 15. Solar PV Global Capacity, by Country/Region, 2005–2015



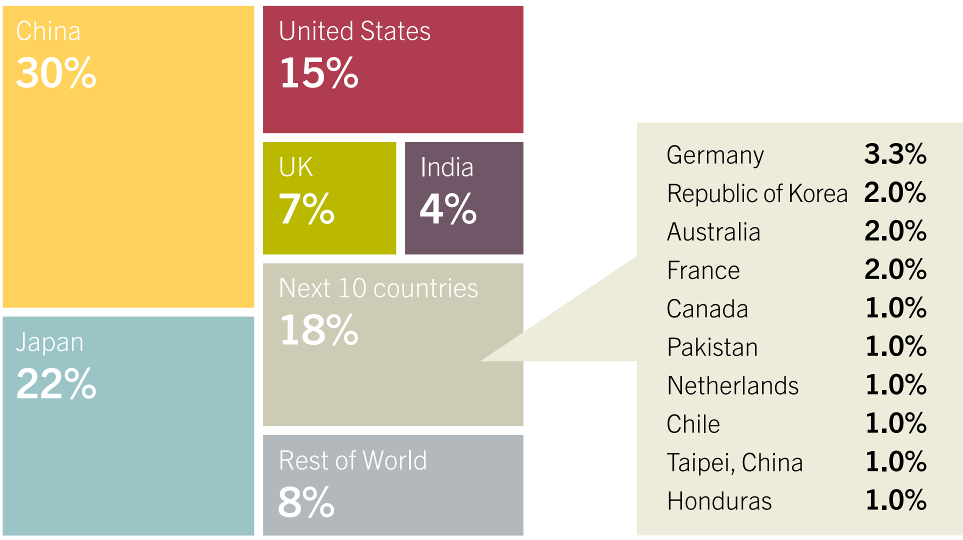
Source: See endnote 9 for this section.

Figure 16. Solar PV Capacity and Additions, Top 10 Countries, 2015



Source: See endnote 14 for this section.

Figure 17. Solar PV Capacity Additions, Shares of Top 15 Countries and Rest of World, 2015



Source: See endnote 72 for this section.

Utilities in Australia also are facing major impacts from solar PV. The country added more than 0.9 GW, ranking seventh globally for new installations and ending the year with 5.1 GW – the equivalent of one panel per inhabitant.[64] Australia's market has been predominantly residential, with rooftop systems on almost 16% of homes as of early 2016, although the commercial and large-scale sectors started to take hold in 2015.[65] Grid-based electricity consumption has fallen significantly in Eastern Australia since 2009 thanks in part to the growth of solar PV, which has eliminated afternoon "super peaks" in electricity demand.[66]

Australia's very low wholesale electricity prices and high retail prices are encouraging a shift to solar PV with little incentive to sell into the grid. As a result, there is a small but growing market for storage, and several companies started rolling out affordable options for homeowners in 2015.[67] Storage applications are developing quickly in Australia as well as in several other developed countries (e.g., Greece, Japan, Sweden) for on- and off-grid applications, and in some developing countries (e.g., Bangladesh, India, Peru), particularly off-grid.[68] (→ *See Distributed Renewable Energy chapter.)*

Latin America and the Caribbean added an estimated 1.1 GW in 2015 to more than double regional capacity.[69] Chile installed over 0.4 GW, mostly in very large-scale projects, with a year-end total exceeding 0.8 GW.[70] By some accounts, solar PV has become the country's cheapest source of electricity.[71] Honduras emerged as an important market and, along with Chile, was among the top 15 countries worldwide for new installations. The country added nearly 0.4 GW thanks to a generous FIT and to regulatory certainty that set it apart from its neighbours.[72] (→ *See Figure 17.)* Mexico and Brazil experienced delays – due to low oil prices and anticipation of the Energy Transition Law in Mexico, and to Brazil's difficult economic climate and lack of transmission capacity – but both countries plus Peru had highly competitive auctions in 2015 and early 2016.[73] Throughout the region, grid access and financing remained key challenges to growth.[74]

In developing and emerging economies, obtaining financing – and at affordable rates – is a common challenge; this is not the case for competitive tenders, however.[75] In 2015, some of the fastest growing markets were in Africa and the Middle East, where deployment is driven by rapidly falling costs, good solar resources, the desire to reduce energy imports, rapidly growing energy demand and the need to expand energy access.[76] Although the Middle East had relatively little capacity in operation at year's end, much was happening in the region.[77] Jordan and the United Arab Emirates held tenders for solar PV in 2015 with record-low bids, and launched several large projects.[78] Israel added 0.2 GW for a total approaching 0.9 GW, and others developing projects included Kuwait, the State of Palestine and Saudi Arabia.[79]

Countries are turning to the sun across Africa as well, with projects ranging from very small to large-scale, both on- and off-grid.[80] Leaders for new capacity were Algeria (adding almost 0.3 GW) and South Africa (0.2 GW), which ended the year with 1.1 GW.[81] Egypt has a burgeoning sector with increasing numbers of international companies announcing plans to finance, develop and construct up to 3 GW of solar PV projects.[82] Projects also were under way in Djibouti, Kenya, Mali, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Tanzania and Zambia, among others.[83] The global off-grid solar PV market is estimated at USD 300 million annually, with the strongest growth in sub-Saharan Africa, followed by

South Asia.[84] However, the African continent faces challenges as it rapidly scales up solar PV installations, including a shortage of skills necessary for installation, operation and maintenance.[85]

Around the world, the number and size of large-scale plants continued to grow.[86] By early 2016, at least 120 (up from 70 a year earlier) solar PV plants of 50 MW and larger were operating in at least 23 countries, with Australia, Denmark, Guatemala, Honduras, Kazakhstan, Pakistan, the Philippines and Uruguay all joining the list during the year.[87] Latin America saw the fastest growth, with the number of plants ≥50 MW increasing from 2 to 10.[88] The world's 50 biggest plants as of February 2016 reached cumulative capacity exceeding 13.5 GW.[89] At least 33 of these came online (or achieved full capacity) in 2015 and early 2016, including the US Solar Star project (750 MW) and, by some accounts, phase two of China's Longyangxia hybrid hydropower–solar PV plant (boosting the total to 850 MW).[90]

The market for concentrating PV (CPV) is young and remains small, but there is interest in niche markets due greatly to higher efficiency levels in locations with high direct normal insolation (DNI) and low moisture.[91] CPV includes an optical system to focus large areas of sunlight onto each cell and usually is combined with a tracking system.[92] After a number of installations came online during 2012–2014, many projects were cancelled, and little new capacity was added during 2015.[93] By end-2015, global CPV capacity totalled 360 MW, most of which is high-concentration systems.[94]

Solar PV plays a substantial role in electricity generation in some countries. During 2015, solar PV met 7.8% of electricity demand in Italy, 6.5% in Greece and 6.4% in Germany.[95] By year's end, Europe had enough solar PV capacity to meet an estimated 3.5% of total consumption (up from 0.3% in 2008) and 7% of peak demand.[96] An estimated 22 countries (including several in Europe as well as Australia, Chile, Israel, Japan and Thailand) had enough solar PV capacity at end-2015 to meet more than 1% of their electricity demand.[97] By the end of 2015, China had achieved 100% electrification in part because of significant off-grid solar PV systems installed since 2012.[98] Global capacity in operation at year's end was enough to produce close to 275 TWh of electricity per year.[99]

SOLAR PV INDUSTRY

The solar PV industry recovery further strengthened in 2015 due to the continued emergence of new markets and to strong global demand. Most top-tier companies were back on their feet in 2015, and strong demand and relative price stagnation helped to consolidate the positions of leading companies.[100] It was another challenging year in Europe, however, where shrinking markets in most countries left many installers, distributors and others struggling to stay afloat, and companies diversified risk by moving downstream (e.g., into operation and maintenance, O&M) and focusing on markets elsewhere.[101] Low module prices continued to challenge many thin film companies and the concentrating solar industries, which have struggled to compete.[102] International trade disputes also continued.[103]

Average module prices fell further in 2015, but less rapidly than during the 2008–2012 period.[104] Spot prices for multicrystalline silicon modules were down about 8% year-over-year to USD 0.55/Watt and below.[105] The industry continued to focus on soft costs (non-hardware) through optimisation and improvements of equipment, including: reducing mechanical mounting parts; using robotic technology for installation and maintenance; developing "smart" modules that help optimise output, and 1,500 volt modules that reduce transmission losses.[106] Soft costs continued their decline, due also to improved module efficiency and to an increase in average system size.[107] Soft costs still differed significantly depending on project location and scale: for example, they were higher in the United States than in Australia, China, Germany or even Japan.[108]

Record low bids in tenders show that solar PV is competitive – or expected to be when projects are built – in several locations.[109] Brazil, Chile, India, Jordan, Mexico, Peru and the United Arab Emirates all saw very low bids for unsubsidised solar PV in tenders in 2015 and early 2016, including Dubai's contract to ACWA Power (USD 58.5/MWh) in early 2015, and winning bids in Peru (the lowest was under USD 48/MWh) and Mexico (average of USD 45/MWh) in early 2016.[110] The year also brought record lows in Germany, with contracts signed for under USD 87/MWh (EUR 80/MWh), and PPAs for utility-scale solar in the United States in the range of USD 35–60/MWh (including the national tax credit).[111] Distributed rooftop solar PV remains more expensive but has followed similar price trajectories, and is competitive with retail prices in many locations.[112]

Global production of crystalline silicon cells and modules rose in 2015. Mono-crystalline cells and modules continued to gain share (about 25% in 2015) from multi-crystalline cells during the year.[113] Estimates of cell and module production, as well as of production capacity, vary widely; increasing outsourcing and rebranding render the counting of production and shipments more complex every year.[114] Preliminary estimates of 2015 production capacity exceeded 60 GW for cells, and ranged from about 63 GW to 69 GW for modules.[115] Thin film production increased by an estimated 13%, accounting for 8% of total global PV production (down from 10% in 2014).[116]

China has dominated global shipments since 2009.[117] By 2015, Asia accounted for 87% of global module production, with China producing about two-thirds of the world total.[118] Europe's share continued to fall, to about 6% in 2015, and the US share remained at 2%.[119] Among the leading module manufacturers were several Chinese companies, including Trina, JinkoSolar, JA Solar, Yingli, SFCE (formerly Suntech) and ReneSolar; other top manufacturers included Canadian Solar (Canada), Hanwha Q-Cells (Republic of Korea), First Solar and Sunpower Corp. (both United States).[120] There are also rising numbers of manufacturers that shipped around 1 GW each during 2015.[121]

To meet growing demand and better serve new markets (in some cases driven by domestic content laws), and to avoid import tariffs in some countries, manufacturers increased production capacity around the world, particularly for module assembly.[122] New module manufacturing facilities began operation during 2015 in several countries (including Algeria, Brazil, Egypt, Iran, South Africa and Thailand), while expansion plans were announced or under way in several others (including China, Germany, India, Japan, Saudi Arabia and the United States).[123] By year's end, according to company announcements, top manufacturers were constructing almost 7 GW of new factory capacity, aiming to expand in-house to reduce the need for outsourcing and to crowd out smaller competitors.[124]

Consolidation continued in 2015, but there were far fewer victims than in the high period of 2011–2012. Many solar product manufacturers in China had low profit margins, too much production capacity and significant debt.[125] Tianwei (China) defaulted on an interest payment for a domestic bond and then collapsed, Yingli required a government bailout, and Hanergy came under investigation by Hong Kong's Securities and Futures Commission.[126] Power production curtailment and delay of subsidy payments forced some project developers in China to sell projects and halt further development.[127]

In the United States and Europe, a handful of companies – including manufacturers of modules, trackers and microinverters – closed, became insolvent or were acquired in less-than-positive circumstances.[128] SunEdison's (United States) reversal of fortune, due largely to large acquisitions that increased debt and to a steep decline in the value of two yieldcos (see below), was the year's biggest loss, and the company filed for bankruptcy in April 2016.[129]

Mergers and acquisitions, as well as new partnerships, continued among manufacturers and installers as part of the trend to enter other markets (locations or applications) or to capture value in project development.[130] For example, Shunfeng International (China), the owner of once-bankrupt Suntech, acquired a majority stake in Suniva, gaining the opportunity to operate in the United States.[131] Canadian Solar purchased Recurrent Energy (United States) from Sharp (Japan) to move further into construction and to boost demand for its products.[132] SunPower acquired Cogenra (both United States) to build a new line of modules to tap into markets in Africa, China and India.[133] The Chinese government continued to push for mergers and acquisitions among domestic solar manufacturers.[134]

Market consolidation also continued among O&M providers in 2015.[135] Most leading solar PV manufacturers have expanded downstream into project development and into engineering, procurement and construction (EPC) to keep more business in-house and reduce costs, and many EPCs (including manufacturers) have moved into O&M of the plants they construct.[136] In 2015, European-based EPC companies continued looking towards growth markets, particularly in Japan, the United States and in the Middle East.[137] The market for megawatt-scale O&M sustained its rapid growth as more plants aged out of warranty coverage, and because the industry remains attractive even when construction slows (as in Europe).[138] By the end of 2015, the global megawatt-scale O&M market exceeded 130 GW.[139] New trends that became more apparent during 2015 are the growing split between O&M for large-scale projects, and the increased interest of inverter companies in the O&M business.[140]

Several strategic partnerships were established, including: SoftBank Group (Japan) and Sharp joined forces with the aim of dramatically reducing installation and maintenance costs; leading US installer SolarCity partnered with DirecTV and the home automation company Nest; and US rooftop developer Sungevity teamed with E.ON to advance initiatives in Europe.[141] In addition, several partnerships focused on energy storage options for commercial and residential markets in Australia, Japan, the United States, some European countries and elsewhere.[142]

The year 2015 saw the formation of several new yield companies (yieldcos). They accounted for nearly one third of large-scale project acquisitions during the second quarter.[143] But after soaring in early 2015, the value of many yieldcos plummeted mid-year, largely in response to declining crude oil prices, prompting many companies to attract investors in other ways.[144]

Other innovative financing options and business models – including solar leases, behind-the-meter PPAs, green bonds and crowdfunding – continued to spread, reducing barriers to customer adoption while increasing the potential for profits.[145] An increasing number of firms – including solar developers and installers, investment companies and major banks – have entered the solar financing market, particularly in the United States.[146] New online investment platforms are enabling people to invest in solar PV projects around the world.[147] In late 2015, CrossBoundary Energy (United States/Kenya) announced the first close of a dedicated fund for commercial and industrial solar in Africa through SolarAfrica (United Kingdom).[148]

Innovations also focused on technology improvements including streamlining manufacturing processes, lowering costs through materials substitution, reducing environmental impacts and improving efficiency.[149] Efficiency records were achieved for new cells and modules, some of which were set to begin production in 2016.[150] Perovskites[i] furthered their rapid advance, with efficiency increasing five-fold in six years, but hurdles remain before they can be commercialised.[151] For the near term, Passivated Emitter and Rear Cell[ii] (PERC) coating technology shows promise for increasing cell efficiency in standard production processes.[152] Innovations also continued in areas such as solar windows, spray-on solar and printed solar cells, and both Merck (Germany) and Emirates Insolaire (United Arab Emirates) announced the availability of new building-integrated solar PV (BIPV) products for the façades of buildings.[153] Although they remain a niche market, "smart" and AC modules[iii] – incorporating electronics to maximise output – were offered by an increasing number of module makers in order to differentiate their products.[154] (For information on another development, PV-T, see Solar Thermal Heating and Cooling section.)

By late 2015, several energy storage management system vendors, startups, major inverter makers (including Enphase (United States) and SolarEdge (Israel)), grid vendors and battery makers (e.g., Tesla, NEC and Panasonic) were involved in advancing storage in the solar PV sector.[155] US thin film manufacturer First Solar joined other solar companies – including SunPower and

i Perovskite solar cells include perovskite (crystal) structured compounds that are simple to manufacture and are expected to be relatively inexpensive to produce. They have experienced a steep rate of efficiency improvement in laboratories over the past few years.

ii PERC is a technique that reflects solar rays back to the rear of the solar cell (rather than being absorbed into the module), thereby ensuring increased efficiency as well as improved performance in low-light environments.

iii Modules with integrated alternating current (AC) inverters that enable them to generate grid-compatible AC power.

Sharp – in the storage market by investing in the startup Younicos (Germany), which develops software to control batteries.[156] Most solar PV installers offered energy storage solutions to German customers during 2015, and energy storage was offered with commercial solar systems in some US markets.[157] Sonnen (formerly SonnenBatterie; Germany) launched its solar-plus-storage systems for customers in Australia, Germany and the United States to compete with Tesla's (United States) Powerwall system, also introduced in some markets in 2015.[158]

Even as technologies advanced, the poor quality of some cells and modules continued to raise concern, with reports of modules as young as two years old failing in the field.[159] In China, the rate of module failure (and replacement) accelerated in 2015.[160] In some developing and emerging countries, uncertainty about energy yield has contributed to reluctance to provide financing, which is holding back development.[161]

Inverters address active system functions – such as power conversion and active grid support – and (especially for central inverters) pose the greatest risk to overall system reliability. Thus, manufacturers are working to improve long-term reliability and system-prediction methods.[162] New inverter products provide more functions, such as safety and storage management, to appeal to a broader customer base and provide needed grid services.[163] In 2015, several companies launched partnerships or products to help integrate solar PV systems with batteries: for example, Enphase launched a next-generation management system, and SolarEdge collaborated with Tesla to provide an inverter that is compatible with Tesla's Powerwall battery, launching the product in early 2016.[164] A proliferation of virtual power plants, especially in Germany and the United States, and growing demand for integrated home systems is forcing inverter manufacturers to make "smarter" systems.[165] There is also a trend towards 1,500-volt direct current inverters, which reduce power loss during transmission.[166]

Rising competitiveness in the inverter industry, a shift to utility-scale installations and increased acceptance of Chinese products has put price pressure on the global inverter market. Even as demand increased in 2015, prices declined.[167] Both Enphase and SMA (Germany) restructured and laid off staff in 2015.[168] Even so, SMA sold its one-millionth Sunny Boy TL inverter in June, after 30 years in the business, and saw strong demand in overseas markets.[169] A few months later, KACO (Germany) and the Saudi Arabian Advanced Electronics Company (AEC) launched Saudi Arabia's first inverter manufacturing line.[170]

The CPV industry had another challenging year. Despite record module and cell efficiencies of CPV technologies, and declining system prices since its introduction to the market, CPV has not achieved economies of scale and has been unable to compete with falling prices of conventional solar PV.[171] Most notably, in early 2015, Soitec (France) announced plans to exit the industry.[172] Suncore (China) also announced plans to halt CPV module production, and Silex Systems (Australia) stopped operations in late 2015; by early 2016, the industry was in crisis following the exit of its largest manufacturers and was in the process of restructuring.[173] Those remaining in the industry were working to improve products and to expand their focus, including actively marketing in the MENA region and China, and forming partnerships to expand project pipelines.[174]

CONCENTRATING SOLAR THERMAL POWER (CSP)

CSP MARKETS

2015 was a year of challenges and changes for concentrating solar power (CSP), also known as solar thermal electricity (STE). Capacity growth in the CSP market decelerated somewhat in 2015. Global operating capacity increased by 420 MW to reach nearly 4.8 GW at year's end.[1] (→ *See Figure 18 and* ***Reference Table R7.***) Nonetheless, a wave of new projects was under construction as of early 2016, and several new plants are expected to enter operation in 2017.[2]

The year was a turning point in market expansion beyond Spain and the United States, which account for nearly 90% of installed CSP capacity.[3] By year-end, facilities were under construction in Australia, Chile, China, India, Israel, Mexico, Saudi Arabia and South Africa.[4] Morocco and South Africa surpassed the United States in capacity added, with Morocco becoming the first developing country to top the global CSP market.[5]

Whereas early commercial CSP development focused entirely on parabolic trough technology, markets now are balanced fairly evenly between parabolic trough and tower technologies. Fresnel and parabolic dish technologies have become largely overshadowed.[6] For the first time, all of the facilities added in 2015 (as well as facilities added in early 2016) incorporated thermal energy storage (TES) capacity, a feature now seen as central to maintaining the competitiveness of CSP through the flexibility of dispatchability.[7]

Morocco was highly active and brought the 160 MW Noor I plant online.[8] Noor I forms part of the 500 MW multi-stage Noor-Ouarzazate CSP complex, which is expected to be fully operational by 2018.[9]

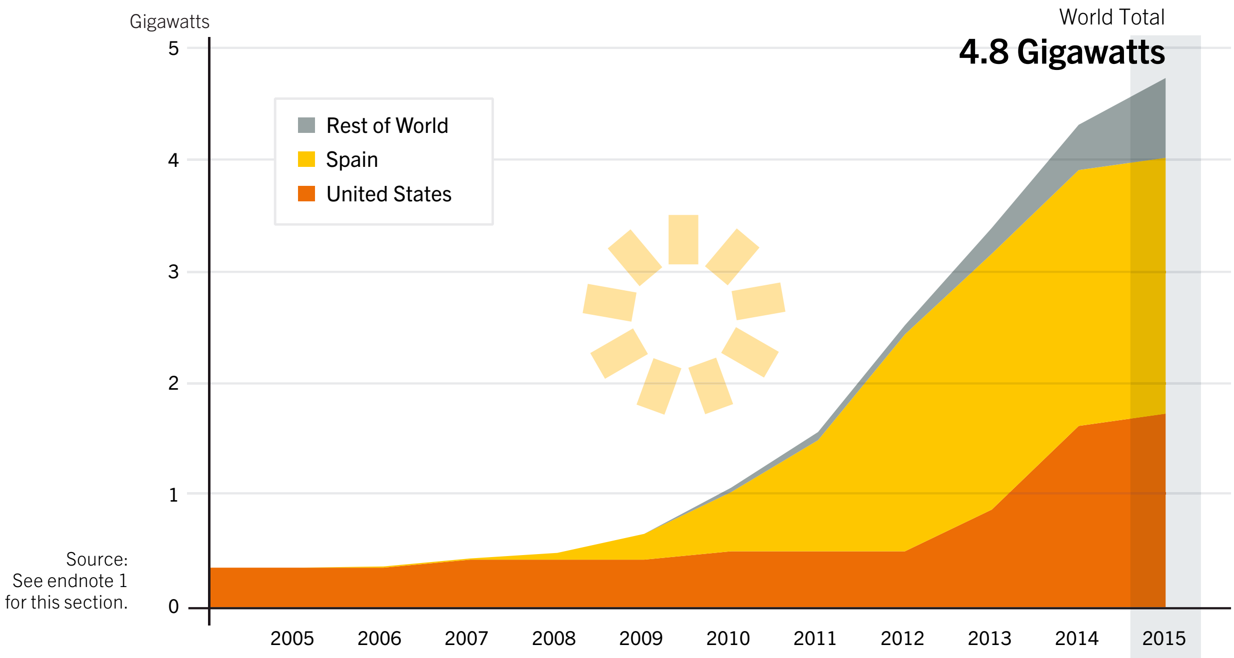
South Africa brought its first commercial CSP capacity online in 2015 with the 100 MW KaXu Solar One facility and the 50 MW Bokpoort facility.[10] A further 50 MW was added in early 2016 when the Khi Solar One facility came online, bringing South Africa's total capacity to 200 MW; an additional 200 MW also was under construction.[11] Grid access in areas of high insolation has emerged as a key challenge for South African CSP projects, many of which are being planned in regions with constrained transmission networks.[12]

The United States followed, adding the 110 MW Crescent Dunes facility to end the year with more than 1.7 GW in operation.[13] This followed a record year in the country in 2014, during which almost 0.8 GW was brought online.[14] As of early 2016, no new CSP capacity was under construction in the United States. Permitting challenges, a surging solar PV sector and low natural gas prices have resulted in indefinite delays to several large CSP projects.[15]

Spain remains the global leader in existing CSP capacity, with 2.3 GW at year's end. However, no capacity came online in 2015, and, as of early 2016, no new CSP facilities were under construction or being planned or developed in the country.[16]

While Noor I in Morocco was the highlight for the North African market, developments also were under way in other countries in the region. For example, in early 2016, Egypt

Figure 18. Concentrating Solar Thermal Power Global Capacity, by Country/Region, 2005–2015



announced 14 prequalified bidders (including numerous MENA-based developers) for a 50 MW facility.[17] In Algeria, where the government announced plans in 2015 to develop 2 GW of CSP by 2030, a number of new projects were in the development stage.[18]

In the Middle East, construction started on Israel's 121 MW Ashalim Plot B facility. Commercial operation is expected in 2017, and an additional 110 MW phase is expected to come online in 2018.[19] In Saudi Arabia, Integrated Solar Combined Cycle (ISCC)[i] facilities under construction in Duba and Waad Al Shamaal will incorporate 50 MW each of CSP technology when they enter operation in 2017 and 2018, respectively.[20] As domestic energy demand rises in Saudi Arabia, CSP is considered a strategically important technology for maintaining the country's status as a fossil fuel exporter.[21]

China's proposed CSP target of 5–10 GW by 2020 came amidst a flurry of development activity.[22] Construction at the 50 MW Qinghai Delingha facility commenced in late 2015.[23] The facility, which will mark the country's first commercial CSP plant, is expected to come online in 2017.[24] Additional facilities totalling several hundred megawatts are in various stages of construction, although timelines for completion remain unclear.[25] Elsewhere in Asia, India's 25 MW Gujarat Solar One facility entered construction after significant permitting delays.[26]

In Latin America, construction continued on Chile's 110 MW Atacama 1 plant.[27] Chile saw a notable milestone for CSP when a hybrid CSP/PV facility (incorporating 100 MW) won a baseload tender that also was open to combined-cycle gas technology.[28]

CSP continued its push into developing markets with high DNI levels and specific strategic and/or economic alignment with the benefits of CSP technology. In this respect, CSP is receiving increased policy support in countries with limited oil and gas reserves, constrained power networks, or strong industrialisation and job creation agendas, including South Africa, Morocco and China.[29]

i Integrated Solar Combined Cycle facilities are hybrid gas and solar plants that utilise both solar energy and natural gas for the production of electricity.

CSP INDUSTRY

It was a watershed year for industry as companies adapted to the shift of CSP markets. The continued stagnation of the Spanish market, along with a long predicted slowdown in the United States, resulted in increased capacity building in new focus markets. Established CSP players created new partnerships and invested in assets in new markets, while local industrial activity emerged in South Africa, the MENA region and China.[30]

Recognising CSP's potential for local manufacturing, engineering and skills development, many countries – including Morocco, Saudi Arabia, South Africa and the United Arab Emirates – continued to promote or enforce local content requirements in their CSP programmes during 2015.[31]

Abengoa, the industry's largest developer and builder, faced bankruptcy proceedings before reaching an agreement with its creditors and avoiding liquidation in early 2016.[32] The company's rising debt was partially a result of Spanish energy reforms enacted in 2013, which reduced feed-in tariffs for CSP facilities.[33] As of early 2016, the company was expected to dispose of equity in several CSP facilities as it restructured its operations over the year.[34]

Nonetheless, Abengoa and Saudia Arabia's ACWA Power led the market in ownership of projects that either commenced operations or were under construction during 2015.[35] As a developer, owner and operator, ACWA continued to make strong inroads into the global CSP market, most notably through projects in South Africa and Morocco.[36]

Other top companies in 2015, including those engaged in construction, operation and/or manufacturing, were Rioglass Solar (Belgium); Acciona, ACS Cobra, Sener and TSK (all Spain); and Brightsource, GE and Solar Reserve (all United States).[37]

Leading manufacturer Schott Solar (Germany) sold its CSP receiver business to Rioglass Solar, the world's largest manufacturer of CSP mirrors with plants in Chile, Israel, South Africa, Spain and the United States.[38] Rioglass Solar previously purchased the CSP receiver business of Siemens (Germany) in 2013.[39] GE acquired the power business of Alstom (France) – including the company's CSP business – towards the end of 2015.[40]

Developers continued to focus on larger plants, with many facilities exceeding 100 MW in size. South Africa increased the size limit of CSP plants under its Independent Power Producer Procurement programme from 100 MW to 150 MW.[41] These larger plants are being developed increasingly in water-scarce regions, so most new facilities are making use of dry cooling technology to reduce water consumption as well as environmental impact.[42]

Almost all new CSP plants are being developed with TES systems, and global storage capacity is on the rise. The US Crescent Dunes facility represented a major step forward in this regard: with 10 hours of storage, the plant is capable of generating power at any time of day or night for half of the year.[43] In Morocco, the storage capacity planned for the Noor II facility, currently under construction, was increased from three to seven hours.[44]

Faced by competition from solar PV due to its rapidly declining prices, the CSP industry has focused increasingly on maximising value through TES systems that provide dispatchable power.[45] Research conducted by the US National Renewable Energy

Laboratory (NREL) on California power markets found that a large fraction of the value of CSP operating with TES appears to be derived from its ability to provide firm system capacity; this is especially the case where the penetration of variable renewables is high, or where there is a shortage of baseload capacity.[46]

Under South Africa's competitive bidding process, decreasing price caps coupled with strong competition resulted in a reduction of CSP bid prices by nearly 40% from round one (in late 2011) to round three (in late 2013) of the procurement process.[47] This trend was expected to continue with the announcement of new preferred bidders, originally scheduled for early 2016.[48] In Morocco, the next phases of the Noor Ouarzazate CSP complex will operate at significantly lower tariffs than other operational facilities in the region as a result of cheaper debt and learnings from the first phase.[49] A shift to cheaper component suppliers and the establishment of partnerships between leading CSP technology companies and Chinese counterparts also are helping to reduce costs.[50]

R&D in the CSP sector is being driven by both private and public entities, often through partnerships between leading CSP firms or between private groups and government programmes. Improvements and cost reductions in TES continue to be strong focus areas of these activities. Related research programmes, some of which focused on novel storage media such as sand and concrete, were under way during 2015 in several countries, including Italy, the United States and the United Arab Emirates.[51]

R&D programmes backed by the United States and the United Arab Emirates concentrated on improving CSP efficiency through the application of higher-temperature processes, which allow the more efficient transfer of heat and conversion of energy. Related research in 2015 was focused largely on the development of materials capable of housing high-temperature processes.[52]

Other research was directed towards incremental cost reductions in CSP components, including heliostats and mirrors; the reduction of water usage in both steam/power generation and mirror cleaning; and the reduction of land requirements for CSP systems.[53]

SOLAR THERMAL HEATING AND COOLING

SOLAR THERMAL HEATING/COOLING MARKETS

Solar thermal technology is used extensively in all regions of the world to provide hot water, to heat and cool space, and to provide higher-temperature heat for industrial processes. Global capacity of glazed and unglazed solar thermal collectors continued to rise in 2015. The 18 largest markets in 2015 are spread across all continents and represent 93–94% of total the year's global additions.[1] (→ *See Figure 19 and* ***Reference Table R8.***) In 2015, their newly installed capacity totalled an estimated 37.2 GW_{th} (53.1 million m²), down 14% from the 43.4 GW_{th} installed by these countries in 2014.[2]

The continued slowdown in 2015 was due primarily to shrinking markets in China and Europe. Despite the overall negative trend, significant market growth was reported from Denmark (up 55% over 2014), Turkey (10 %), Israel (9%), Mexico (8%) and Poland (7%).[3]

Among the top 18 countries, vacuum tube collectors made up 76% of new installations, flat plate collectors 20% and unglazed water collectors (mostly for swimming pool heating) the remaining 4%.[4] These additions brought total global solar thermal capacity to an estimated 435 GW_{th} (622 million m²) at the end of 2015, up from 409 GW_{th} one year earlier.[5] (→ *See Figure 20.)* There was enough capacity by year's end to provide approximately 357 TWh (1,285 PJ) of heat annually.[6]

The top countries for new installations in 2015 were China, Turkey, Brazil, India and the United States , and the top five for cumulative capacity at year-end were China, the United States, Germany, Turkey and Brazil.[7] (→ *See Figure 21 and* ***Reference Table R8.***) Of the top 18 installers, the leading countries for average market growth between 2010 and 2015 were Denmark (34%), Poland (14%) and Brazil (8%); the most significant market decline over this period was seen in France (-17%), Austria (-14%) and Italy (-14%).[8]

China again was the largest market by far in 2015, with gross additions of 30.45 GW_{th} (43.5 million m²) – 21 times more capacity than was added in second-placed Turkey.[9] At year's end, China's cumulative capacity in operation was an estimated 309.4 GW_{th}, or about 71% of the world's total.[10] China's market contracted for the second consecutive year – falling 17% in 2015, after an 18% drop in 2014 – due to the slowdown in the construction industry and the weak national economy.[11] Vacuum tubes continued to dominate the Chinese market in 2015, accounting for 87% of added capacity; however, flat plate collectors were again popular, especially for roof and façade integration in urban areas.[12]

Even though Turkey provides little policy support for solar thermal technologies, annual installations were up 10% in 2015, to an estimated 1.47 GW_{th} (2.1 million m²). These new installations were delivered by a strong supply chain that includes about 800 sales points and around 3,000 specialised installers.[13] The share of vacuum tube collectors increased again in 2015, to 49% (44% in 2014), up from almost zero 10 years earlier.[14]

Brazil ranked third for new installations in 2015, with 982 MW_{th} (1.4 million m²) of glazed and unglazed collectors.[15] However, deployment remained below expectations, with the market down by 3% relative to 2014; this compares with Brazil's high average annual growth rate of 8% between 2010 and 2015.[16] Constraints on the market included the national economic crisis, which reduced investment and purchasing power, and delay in implementing the next phase of the social housing programme Minha Casa Minha Vida.[17]

India was fourth for new installations. Although there is high uncertainty regarding the market volume in fiscal year 2015–2016, preliminary estimates show that the market was stable compared to the previous year, when 826 MW_{th} (1.18 million m²) of capacity was installed, and the share of vacuum tube collectors was around 80%.[18] A temporary reduction in demand has resulted from the suspension of India's national grant scheme in 2014. As of early 2016, India's government and solar thermal industry were discussing new support measures and, as a consequence, a renewable heating obligation was being drafted that, if enacted, would be the first of its kind worldwide.[19]

The United States was the fifth biggest market for solar thermal collectors in 2015 and the world's largest market for unglazed collectors for swimming pools, followed by Brazil (427 MW_{th}) and Australia (280 MW_{th}).[20] The unglazed segment accounted for 87% of US cumulative solar thermal capacity of 17 GW_{th} at the end of 2014.[21] In the significantly smaller segment of glazed collectors, a capacity of 119 MW_{th} was added in 2015; this was down 7% (after falling 19% in 2014) in response to low oil and gas prices and an increased focus on solar PV, driven by strong marketing efforts by solar PV system providers.[22]

In the EU-28, the market volume dropped again in 2015 (down 6%), to an estimated 1.9 GW_{th} (2.7 million m²), following a 7% decline in 2014.[23] The EU's total installed capacity in operation at the end of 2015 was approximately 33.3 GW_{th}, representing around 8% of the world's total.[24]

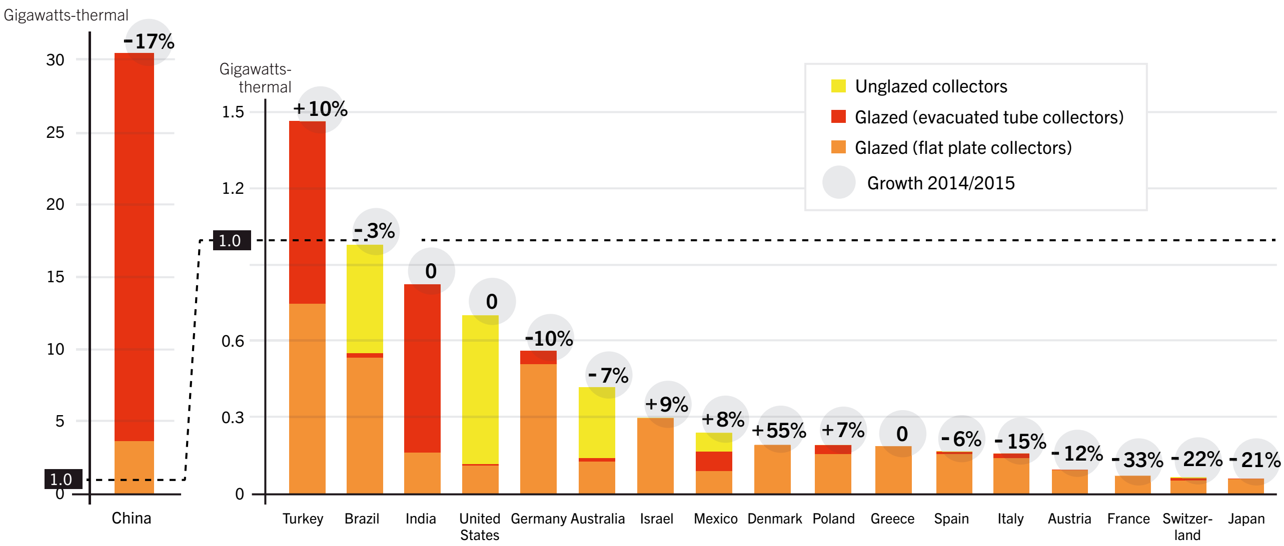
With the exception of Denmark and Poland, all major European solar thermal markets contracted significantly in 2015: Austria's market shrank by 12% relative to 2014, and declines also were seen in Germany (-10%), Spain (-6%), Italy (-15%) and France[i] (-33%).[25] Following 19% market growth in 2014, Greece maintained the same volume (189 MW_{th}, 270,000 m²) in 2015, and its exports increased by another 7% (to 202 MW_{th}, 288,571 m²) thanks to rising demand in the MENA region.[26]

Low oil and gas prices contributed significantly to the shrinking markets seen in much of Europe. In Germany, for example, low fuel prices drove up sales of gas- and oil-condensing boilers (by 7% and 30%, respectively); by contrast, the solar thermal market contracted by 10% to 100,500 systems, for a total of 564 MW_{th} (806,000 m²) added during the year.[27] This significant reduction occurred despite an increase in Germany's national incentive programme in April 2015.[28] Additional challenges for Italy, Spain and France included bureaucratic processes associated with national subsidy schemes, a slowdown in the housing industry and increased competition from other renewable heat technologies.[29]

i Metropolitan France only, which includes mainland France and nearby islands in the Atlantic Ocean, English Channel and the Mediterranean Sea (not Overseas France).

SOLAR THERMAL HEATING AND COOLING

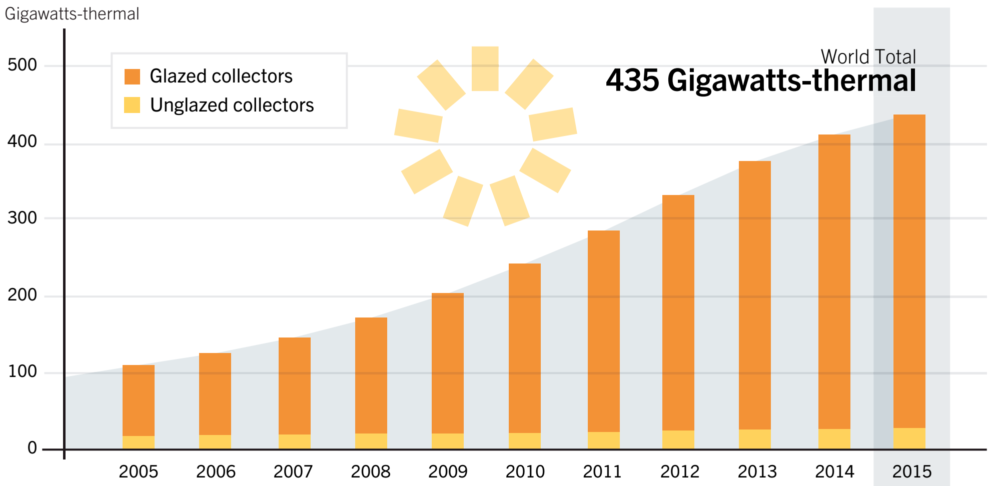
Figure 19. Solar Water Heating Collectors Additions, Top 18 Countries for Capacity Added, 2015



Source: See endnote 1 for this section.

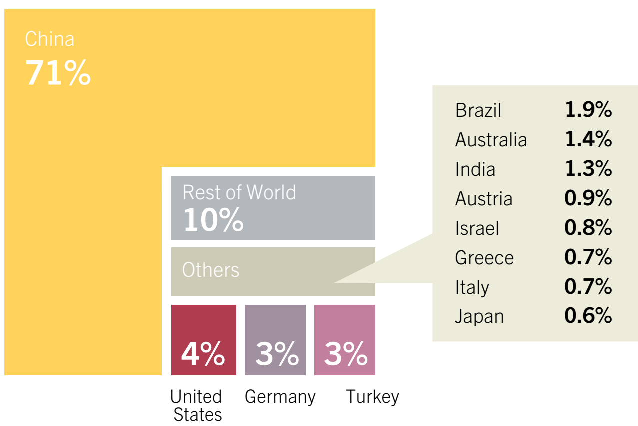
Additions represent gross capacity added.

Figure 20. Solar Water Heating Collectors Global Capacity, 2005–2015



Source: IEA SHC. See endnote 5 for this section.

Figure 21. Solar Water Heating Collectors Global Capacity, Shares of Top 12 Countries and Rest of World, 2014



Source: IEA SHC. See endnote 7 for this section.

Data are for solar water collectors only (not including air collectors).

02

Over the last five decades, the primary application of solar thermal technology globally has been for water heating in single-family houses; the residential segment accounted for 63% of the total installed collector capacity at the end of 2014 (the most recent data available).[30] In recent years, however, markets have been transitioning to large-scale systems for water heating in multi-family buildings and in the tourism and public sectors. In 2014, this commercial sector accounted for only 28% of the total collector capacity in operation worldwide, but it represented 50% of newly installed collector capacity.[31] (→ *See Figure 22.)*

The transition from single-family houses to the commercial sector continued during 2015 in many countries around the world.[32] The best examples were China and Poland, where the commercial markets grew rapidly, whereas the residential sector declined drastically.[33] In China, solar thermal systems for multi-family houses, tourism and the public sector accounted already for 61% of newly installed collector area in 2015.[34] In Poland, the major market driver was larger systems in public buildings, financed with international funds. While such projects saw an increase of up to 10% in volume relative to 2014, the residential segment declined significantly in response to the national residential subsidy scheme that favours solar PV.[35]

The use of solar thermal for space heating also continued to gain ground, particularly in Europe, where an increasing number of large-scale solar thermal systems feeds into district heating grids. As in past years, Denmark dominated Europe's solar district heating market in 2015. Beyond Denmark, only three other district heating installations larger than 350 kW_{th} went into operation: Austria, Italy and Sweden each brought one plant online.[36]

Denmark brought 17 new and 3 expanded solar district heating plants (totalling 187 MW_{th}) into operation in 2015; this compares with only 7 MW_{th} of solar water heaters installed in single-family houses during the year.[37] At year's end, Denmark had 79 solar district heating plants in operation, with a combined capacity of 577 MW_{th}; an additional 364 MW_{th} of large-scale solar heating systems was in the pipeline.[38] Denmark's situation is unique in that it has inexpensive and sufficient land in the vicinity of its municipalities; taxes on fossil fuels; and cost-effective mounting systems developed by the domestic industry for large ground-mounted collector fields.[39]

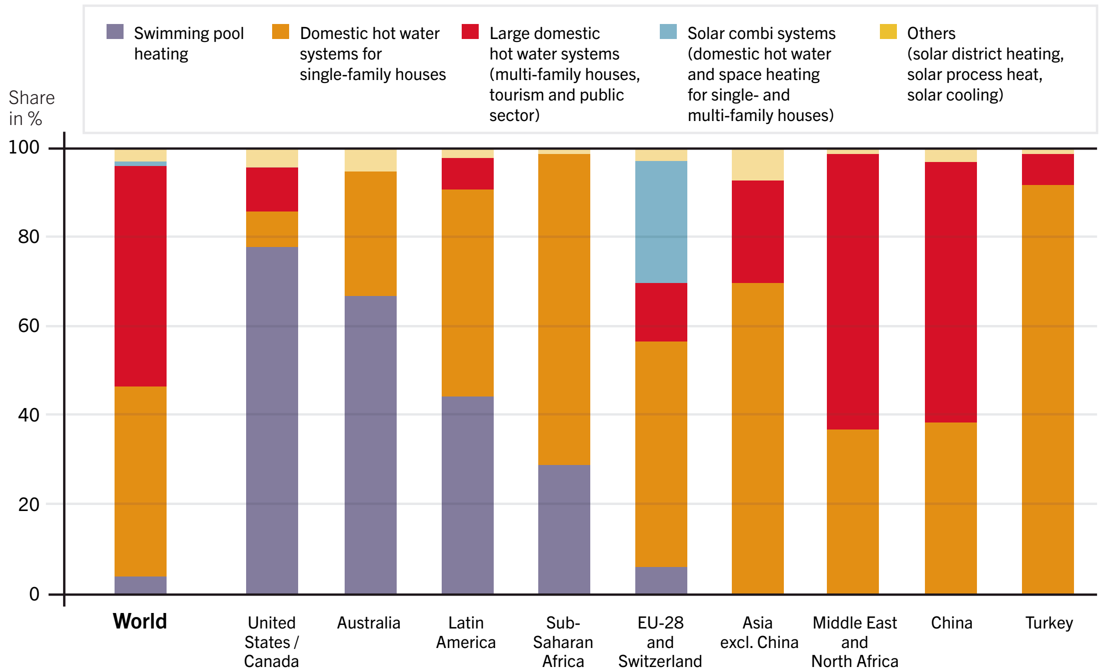
At the end of 2015, Europe was home to 252 large-scale systems with a total of 745 MW_{th}, making up around 2% of the region's total operating solar thermal capacity.[40] Nearly half (48%) of these large systems are connected to block heating (mostly stand-alone boilers); another 36% are connected to district heating systems; and the remaining 16% are used for other applications, primarily for solar cooling and solar process heat.[41] After several years with no new large-scale installations, both Germany and Spain had several large-scale solar thermal systems in the pipeline as of early 2016.[42]

Solar heat is being used in an expanding range of heat-based industrial processes, such as water preheating, evaporation, cleaning, drying, boiling, pasteurisation, as well as thermal separation. The most popular sectors for solar process heat applications in recent years have been the food and metal processing, textile, beverage and mining industries.[43] In 2015, a variety of industries invested in solar process heat installations, among them the Dairy Bonilait (France), the automotive supplier Harita Seating systems (India), an Italian cheese producer, a garment manufacturer in India and the pharmaceuticals producer Ram Pharma based in Jordan.[44]

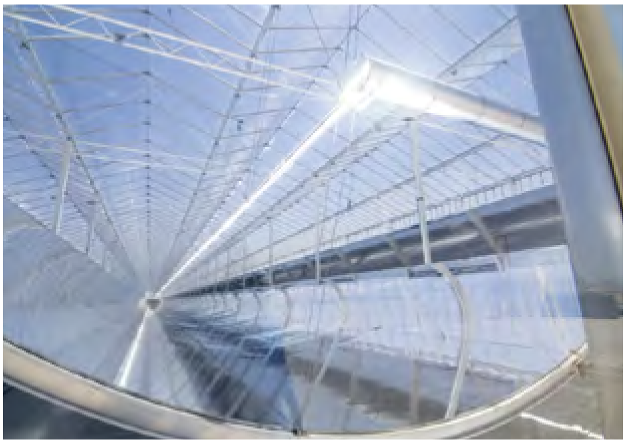
The largest investor was Petroleum Development Oman (CPD), which began construction in November of its 1 GW_{th}, USD 600 million Miraah solar steam-producing plant, located next to the Amal West Oil field in Oman.[45] Once completed, in 2017, Miraah is expected to be the largest solar steam-producing plant worldwide.[46]

As of March 2016, at least 188 solar process heat projects, with a combined capacity of 106 MW_{th}, were operating in 32

Figure 22. Solar Water Heater Applications for Newly Installed Capacity, by Country/Region, 2014



Source: IEA SHC. See endnote 31 for this section.



countries.[47] Deployment in the industry sector is a fraction of that in the residential sector, even though the long-term potential for both segments is almost the same.[48] Top countries for solar process heat capacity in operation included Austria, Chile, China, the United States and India.[49]

Four major barriers have slowed the uptake of solar process heat installations, including: high system and planning costs; the absence of guidelines and tools for planners and engineers; a dearth of business models; and a lack of knowledge among potential customers.[50] To address some of these barriers, Australia established a grant to cover 50% of the project costs for solar process heat facilities. The grant programme, combined with educational workshops organised specifically for the dairy industry, resulted in some projects being in the first planning stage as of early 2016.[51] Other countries with support mechanisms for solar process heat include Austria, Germany and India.[52]

An additional barrier in 2015 was low oil and gas prices, which made solar process heat less competitive in many countries by extending system payback periods. In response to low oil prices, Thailand halted its process heat subsidy scheme for 2015–2016.[53]

Low fuel prices also affected the solar cooling market and, combined with the still high costs and complexity of cooling systems, reduced demand in 2015.[54] Demand for solar thermal-driven air conditioning systems also was tempered by rapidly falling costs of solar PV systems in conjunction with split air conditioning systems (especially in buildings with relatively small cooling loads).[55] An estimated 125 new solar cooling systems were added in 2014 (the last year for which global statistics are available), for a total of at least 1,175 by year's end.[56] The peak year for new installations was 2012, when around 200 systems were added.[57]

Even so, several larger solar cooling systems were installed in 2015, or were under construction as of early 2016. These include systems for the European companies Wipotec (Germany) and AVL (Austria), and for the Sheikh Zayed Desert Learning Center in Abu Dhabi.[58] There also was growing demand for solar cooling R&D and demonstration plants in China and the Middle East in 2015.[59] The main driver of demand for solar cooling technology is its potential to reduce peak electricity demand, particularly in countries with significant cooling needs.[60]

Absorption and adsorption chillers have long dominated the solar cooling market and account for approximately 71% of capacity in operation. In 2015, they increased their market share, whereas desiccant cooling systems saw their market share decline.[61]

SOLAR THERMAL HEATING/COOLING INDUSTRY

Success and crisis were close together in the global solar heating and cooling industry in 2015. Within individual countries, some players failed while others succeeded by changing their business models; and, from country to country, market development and, therefore, industry health varied considerably. For example, collector manufacturers in sunbelt countries with strong demand – such as India, Mexico and Turkey – invested in new production capacity.[62] By contrast, in much of Europe, China and some other countries, manufacturers faced declining sales and overcapacity.

In India, component suppliers built new manufacturing facilities in response to the country's growing demand for concentrating collector systems for industry and large-scale cooking applications, which has been driven by investment subsidies.[63] Mexico has evolved into a technology hub in Central America and, in 2015, had two factories under construction, one for polymer collectors and one for vacuum tubes.[64] Turkey's three vacuum tube manufacturers extended their production capacities in 2015 based on rising national demand and plans for increased export.[65]

The collector industries in Greece and Austria continued to have high export numbers throughout 2015. Greek manufacturers saw their exports increase by 7%, following a 16% rise in 2014, while the Austrian collector industry's export share remained high, at around 80% in 2015.[66]

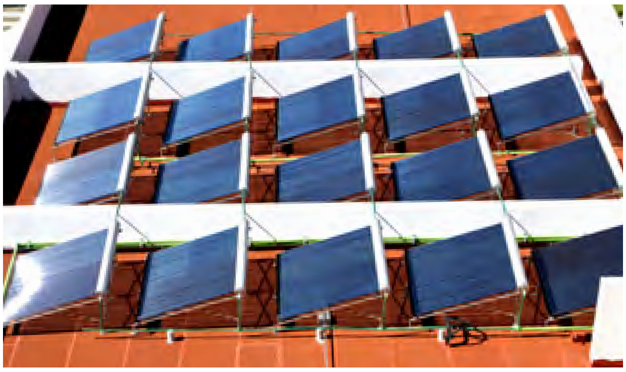
Elsewhere, developments in 2015 were not as bright. Dark clouds were over Chile, for example, where the domestic industry went through a severe crisis. Chile's new tax credit scheme for the housing industry, originally expected to be approved in early 2015, did not come into effect until February 2016; as a result, several manufacturers and system suppliers were forced to temporarily suspend their solar thermal activities.[67]

The Chinese industry was troubled by a second year of significant market contraction, driving industry consolidation at all levels of the supply chain. In 2014, Linuo New Material (once the world's largest manufacturer of glass tubes and vacuum tubes) made the decision to stop production; this was followed, in 2015, by the Sunrain Group's acquisition of a 30% stake in the large flat plate collector manufacturer Pengpusang.[68]

Manufacturers in several Central European countries also faced overcapacities and an associated drop in collector prices. This development resulted in serious financial troubles for four high-profile companies: Watt (Poland), Astersa (Spain), Solvis (Germany) and Clipsol (France).[69]

However, even in this period of declining markets all over Europe, several European solar thermal manufacturers managed to increase their sales in 2015 by developing new business models. In Poland, some system suppliers – such as Hewalex and Ensol – profited from a growing number of public tenders for social housing projects and public hospitals.[70] Spanish solar thermal manufacturers offered innovative financing schemes in order to decrease the industry's dependence on subsidies.[71]

In addition to the well-established energy service companies (ESCOs) for solar thermal – including, S.O.L.I.D. (Austria) and Nextility (formerly Skyline Innovations; United States) – an increasing number of turnkey suppliers specialised in energy service contracts during 2015 to eliminate the barrier of high upfront costs for potential commercial clients.[72] Such suppliers include Sumersol (Spain), Sunti (France), Enertracting (Germany) and Sunvapor (United States).[73]



In Austria, where market penetration is high and the number of new installations has declined, companies have found new business opportunities in the replacement market.[74] This sales segment is gaining importance in countries that have a long history of solar thermal deployment, including also Germany, Greece, Israel and Turkey; in Israel, for example, more than 80% of the collector area installed between 2010 and 2014 was used to replace existing systems.[75]

Despite the market contraction in Germany throughout 2012–2015, German flat plate collector manufacturers continued to dominate the ranking of the world's 20 largest manufacturers with regard to collector area produced in 2014 (latest data available). Five German companies were on the list: Bosch, Viessmann, Vaillant, Thermosolar and Wolf.[76] China ranked second for number of manufacturers, with four (Five Star, Prosunpro, BTE Solar and Sunrain), and Turkey placed third with three producers (Ezinc, Solimpeks and Eraslanlar). For the first time, a Polish company, Hewalex, was among the top 20.[77] The world's three largest vacuum tube collector manufacturers – Sunrise East Group (includes the Sunrain and Micoe brands), Himin and Linuo-Paradigma – all are based in China.[78]

Since 2012, the European industry has worked hard to overcome two main barriers that prevent rapid growth in the solar thermal market: high system prices and a lack of transparency in solar yield. To further progress in addressing the first of these barriers, in 2015 the Solar Heating and Cooling Programme of the International Energy Agency (IEA SHC) launched a project to investigate ways to reduce the purchase price of solar thermal systems by up to 40%, covering all aspects of the supply chain.[79]

Ongoing efforts to reduce prices for high-end consumer systems began to bear fruit in 2015. Several manufacturers have developed standardised and pre-fabricated solutions to reduce post-production costs. For example, Aschoff Solar (Germany) and Sunoptimo (Belgium) focus on solar circuit hydraulics that they pre-mount in containers for on-site installation by overseas clients.[80] Other companies are manufacturing domestic hot water supply stations that are pre-mounted to the tank.[81] Additional 2015 innovations that attracted regional attention are the switching absorption layer of Viessmann that avoids stagnation temperatures, and a well-designed polymer collector from Sunlumo (Austria).[82]

Another 2015 development that aids in cost savings in the industry was reached within the Global Solar Certification Network, developed by the IEA SHC.[83] Researchers and industry representatives worldwide agreed on a mutual recognition approach that will maintain existing national and regional certification schemes, allowing manufacturers to use test and inspection reports under one certification scheme and to apply for certification in another.[84]

Labelling of solar thermal systems and collectors also was an important issue in Europe during 2015. After two years of preparation, the labelling of water, space and combi heaters under the Ecodesign Directive (2005/32/EC) became mandatory in all 28 EU Member States in September.[85] Even so, there was great scepticism among Europe's collector manufacturers about whether or not the energy labelling will increase demand for solar thermal systems, since heat pumps receive a high rating even without the use of solar power.[86] Also launched in 2015 was a voluntary collector label by the newly established Solar Heating Initiative; the label, Solergy, rates collectors based on their annual energy output.[87]

An increasing number of small countries worldwide showed interest in joining regional quality infrastructure (QI) schemes (certification procedures, standards, product labels) in 2015, as QI is crucial in emerging markets to promote customer confidence.[88] Examples of such schemes include the Solar Heating Arab Mark and Certification Initiative (SHAMCI) in the Arab region, and the initiative of the Pan American Standards Commission (COPANT).[89]

For medium-temperature process heat applications, parabolic trough remains the dominant collector technology, followed by linear Fresnel collectors.[90] An increasing number of companies manufacture concentrating solar thermal collectors; as of late 2015, at least 39 manufacturers were producing 76 collector types in 13 countries worldwide, with the majority of these companies headquartered in Europe.[91] Several additional companies that are new to the process heat sector – including Artic Solar and Skyven Technologies LLC (both United States) and Oorja Energy (India) – were developing concentrator collectors as of early 2016.[92] Because the industry is still in the early stages of development, product scale and components differ significantly from one linear Fresnel or parabolic trough collector to the next.[93]

In dense urban environments, where rooftop space is restricted, solar PV / solar thermal hybrid (PV-T) systems have become an option for generating both power and heat.[94] As of early 2015, a large variety of PV-T technologies was on the market with different target applications, installed costs and performance characteristics, and dominated by unglazed PV-T elements.[95]

The global solar cooling industry followed two divergent trends in 2015: a shift towards large-scale systems with a better performance; and the development of plug-and-play system kits with cooling capacities below 5 kW.[96] Among the 45 sorption (heat-driven) chiller manufacturers worldwide, several European manufacturers – including Purix (Denmark), Solarinvent (Italy), Solabcool (Netherlands) and Meibis (Germany) – launched or developed a new generation of compact and easy-to-install solar cooling system kits up to 5 kW in size in 2015.[97]

Compact storage technologies are a key research field in the solar thermal industry.[98] With both types of materials used for compact storage – phase-change materials (PCM) and thermochemical materials (TCM) – heat can be stored in a more dense form and with lower losses than is possible with conventional heat storage systems, such as hot water storage tanks.[99] In early 2015, the IEA SHC defined measurement standards for PCM and preliminary estimates of their maximum costs.[100]

WIND POWER

WIND POWER MARKETS

Wind power experienced another record year in 2015, with more than 63 GW added – a 22% increase over the 2014 market – for a global total of around 433 GW.[1] (→ *See Figure 23.)* More than half of the world's wind power capacity has been added over the past five years.[2] By the end of 2015, more than 80 countries had seen commercial wind activity, while 26 countries – representing every region – had more than 1 GW in operation.[3] Wind was the leading source of new power generating capacity in Europe and the United States and placed second in China, and, by one estimate, wind supplied more new power generation worldwide than any other technology in 2015.[4]

China led for new installations, followed distantly by the United States, Germany, Brazil and India.[5] Others in the top 10 were Canada, Poland, France, the United Kingdom and Turkey.[6] (→ *See Figure 24 and* ***Reference Table R9.***) Non-OECD countries again were responsible for the majority of installations; most of the new capacity was added in China, which alone accounted for nearly half of global additions, but new markets are opening across Africa, Asia, Latin America and the Middle East.[7] Guatemala, Jordan and Serbia all installed their first large-scale wind plants, and Samoa added its first project.[8] At the end of 2015, the leading countries for total wind power capacity per inhabitant were Denmark, Sweden, Germany, Ireland and Spain.[9]

Growth in some of the largest markets was driven by uncertainty about future policy changes; however, wind deployment also was driven by wind power's cost-competitiveness and by environmental and other factors.[10] Wind has become the least-cost option for new power generating capacity in an increasing number of markets.[11]

Asia was the largest market for the eighth consecutive year, accounting for 53% of added capacity, followed by the European Union (20.1%) and North America (16%).[12] All regions but Africa saw market growth relative to 2014.[13]

China added a staggering 30.8 GW of new capacity in 2015, for a total exceeding 145 GW – more wind capacity than the entire EU.[14] Nearly 33 GW was integrated into the national grid and started receiving the FIT premium, with approximately 129 GW considered officially grid-connected by year's end.[15] Significant growth was expected in anticipation of reduced FIT levels (as of 1 January 2016), but the market surpassed expectations, particularly in light of China's economic slowdown.[16] The market also was driven by a national government push to improve energy security and, in particular, to reduce coal consumption due to growing concerns about climate change and air pollution.[17]

At year's end, Inner Mongolia had 18.7% of China's cumulative capacity, followed by Xinjiang (12.5%), Gansu (9.7%) and Hebei (7.9%) provinces.[18] Difficulties continued in transmitting China's wind power from turbines to population centres and, combined with slow growth in electricity demand (0.6%), led to significant grid curtailment.[19] Curtailment rose in 2015 to an average 15%, up from 8% in 2014, with 33.9 TWh of potential generation kept from the grid.[20] In addition, many unused turbines sat awaiting completion of long-distance transmission capacity. In the meantime, some companies were building wind farms at sites in the country's east and south, with lower wind speeds but closer to demand and with better grid infrastructure.[21] Wind energy generated 186.3 TWh in China during 2015, accounting for 3.3% of total electricity generation in the country (up from 2.8% in 2014).[22]

India installed about 2.6 GW, passing Spain to rank fourth globally for total wind power capacity, with nearly 25.1 GW by year's end.[23] India added less capacity than expected, despite wind's cost-competitiveness in much of the country and strong national and state-level policy support, due largely to a shortage of available transmission capacity.[24] Other Asian countries that added

capacity included Japan and the Republic of Korea (both over 0.2 GW), helping to bring the region's total installations above 175 GW.[25] Chinese wind projects also were under construction in Pakistan, although no new capacity came online in 2015.[26]

The United States ranked second for additions (8.6 GW) and cumulative capacity at year's end (74 GW) and held onto first place for wind power generation (190.9 TWh) during 2015.[27] Wind power was the top source for new US power generating capacity, accounting for over 40% of the total.[28] More capacity was added in the fourth quarter of 2015 than in all of 2014; the jump (+77%) in annual additions was driven by short-term extensions of the Production Tax Credit (PTC) in 2013 and 2014.[29] In late 2015, a multi-year PTC extension and phase-out promised to provide policy stability for a longer period than ever before.[30] Texas led for capacity added (1.3 GW), followed by Oklahoma, Kansas and Iowa; Connecticut installed its first utility-scale project.[31]

US utilities continued to invest strongly in wind power, with some going beyond state mandates based on favourable economics.[32] The cost-competitiveness of wind power also drove corporate and other purchasers, making 2015 the first year in which non-utility customers represented about half of the known (4 GW) US wind power purchase agreements.[33] By year's end, an additional 9.4 GW of capacity was under construction.[34]

Neighbouring Canada added 1.5 GW for a total of 11.2 GW, ranking sixth globally for additions and seventh for total capacity.[35] Although growth slowed relative to 2014, wind energy has remained Canada's largest source of new electricity generating capacity for five years.[36] Ontario continued to lead, adding 0.9 GW (for a total of 4.4 GW), followed by Québec (added 0.4 GW) and Nova Scotia (added 0.2 GW), which installed one of Canada's largest municipally owned wind projects.[37] Wind power capacity at end-2015 was enough to supply 5% of Canada's electricity demand, with much higher shares in some provinces.[38]

The European Union saw a new record for annual installations, due largely to Germany, which accounted for nearly half of the region's market in 2015. The EU brought online some 12.8 GW of wind power capacity, for a total approaching 141.6 GW, including 11 GW operating offshore.[39] Offshore capacity accounted for almost one-fourth of 2015 additions, twice the previous year's share.[40] Wind represented the largest percentage of new power capacity in the region (over 44%), followed by solar PV; new fossil fuel power capacity (about 23% of installations) was far exceeded by retirements.[41] Between 2000 and 2015, wind increased from 2.4% to 15.6% of total EU power capacity.[42] However, these advances and the scale of the EU market mask volatility in many countries due to weakened policy frameworks.[43]

Germany installed over 6 GW (net 5.7 GW, considering decommissioned capacity), for a total of almost 45 GW.[44] These installations reflected the grid connection of a large amount of offshore capacity that was constructed in 2014, and a rush to complete new projects before Germany switches to a tendering scheme in 2017.[45] Germany's gross generation from wind power was 88 TWh – up 53% relative to 2014 due to increased capacity and good wind conditions.[46]

After Germany, the leading EU installers were Poland (1.3 GW), which overtook the United Kingdom for additions (1 GW), and France (1.1 GW).[47] Finland, Lithuania and Poland experienced the highest annual growth rates; Poland's record additions (nearly three times the 2014 level) were driven by the anticipation of a new policy scheme in 2016.[48] Spain continued to rank second in the EU for total operating capacity (23 GW) but did not add wind capacity in 2015.[49]

After Asia, Europe and North America, Latin America was the next largest installer by region, with nine countries adding nearly 4.4 GW to reach about 15.3 GW.[50] Brazil (2.8 GW) was responsible for about 57% of the region's market, despite its political and economic woes, and ended the year with 8.7 GW.[51] About 357 MW of Brazil's new capacity was commissioned but not yet grid-connected by year's end.[52] Wind power has enabled Brazil to avoid power rationing and has brought economic revival to Rio Grande do Norte, Brazil's leading state for wind capacity.[53] Brazil was followed by Mexico (adding 0.7 GW to pass 3 GW), Uruguay (adding 0.3 GW) and Panama (adding 0.2 GW).[54]

Turkey again ranked in the top 10 for new capacity in 2015, adding nearly 1 GW to end the year just above 4.7 GW.[55] In the Middle East, Jordan opened its first large commercial wind farm.[56] Others in the region advanced projects – including Iran, with as much as 155 MW at year's end and plans for several additional projects, and Kuwait, which was planning its first wind farm.[57]

The total African market was smaller than in 2014, due in part to financial difficulties in South Africa.[58] Even so, South Africa added nearly 0.5 GW (for a total just over 1 GW) to surpass Morocco and lead the continent past the 3 GW mark.[59] Egypt added 200 MW, and Ethiopia installed a large plant (153 MW), nearly doubling the national total.[60] Projects in Kenya, including the 300 MW Lake Turkana wind farm, were stalled due to land disputes.[61] However, by year's end there was significant activity under way in Egypt and Morocco, and numerous small projects were being launched across Africa.[62]

Australia was responsible for nearly all new capacity in the Pacific.[63] The country added almost 0.4 GW for a total approaching 4.2 GW, and wind power accounted for about 5% of national electricity consumption in 2015.[64]

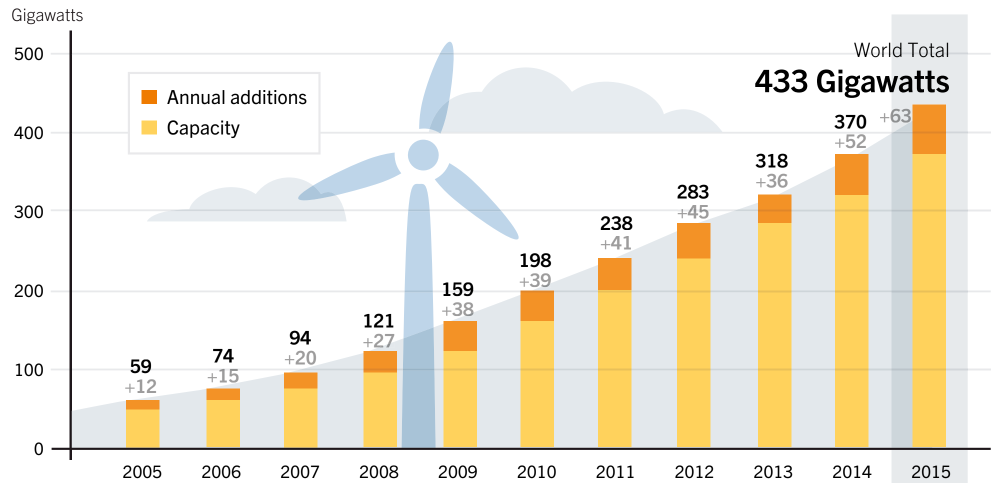
Offshore, an estimated 3.4 GW of capacity was connected to grids in 2015, about double the additions in 2014, for a world total exceeding 12 GW.[65] The vast majority of added capacity (89%) and total operating capacity (91%) was in Europe, where a record 3 GW was installed for a total 11 GW of grid-connected capacity off the coasts of 11 countries.[66] Germany accounted for about two-thirds of global offshore additions (adding 2.2 GW), counting capacity installed but not grid-connected in 2014.[67] It was followed by the United Kingdom (571 MW), China (361 MW), the Netherlands (180 MW) and Japan (3 MW), the only other countries to add capacity offshore in 2015.[68] Although policy changes have delayed some development, the United Kingdom continued to lead in total offshore capacity with 5.1 GW at year's end; it was followed by Germany (3.3 GW), Denmark (1.3 GW) and China (1 GW).[69]

Deployment offshore has been relatively slow in Asia and North America.[70] China is about three years behind its 2015 target to deploy 5 GW, delayed by high costs, challenging environmental conditions, and regulatory and technical issues.[71] India approved an offshore wind power policy, opening the door for future development.[72] In the United States, construction began on the first project (30 MW).[73]

Offshore and on land, independent power producers (IPPs) and energy utilities remained the most important clients in terms of capacity under construction and in operation, but

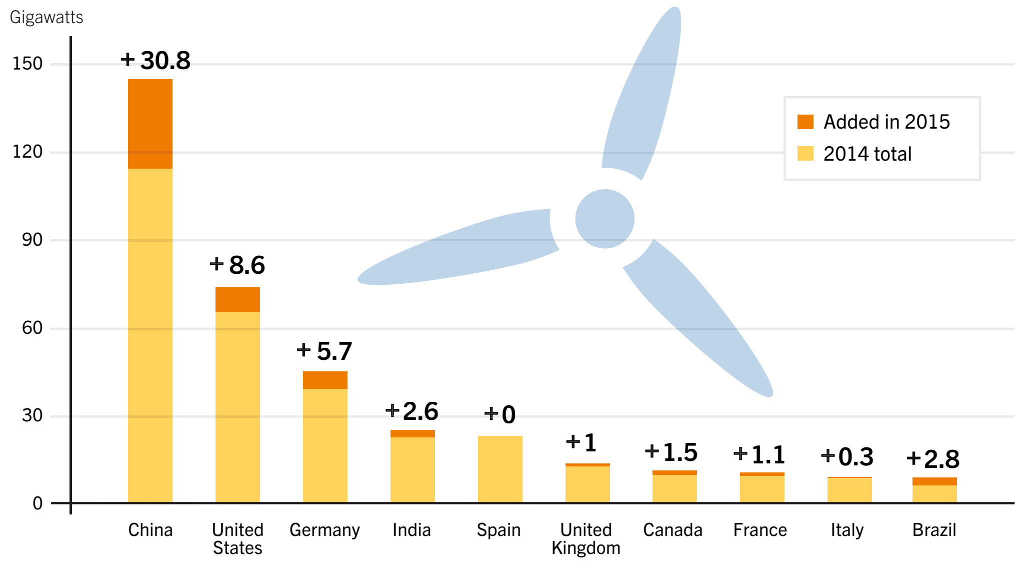
WIND POWER

Figure 23. Wind Power Global Capacity and Annual Additions, 2005–2015



See endnote 1 for this section.

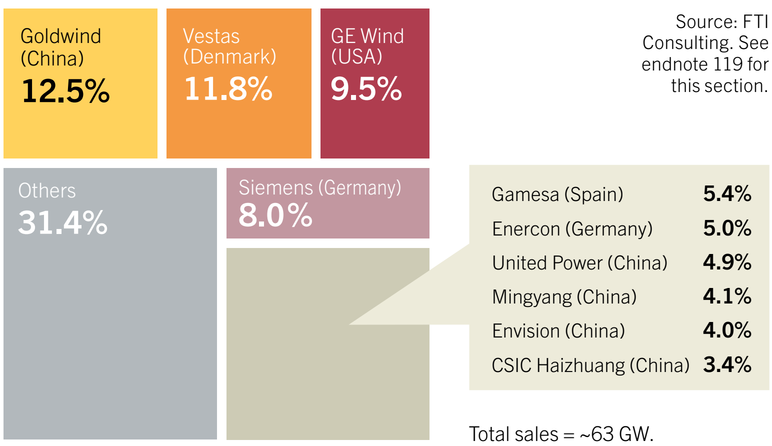
Figure 24. Wind Power Capacity and Additions, Top 10 Countries, 2015



Source: See endnote 6 for this section.

Additions are net of repowering/ decommissioning.

Figure 25. Market Shares of Top 10 Wind Turbine Manufacturers, 2015



02

interest continues to grow in other sectors.[74] The number of private purchasers of wind-generated electricity and turbines rose during 2015, as did the scale of their purchases.[75] Corporations increasingly are purchasing wind power from utilities, signing PPAs, or buying their own turbines to power operations – particularly in the United States, but increasingly in other regions – to obtain access to reliable low-cost power.[76] Investment funds, insurance companies, banks and institutional players are investing in wind energy because of its stable return.[77]

Community and citizen ownership also continued to expand in several countries and regions during 2015, including in Australia, Europe, Japan, New Zealand, North America and South Africa.[78] (→ *See Feature*.) However, there is concern that policy changes – such as Germany's shift towards tenders and Nova Scotia's cancelation of the community tariff under its FIT – could slow future development.[79]

Small-scale[i] turbines are used for a variety of applications, including defence, rural electrification, water pumping, battery charging and telecommunications, and they are deployed increasingly to displace diesel in remote locations.[80] Following a decline in 2013, the global market grew by 8.3% in 2014 (latest data available), and total capacity was up an estimated 10.9%.[81] By end-2014, more than 830,330[ii] small-scale turbines, or over 830 MW, were operating worldwide (up from 749 MW at end-2013).[82] The average size of small-scale turbines continues to creep up, with significant differences among countries, due largely to increasing interest in larger grid-connected systems (in some cases driven by policy structure).[83]

While most countries have some small-scale turbines in use, the majority of units and capacity operating at the end of 2014 was in China (343.6 MW), the United States (226 MW) and the United Kingdom (132.8 MW).[84] Other leaders included Italy (32.7 MW), Germany (24 MW), Ukraine (14.6 MW) and Canada (13.1 MW)[iii].[85] The US market continued to struggle, reflecting continuing competition with solar PV and the low cost of other electricity sources, although new leasing models are building momentum.[86] Markets boomed in both Italy and the United Kingdom during 2014, but UK deployment rates remained significantly below the 2012 level.[87]

Repowering has become a billion-dollar market, particularly in Europe.[88] While most repowering involves the replacement of old turbines with fewer, larger, taller, and more-efficient and reliable machines, some operators are switching even relatively new machines for upgraded turbines that include software improvements.[89] During 2015, at least 300 turbines (totalling an estimated 300 MW) were dismantled in Europe, two turbines (0.7 MW) in Japan and one unit (2 MW) in Australia.[90] The largest market for repowering was Germany.[91] There also is a thriving international market for used turbines in Africa, Asia and elsewhere.[92]

Wind power is playing a major role in power supply in an increasing number of countries. In the EU, capacity in operation at end-2015 was enough to cover an estimated 11.4% of electricity consumption in a normal wind year.[93] Several EU countries – including Denmark (42%), Ireland (over 23%), Portugal (23.2%) and Spain (over 18%) – met higher shares of their demand with wind energy.[94] Four German states had enough wind capacity at year's end to meet over 60% of their electricity needs.[95] In the United States, wind power represented 4.7% of total electricity generation and accounted for more than 10% of generation in 12 states, including Iowa (31.3%).[96] Brazil reached almost 3%, and Uruguay generated about 15.5% of its electricity with the wind.[97] Globally, wind power capacity in place by the end of 2015 was enough to meet an estimated almost 3.7% of total electricity consumption.[98]

i Small-scale wind systems generally are considered to include turbines that produce enough power for a single home, farm or small business (keeping in mind that consumption levels vary considerably across countries). The International Electrotechnical Commission sets a limit at approximately 50 kW, and the World Wind Energy Association (WWEA) and the American Wind Energy Association define "small-scale" as up to 100 kW, which is the range also used in the GSR; however, size varies according to the needs and/or laws of a country or state/province, and there is no globally recognised definition or size limit. For more information, see, for example, WWEA, *Small Wind World Report 2016* (Bonn: March 2016), Summary, http://www.wwindea.org/small-wind-world-market-back-on-track-again/.

ii Total numbers of units does not include some major markets, including India, for which data were not available. Taking this into account it is estimated that more than 1 million units are operating worldwide, from WWEA, *Small Wind World Report 2016*.

iii Data are for end-2014 with the exception of Canada (year 2011).

WIND POWER INDUSTRY

The wind power industry had another outstanding year thanks to record installations. Most of the top turbine manufacturers broke their own annual installation numbers.[99] By early 2016, manufacturers had full order books, with some receiving record orders for on- and offshore turbines, presaging momentum for future years.[100] But rising competition in the global marketplace and fragmentation in the market required that manufacturers and developers be flexible to adapt in different environments.[101] Spain's manufacturers, for instance, survived by exporting 100% of their production.[102] Ongoing technology improvements that are increasing capacity factors (such as custom turbine configurations), as well as economies of scale and financing innovations, continued to drive down prices, making onshore wind power directly competitive with fossil fuels in an increasing number of locations.[103]

Costs vary widely according to wind resource, regulatory and fiscal framework, the cost of capital and other local influences.[104] In 2015, the levelised cost of electricity (LCOE) from onshore wind continued to fall, while the LCOE for new fossil generation increased.[105] Wind was the most cost-effective option for new grid-based power during 2015 in many markets – including Brazil, Canada, Mexico, New Zealand, South Africa, Turkey, and parts of Australia, China and the United States.[106] In late 2015, Morocco secured new record-low tender bids – averaging USD 25–30 per MWh – for wind capacity that is projected to be in operation between 2017 and 2020.[107] Although offshore wind remains significantly more expensive, the LCOE for offshore wind generation also declined further in 2015.[108]

As the amount of wind output and its share of total generation have increased, so have grid-related challenges in several countries. Challenges for wind power – both onshore and offshore – include lack of transmission infrastructure, delays in grid connection, the need to reroute electricity through neighbouring countries, lack of public acceptance, and curtailment where regulations and current management systems make it difficult to integrate large amounts of wind energy and other variable renewables.[109]

Curtailment in China cost the country's industry an estimated USD 2.77 billion (RMB 18 billion) in 2015.[110] To reduce curtailment, China's government has urged north-western regions to attract more energy-intensive industries and to use wind power for heating (with the added benefit that it can displace coal), among other options; new transmission capacity is under construction, and new pumped storage facilities are being planned.[111] In the United States, curtailment is down dramatically in Texas following the completion of new transmission lines.[112] Across the globe in 2015, projects were in planning stages or under way in every region to strengthen and expand transmission capacity to efficiently move wind-generated electricity to where it is needed.[113]

Most wind turbine manufacturing takes place in China, the EU and the United States, and the majority is concentrated among relatively few players.[114] In 2015, by some estimates, Goldwind (China) surpassed Vestas (Denmark) to become the world's largest supplier of wind turbines, marking the first time that a Chinese company has held this spot.[115] Almost all of Goldwind's recent growth (and that of other Chinese companies) has occurred at home, although Chinese companies are increasingly active in new markets.[116] Long-term leader Vestas ranked second, followed by US-based GE, which climbed one position due in part to a strong US market and to its acquisition of Alstom (France).[117] Siemens (Germany) dropped two positions to fourth (but ranked first in the offshore market), and Gamesa (Spain) was up three positions to rank fifth, followed by Enercon (Germany).[118] Others in the top 10 were all Chinese companies: United Power, Ming Yang, Envision and CSIC Haizhuang.[119] (→ *See Figure 25.)* Suzlon (India) dropped out of the top 10 due to the sale of subsidiary Senvion (Germany) in 2015.[120]

The world's top 10 turbine manufacturers captured nearly 69% of the 2015 market.[121] However, components are supplied from many countries: blade manufacturing, for example, has shifted from Europe to North America, South and East Asia and, most recently, Latin America, to be closer to new markets.[122] In Africa, major manufacturers are considering new facilities in Egypt, which has set its sights on becoming a regional manufacturing hub.[123]

Increasing demand for turbines and related technologies led to the construction of new factories in 2015 and plans for further development. In Europe, Vestas announced plans to begin producing 80-metre (260-foot) blades for offshore use at its new factory on the Isle of Wight (UK), and Siemens (Germany) said it would construct a new plant for offshore components – its largest German facility to be built in several years.[124] Elsewhere, major manufacturers have scrambled to meet local content requirements, adding capacity to overcome shortages in components.[125] For example, several companies announced plans for manufacturing or service plants in Brazil to focus on the local market, and, across the Atlantic, manufacturers are building facilities to provide turbines to meet local content requirements in Egypt and Morocco.[126]

The year saw a surge in consolidation among turbine manufacturers, developers, data and service companies.[127] For example, GE acquired Alstom's power generation business, gaining a foothold in Europe – including the offshore market – and becoming a leader in the Brazilian market.[128] In early 2016, Nordex (Germany) acquired Acciona Windpower (Spain), which focuses on large-scale wind farms and has production plants in Brazil, Spain and the United States, with one under construction in India.[129] Vestas acquired servicing firm UpWind Solutions (United States) to expand its North American service operations, as well as German service provider Availon; and EDF Renewable Energy purchased OwnEnergy (United States) to move into the community wind market.[130] Investment firm Centerbridge Partners (United States) completed its acquisition of manufacturer Senvion from Suzlon, and asset manager Swiss Energy bought Spanish turbine manufacturer MTOI.[131] In late 2015, Gamesa acquired a 50% stake in NEM Solutions (Spain/United States), which leverages data mining to optimise equipment performance.[132] Challenges are mounting for companies that only manufacture turbines; remaining pure wind turbine manufacturers (that are not part of large conglomerates) include Enercon, Nordex and Vestas.[133]

Projects also changed hands – particularly in the United States and Europe – purchased by companies in the same region or based in Asia and the Middle East.[134] In the United States, many utilities moved to acquire more renewable energy projects to satisfy demand from key corporate customers; an estimated 3.7 GW of US wind project capacity was acquired in 2015.[135] Other players moved into wind projects to expand their foothold into

new regions or new areas of business. China Three Gorges and state-owned SDIC (China) both acquired UK offshore projects within a few months of each other.[136] Canadian pipeline and energy company Enbridge bought a long-delayed wind project in the US state of West Virginia.[137] In addition, the wind industry continued moving into solar PV (and vice versa) – for example, Suzlon (India) began developing a solar project in India – and several solar PV-wind hybrid projects were under development as of early 2016.[138]

Wind energy technology continued to evolve, driven by several factors, including: mounting global competition; efforts to make turbine manufacturing easier and cheaper; the need to optimise power generation at lower wind speeds; and increasingly demanding grid codes to deal with rising penetration of variable renewable sources.[139] To meet increasing demand from grid operators for stable feed-in, Senvion launched a new turbine for the German market.[140] Also in 2015, GE launched new software to track and collect data from individual turbines for optimising performance and increasing output.[141]

To reach stronger winds and boost output, there is a general trend towards larger machines – including longer blades, larger rotor size and higher hub heights.[142] Such changes have driven capacity factors significantly higher within given wind resource regimes, creating new opportunities for wind power in established markets as well as new ones.[143] During 2015, new low-speed turbines were launched by several manufacturers, including Gamesa, GE, Nordex, Siemens and Vestas.[144]

Capacity ratings continued to rise in 2015, with the average size turbine delivered to market up slightly to 2 MW.[145] Average turbine sizes were highest in Europe (2.7 MW) – particularly in Denmark and Germany – followed by Africa (2.4 MW), the Americas (nearly 2.1 MW) and Asia-Pacific (1.8 MW).[146] Turbines for use offshore also are growing, as are project sizes, driven by the need to reduce costs through scale and standardisation.[147] In Europe, the average capacity of new turbines installed offshore was 4.2 MW, up 13% relative to 2014, due to significant deployment of turbines in the 4–6 MW range.[148] By late 2015, there were several orders already on the books for 7 MW and 8 MW machines, and research projects were looking at 10–20 MW turbines for offshore.[149]

The offshore wind industry differs technologically and logistically from onshore wind.[150] In addition to the deployment of ever-larger turbines and projects, the offshore industry continues to move farther out, into deeper waters.[151] By year's end, the distance from shore and water depth of grid-connected projects in Europe averaged 43.3 kilometres and 27.1 metres, respectively (up from 32.9 kilometres and 22.4 metres, respectively, in 2014), due largely to increased deployment in Germany.[152]

The majority of substructures off Europe in 2015 continued to be monopiles (97%), followed by jackets (3%).[153] However, to access winds in even deeper waters – in the Atlantic and Mediterranean, and just off Japan's shore – the industry continues to invest in the development of floating turbines (anchored by mooring systems), which reduce foundation costs and other offshore logistical challenges.[154] In early 2015, a few test turbines were floating offshore worldwide; before the year was out, the world's largest (7 MW) floating turbine was operating off Japan's coast, France had launched the world's first tender for floating turbines, and oil and gas giant Statoil (Norway) had contracted Siemens to build a 30 MW floating wind farm off Scotland.[155]

The most significant challenge facing the offshore industry is the lack of policy stability in key markets, which is important for achieving the scale and low-cost financing that are necessary to reduce costs to competitive levels.[156] In the EU, the lack of co-ordination of regulations across Member States is hampering offshore development.[157]

The price differential between fossil fuel and offshore wind generation remains significant, and the industry is working to close this gap.[158] In early 2015, manufacturers MHI-Vestas and Siemens, and developer DONG Energy signed a joint declaration for a united industry goal to drive the cost of offshore wind energy below USD 112/MWh (EUR 100/MWh) by 2020.[159] During the year, Siemens unveiled a new direct current (DC) solution for connecting offshore wind turbines to the grid at lower cost; the solution also increases transmission capacity and reduces transmission losses.[160] In addition, the company adapted an existing cargo shipping method for the transport of offshore turbine components that reduces costs by eliminating the need for a crane; the first such ship might be launched by late 2016.[161] Another significant development was the diversification of financial structures used during construction and operation: project bonds emerged in 2015 as a competitive financing tool in response to reduced risk perception for offshore projects.[162]

In the small-scale wind industry, five countries (Canada, China, Germany, the United Kingdom and the United States) accounted for more than 50% of turbine manufacturers as of 2014; aside from China, developing countries still play a minor role.[163] UK and US manufacturers continued to rely on export markets as a source of revenue, but exports (in terms of units sold) were down significantly for both countries in 2014 relative to 2013.[164] To increase the competitiveness of small-scale wind, several leading US small-scale and distributed wind companies have begun offering long-term leases to build on the success of third-party financing for solar PV.[165] In early 2016, Statoil and United Wind (United States) announced a joint venture, securing Statoil's entry into the US small-scale and distributed wind market.[166]

See Table 2 on pages 82–85 for a summary of the main renewable energy technologies and their costs and capacity factors; *see also Sidebar 3* for a discussion of technology cost trends.[167]

Sidebar 3. Renewable Power Technology Cost Trends

The past decade has seen a dramatic and sustained improvement in the competitiveness of renewable power generation technologies. Around the world, renewables have benefited from a virtuous cycle of increased deployment leading to greater economies of scale and manufacturing improvements, increased competition, technology improvements[i] and falling costs. Improvements in the competitiveness of renewable power generation technologies continued in 2015.

Biomass, hydro, geothermal and onshore wind power all can provide electricity competitively where good resources exist. The global weighted average levelised cost of electricity (LCOE) of projects commissioned in 2015 was around USD 0.06/kWh for biomass, USD 0.08/kWh for geothermal, USD 0.05/kWh for hydro and USD 0.06/kWh for onshore wind. These technologies compete head-to-head with fossil fuels, which have costs of between USD 0.045/kWh and USD 0.14/kWh. Solar technologies also are increasingly providing low-cost, competitive electricity due to rising economies of scale as well as technology improvements and their associated cost reductions – and this trend will continue.

Onshore wind is now one of the most competitive sources of electricity available. Technology improvements (e.g., higher hub heights and larger swept areas) and declining total installed costs mean that onshore wind is now within the same cost range as, or even lower than, that for new fossil fuel capacity. Onshore wind projects around the world are consistently delivering electricity for USD 0.04/kWh to USD 0.09/kWh, without financial support. Power purchase agreement (PPA) announcements made in 2015 and 2016 for future delivery (e.g., 2017 and beyond) suggest costs at about USD 0.04/kWh.

Based on global data, the weighted average investment cost for onshore wind fell by slightly more than two-thirds between 1983 and 2015, from USD 4,766/kW to USD 1,550/kW[ii], while the LCOE fell from an estimated USD 0.38/kWh to USD 0.06/kWh over the same period. Increased capacity factors (due to technology improvements) and declining wind turbine costs each have accounted for around one-third of the reduction in LCOE since 1983; the remaining one-third is due to other capital cost reductions and declining operation and maintenance costs.

Solar PV also has experienced significant cost reductions. Between 2010 and 2015, the global weighted average LCOE of utility-scale (>1 MW) solar PV fell by almost 60%, driven primarily by reductions in module costs of around three-quarters during this period. In 2015, the most competitive utility-scale solar PV projects were regularly delivering electricity for just USD 0.08/kWh, without financial support, compared to a range of USD 0.045/kWh to USD 0.14/kWh for new fossil fuel power (excluding health and carbon emission costs). But even lower costs are being contracted for 2017 and beyond. Tenders during 2015 and 2016 in Dubai (USD 0.06/kWh), Peru (USD 0.05/kWh) and Mexico (USD 0.035/kWh) ably demonstrate this shift[iii]. Solar PV is now competing head-to-head, without financial support, even in regions with abundant fossil fuels. Tenders in Brazil, Chile, Jordan and South Africa all have highlighted that solar PV can be competitive.

The electricity from CSP and offshore wind power technologies has higher costs than other renewable power generation options (global weighted averages of USD 0.24/kWh and USD 0.165/kWh, respectively, in 2015), although some projects show costs falling within the range of new fossil fuel options. Because both CSP and offshore wind power are in their infancy in terms of deployment, they still have significant potential for future cost reductions. As their costs continue to come down, they will play an increasing role in the future energy mix[iv]. CSP, in particular, has a bright future because of its ability to add low-cost thermal energy storage to allow for dispatchability.

Costs for the more mature renewable power generation technologies – biomass for power, geothermal and hydropower – have been broadly stable since 2010. Where untapped economic resources remain, these technologies can provide some of the cheapest electricity of any source.

Given the installed costs and the performance of today's renewable technologies, and the costs of conventional technologies, renewable power generation is increasingly competing head-to-head with fossil fuels, without financial support, when new capacity is required and despite the fact that fossil fuels do not carry the full cost of their externalities.

i Supported by a 4.6-fold increase in public R&D support in OECD countries between 1990 and 2013, from IEA, Energy Technology RD&D Budgets Database (Paris: 2016).

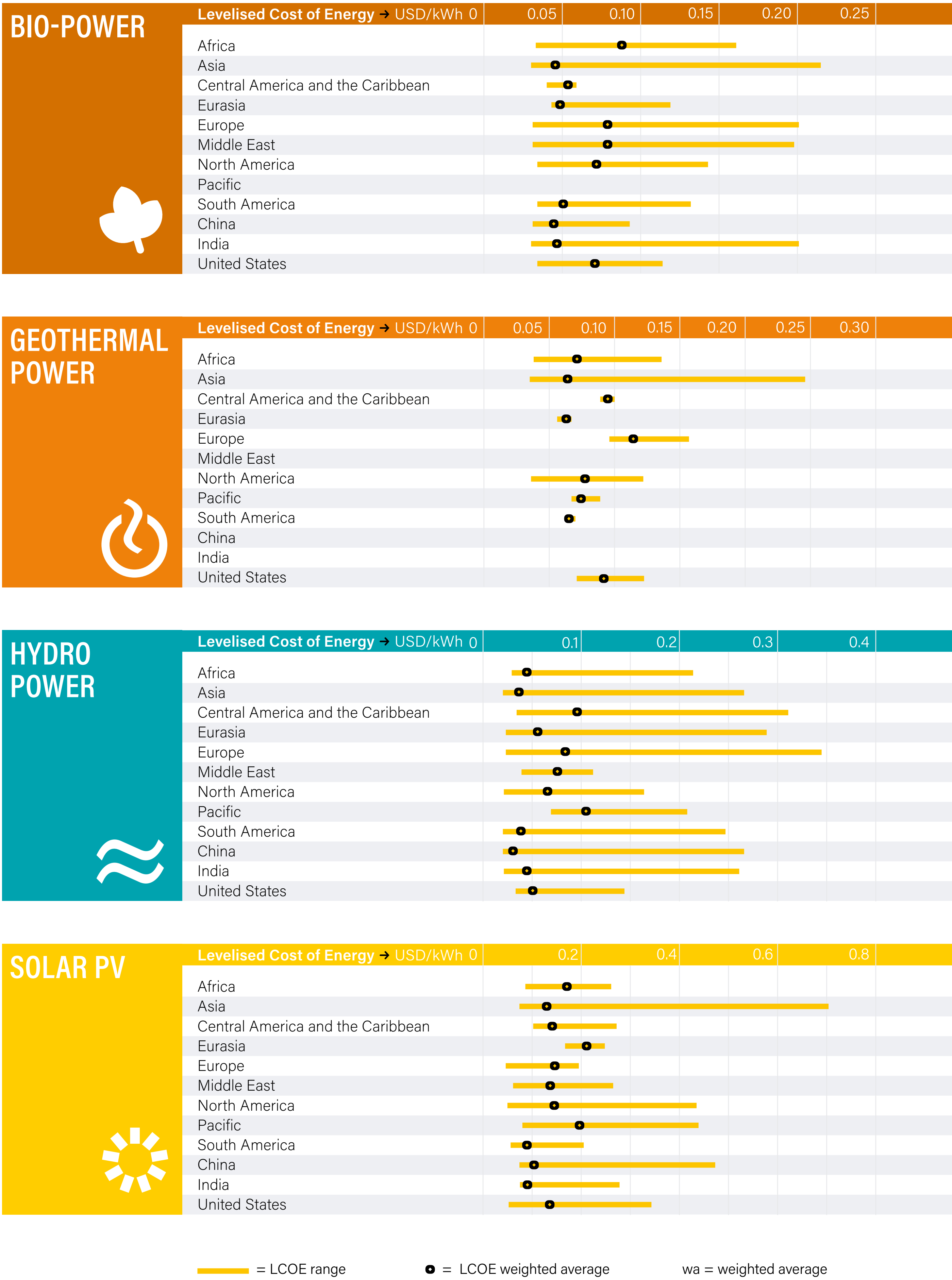
ii Except for tenders, all cost data refer to the year a project comes online.

iii It is important to note that tender and PPA prices are not necessarily equivalent to a calculated LCOE, as headline remuneration rates are usually quoted. Duration of the contract, escalation clauses, partly indexed tariffs and other details can mean that LCOEs can be significantly higher than headline remuneration rates (70% higher in one example in the United States for solar PV).

iv For CSP, the additional value of the dispatchability of plants with low-cost thermal energy storage also needs to be considered, as this is not captured in a simple LCOE metric.

Source: See endnote 167 for this chapter.

Table 2. Status of Renewable Technologies: Costs and Capacity Factors



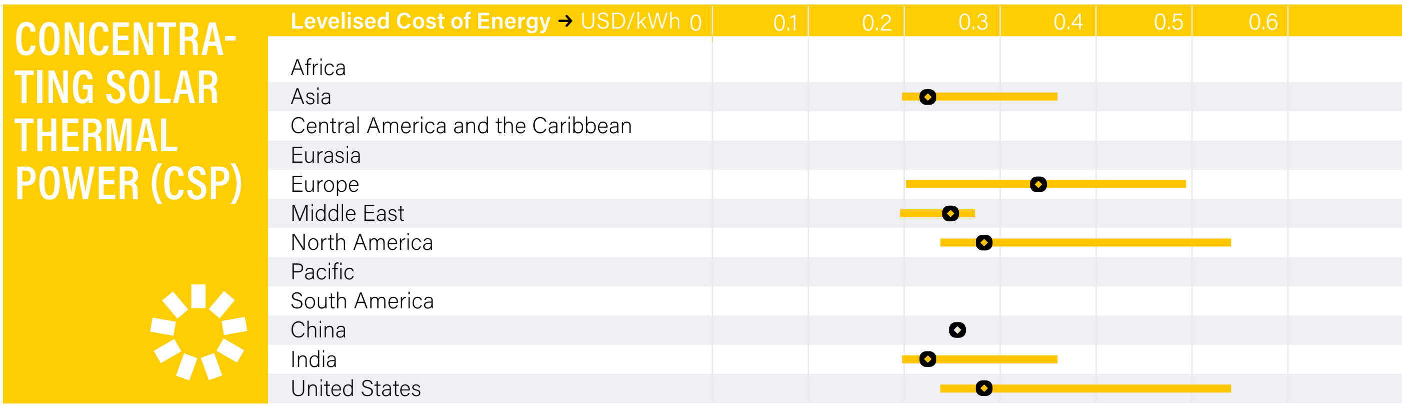
Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	625	5579	● 1654		0.454	0.913	● 0.618
Asia	536	6082	● 1486		0.202	0.95	● 0.623
Central America and the Caribbean	534	7805	● 1021		0.225	0.796	● 0.317
Eurasia	1344	7106	● 1756		0.713	0.958	● 0.831
Europe	507	7957	● 3249		0.228	0.933	● 0.835
Middle East	885	4272	● 2895		0.291	0.929	● 0.566
North America	510	7641	● 3584		0.228	0.958	● 0.847
Pacific	3852	3851	● 3851		0.508	0.506	● 0.507
South America	547	7885	● 1662		0.206	0.942	● 0.531
China	542	6082	● 1576		0.206	0.95	● 0.618
India	536	5497	● 1112		0.202	0.976	● 0.626
United States	1062	7641	● 4076		0.891	0.958	● 0.93

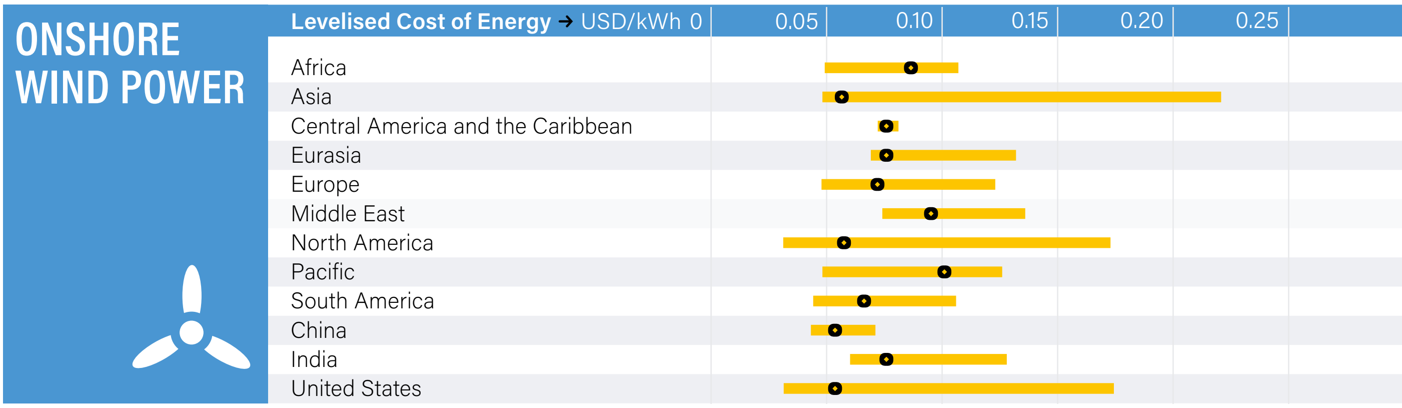
Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	1719	7689	● 3818		0.8	0.92	● 0.84
Asia	1514	8736	● 3148		0.411	0.929	● 0.83
Central America and the Caribbean	3260	3537	● 3413		0.57	0.6	● 0.58
Eurasia	2613	3278	● 3113		0.8	0.8	● 0.8
Europe	3613	8919	● 5209		0.6	0.8	● 0.66
Middle East							
North America	2029	8353	● 5017		0.74	0.923	● 0.83
Pacific	3303	4676	● 3796		0.6	0.8	● 0.8
South America	3027	4348	● 3587		0.8	0.95	● 0.82
China	1501	9722	● 1943				
India	1501	7475	● 2169				
United States	2941	8353	● 5961		0.74	0.9	● 0.79

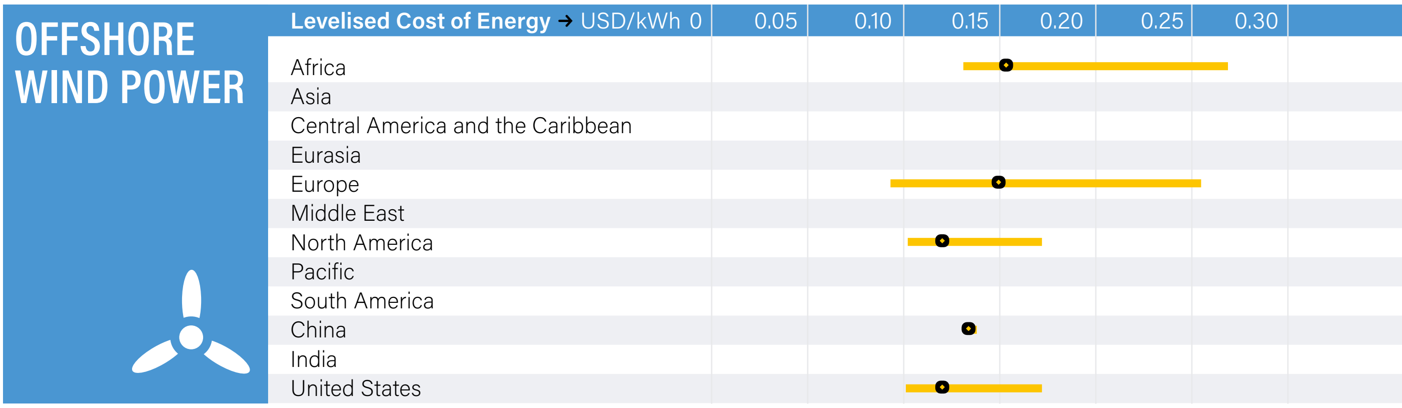
Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	454	6730	● 1478		0.264	0.856	● 0.413
Asia	458	7553	● 1212		0.139	0.947	● 0.46
Central America and the Caribbean	674	5416	● 2945		0.25	0.8	● 0.476
Eurasia	519	5416	● 2945		0.169	0.854	● 0.421
Europe	528	7913	● 1790		0.140	0.713	● 0.353
Middle East	453	2186	● 1303		0.201	0.757	● 0.316
North America	723	7103	● 2252		0.184	0.89	● 0.509
Pacific	1780	4119	● 2984		0.241	0.614	● 0.504
South America	527	7211	● 1851		0.251	0.945	● 0.569
China	458	7220	● 1023		0.131	0.947	● 0.451
India	467	5759	● 1321		0.115	0.898	● 0.451
United States	723	6757	● 1384		0.31	0.779	● 0.398

Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	944	4110	● 2649		0.016	0.278	● 0.199
Asia	819	7997	● 1624		0.101	0.247	● 0.166
Central America and the Caribbean	1600	4000	● 2076		0.155	0.227	● 0.198
Eurasia	1545	3697	● 2775		0.117	0.127	● 0.119
Europe	944	2827	● 1408		0.098	0.30	● 0.123
Middle East	1311	4000	● 2553		0.174	0.347	● 0.256
North America	800	5900	● 2365		0.095	0.336	● 0.196
Pacific	1180	7539	● 2857		0.114	0.271	● 0.191
South America	1132	4326	● 2249		0.130	0.404	● 0.320
China	998	7780	● 1439		0.101	0.184	● 0.170
India	833	4916	● 1403		0.159	0.247	● 0.206
United States	965	5900	● 2336		0.095	0.336	● 0.197

Table 2. Status of Renewable Technologies: Costs and Capacity Factors (continued)







= LCOE range   = LCOE weighted average   wa = weighted average

Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	10094	17402	● 14153		0.194	0.194	● 0.194
Asia	3501	13693	● 4423		0.17	0.535	● 0.275
Central America and the Caribbean							
Eurasia							
Europe	4811	17341	● 8839		0.148	0.631	● 0.308
Middle East	3491	4097	● 3705		0.194	0.263	● 0.22
North America	4714	9009	● 6794		0.18	0.405	● 0.299
Pacific	9735	10767	● 9829		0.21	0.21	● 0.21
South America							
China	3501	13639	● 3680		0.17	0.28	● 0.272
India	3539	7475	● 4328		0.206	0.535	● 0.276
United States	4714	9009	● 6794		0.18	0.405	● 0.299

Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	1345	2848	● 2080		0.214	0.456	● 0.346
Asia	958	2784	● 1280		0.172	0.435	● 0.243
Central America and the Caribbean	1680	2600	● 2268		0.296	0.520	● 0.434
Eurasia	1550	2651	● 1751		0.272	0.35	● 0.344
Europe	1353	3652	● 1917		0.139	0.412	● 0.277
Middle East	1983	3148	● 2497		0.313	0.390	● 0.372
North America	1275	3181	● 1874		0.166	0.516	● 0.352
Pacific	1060	3752	● 2533		0.275	0.436	● 0.337
South America	994	2903	● 1871		0.257	0.534	● 0.426
China	1032	1553	● 1251		0.221	0.36	● 0.242
India	958	1625	● 1228		0.172	0.258	● 0.234
United States	1496	3000	● 1770		0.166	0.608	● 0.358

Investment Cost → USD	min	max	wa	Capacity Factor → %	min	max	wa
Africa	2115	5055	● 2668		0.204	0.312	● 0.26
Asia							
Central America and the Caribbean							
Eurasia							
Europe	2053	6480	● 4207		0.27	0.554	● 0.36
Middle East							
North America	2251	5063	● 2972		0.32	0.363	● 0.33
Pacific							
South America							
China	2115	3061	● 2767		0.204	0.287	● 0.26
India							
United States	2250	5063	● 2972		0.32	0.363	● 0.33

Note: All monetary values are expressed in USD_{2015}. LCOE is computed using a weighted average cost of capital of 7.5% for OECD countries and China and 10% for the rest of the world. For recent cost and characteristics data for heating and cooling, biofuels and DRE technologies, see Table 2 in GSR 2015. The costs and analysis exclude subsidies. Regional groupings are defined in IRENA, *Renewable Power Generation Costs in 2014* (Abu Dhabi: 2015), www.irena.org/costs.

Source: See endnote 167 of Wind Power section in this chapter.

03

Renewable mini-grids – flexibility in application

In the village of **Bancoumanan**, international partners and the local community have collaborated on the installation of a hybrid mini-grid that provides energy for the local population (190 end-users). Local technicians were trained for operation and maintenance tasks, and the system is managed by a local company. Combining solar energy and diesel, the village of Bancoumanan illustrates the flexibility of community-based renewable energy projects.

Bancoumanan, Mali | Created: 2015 | Village energy committee: 11 members | 33 kW solar PV and 68 kW diesel mini-grid

03 DISTRIBUTED RENEWABLE ENERGY FOR ENERGY ACCESS

For well over 1 billion people around the world, obtaining access to the energy required to meet very basic needs remains a daily struggle. In many rural areas of developing countries as well as some urban slums and peri-urban areas, connections to central electric grids are economically prohibitive and may take decades to materialise, if at all.[1] Moreover, grid connectivity does not fully address the need for access to sustainable heating and cooking options.[2]

Distributed renewable energy (DRE)[i] systems – power, cooking, heating and cooling systems that generate and distribute services independently of any centralised system, in both urban and rural areas of the developing world – already provide energy services to millions of people, and numbers continue to increase annually. DRE systems can serve as a complement to centralised energy generation systems, or as a substitute. They offer an unprecedented opportunity to accelerate the transition to modern energy services in remote and rural areas, while also offering co-benefits. Such co-benefits include improved health (through the displacement of indoor air pollution), a contributons to climate change mitigation, as well as positive effects on income growth, women's empowerment and distributive equity.[3] They can provide affordable lighting, enhance communications and facilitate greater quality and availability of education.[4] DRE systems, as well as the hybridisation of existing mini-grids, may also reduce dependence on fossil fuel imports.

This chapter provides a picture of the current status of DRE markets in developing countries and presents an overview of the major networks and programmes that were operational in 2015.

STATUS OF ENERGY ACCESS: AN OVERVIEW

The two most common ways to measure energy access are through 1) metrics related to electricity, and 2) metrics illustrating the level of dependence on solid or traditional fuels, such as biomass, for cooking. Approximately 1.2 billion people around the world (17% of the global population) live without electricity and 2.7 billion people are without clean cooking facilities (38% of the global population), the vast majority of whom are in the Asia-Pacific region and in sub-Saharan Africa.[5] (→ *See Figures 26 and 27.)*

Numbers and trends differ greatly by region. ***(→ See Reference Tables R10 and R11.)*** In Africa, nearly 60% of people have no access to reliable electricity.[6] To put this number in perspective, the entire continent of Africa has about 150 GW of installed power generating capacity, uses about 3% of the world's electricity (mostly within South Africa) and emits only about 1% of the world's carbon dioxide emissions.[7] With 45 GW of installed capacity, the entire electricity supply of sub-Saharan Africa (excluding South Africa) is less than that of Turkey.[8] The official electrification rate for sub-Saharan Africa is 32%.[9]

In Asia, China and many industrialised countries, such as Malaysia and Singapore, have made great strides towards electrification. However, in other countries in the region, comparatively high percentages of national populations remain without access to modern energy. India, for example, is home to more people without reliable access to electricity networks (237 million, or 19% of the population) than any other country worldwide.[10] Bangladesh has approximately 60 million people without electricity access (39% of the population), Pakistan has 50 million people without access (27%) and Indonesia has 49 million people without access (19%).[11] In addition, more than 840 million people in India rely on firewood, dung cakes, charcoal or crop residue to meet their household cooking needs, along with an estimated 450 million people in China, 140 million in Bangladesh, 105 million in Pakistan and 98 million in Indonesia.[12]

Although the Middle East and North Africa (MENA) region has an electrification rate of almost 92%, in some individual countries, high shares of the population still lack access to modern energy. In Yemen, for example, 54% of the population (or 13 million people) does not have access to electricity, and 8 million people lack access to non-solid fuel for cooking.[13]

Similarly, throughout Latin America and the Caribbean, 95% of inhabitants have access to grid electricity; the 22 million people without access are concentrated largely in seven countries: Argentina, Bolivia, Colombia, Guatemala, Haiti, Nicaragua and Peru.[14] About 35 million people in the region (14% of inhabitants) do not have access to clean forms of cooking; in Haiti, 92% of the population use conventional cooking fuels and devices, while Honduras, Guatemala and Nicaragua have access rates of less than 50%.[15]

i See Sidebar 9 in GSR 2014 for more on the definition and conceptualisation of DRE.

DISTRIBUTED RENEWABLE ENERGY TECHNOLOGIES AND MARKETS

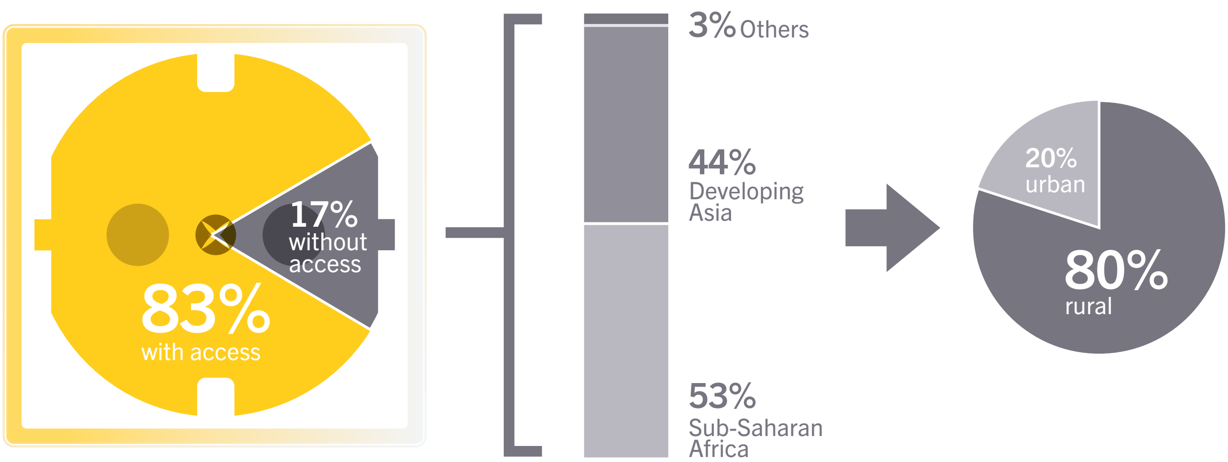
People in rural and remote regions generally acquire improved access to energy in three ways: 1) using isolated devices and systems for power generation at the household level as well as for heating, cooking and productive uses; 2) through community-level mini- or micro-grid systems; and 3) through grid-based electrification, where the grid is extended beyond urban and peri-urban areas. Each of these models has advantages and drawbacks.

Advantages of more-centralised models include generally lower per kW costs in areas of higher population density, a higher load diversity and suitability for industrial use. Advantages of more-distributed models include applicability to small and remote communities and urban areas, reduced transmission and distribution losses, the allowance for direct and local private investment, local employment, and increased security of supply, as well as, in some cases, improvements in reliability, speed of deployment, local spill-over costs and reduced environmental burdens.[16] DRE systems also have benefited from trends of decreasing system sizes, improved system costs and enhanced affordability linked to efficient appliances. This section focuses on the first two (distributed) means of improving energy access.

At the household and community scale, DRE technologies include small-scale solar PV and stand-alone lighting systems; wind, biodiesel generators, and micro- and pico-hydro stations for electricity generation; and solar and biomass heating and cooling units and cooking devices. Many of these technologies provide productive or mechanical energy for commercial purposes as well. For the purposes of this section, renewable energy-based micro- and mini-grids also qualify as DRE technologies.

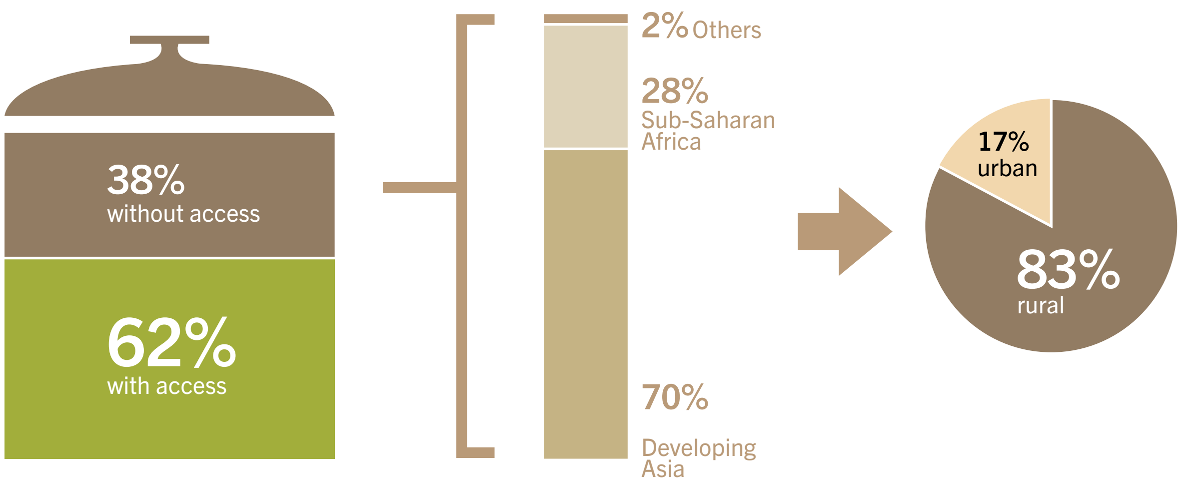
According to the most recently available data, an estimated 26 million households (or 100 million people) worldwide are served through DRE systems, including some 20 million households through solar home systems, 5 million households

Figure 26. World Electricity Access and Lack of Access, by Region, 2013



Source: See endnote 5 for this chapter.

Figure 27. World Clean Cooking Access and Lack of Access, by Region, 2013



Source: See endnote 5 for this chapter.

through renewables-based mini-grids (usually powered by micro-hydro), and 0.8 million households through small-scale wind turbines.[17] (→ *See DRE Dashboard*[i]*.)* Markets for DRE systems continue to grow rapidly. In some countries, DRE systems already have comparatively high market penetration.[18] (→ *See Figure 28.)*

Globally, some 44 million off-grid pico-solar products had been sold by mid-2015, representing a market of USD 300 million annually.[19] As of end-2015, approximately 70 countries worldwide had some off-grid solar capacity installed or programmes in place to support off-grid solar applications.[20] The largest market for off-grid solar products was sub-Saharan Africa (1.37 million units sold), followed by South Asia (1.28 million units sold).[21]

The smallest distributed solar PV systems are pico-PV systems (1–10 W_P), which can power small lights, low-power appliances or mobile phone charging stations. These systems typically decrease in size as the efficiency of appliances that utilise the generated power improves. They replace kerosene lamps, candles and battery-powered flashlights and are the most widely used DRE technologies by far. Worldwide, some 20 million branded pico-solar products (mainly portable lights) had been sold by mid-2015, most of which are concentrated in India and sub-Saharan Africa.[22] (→ *See Figure 29.)* In sub-Saharan Africa the market for solar portable lights has grown by 90% annually for the last four years.[23] In India, 3.2 million solar lanterns had been sold or distributed by the end of 2015.[24] In Pakistan, women are putting solar lanterns to productive use to start new businesses and become entrepreneurs.[25]

Solar home systems (SHS) (10–500 W) generally consist of a solar module and a battery, along with a charge control device, so that direct current (DC) power is available during dark and cloudy periods. SHS provide electricity to off-grid households for lighting, radios, television, refrigeration and access to the Internet. This sized system also can be used for non-domestic applications such as telecommunications, water pumping, navigational aids, health clinics, educational facilities and community centres. For higher power demands (e.g., 500–1,000 W), larger solar panels, additional battery capacity and inverters to supply alternating current (AC) power may be needed; the advantages of such systems lie in their ability to power more-sophisticated electric appliances.[26]

As of early 2015, more than 6 million SHS and kits were estimated to be in operation worldwide, with Asia being the largest market by far.[27] (→ *See Figure 30.)* The SHS market in Bangladesh – the largest worldwide – has grown at an astounding average of 60% annually over the past decade, with 60,000 households being connected to a SHS every month.[28] As of early 2015, India, China and Nepal had installed over 2 million systems collectively.[29] In Latin America, some 13,600 SHS (884 kW) were installed in Guyana.[30] The SHS market also has started to boom in Africa, particularly in East Africa. In 2014–2015, M-KOPA sold about 300,000 SHS in Kenya, Uganda and Tanzania, and the company targets a total of 1 million households by end-2016.[31]

Micro- and pico-hydropower stations as small as 1 kW continue to be constructed, providing local communities with affordable electricity. Typically, such hydro systems can be built on existing dams and operate reliably for at least 20 years, requiring minimal maintenance.[32] It is estimated that in 2015, more than 600 micro-hydro plants were providing electricity off-grid to rural areas of Indonesia, while in Nepal, around 1,300 micro-hydro plants and 1,600 pico-hydro systems were in operation for a combined capacity of 27.7 MW.[33]

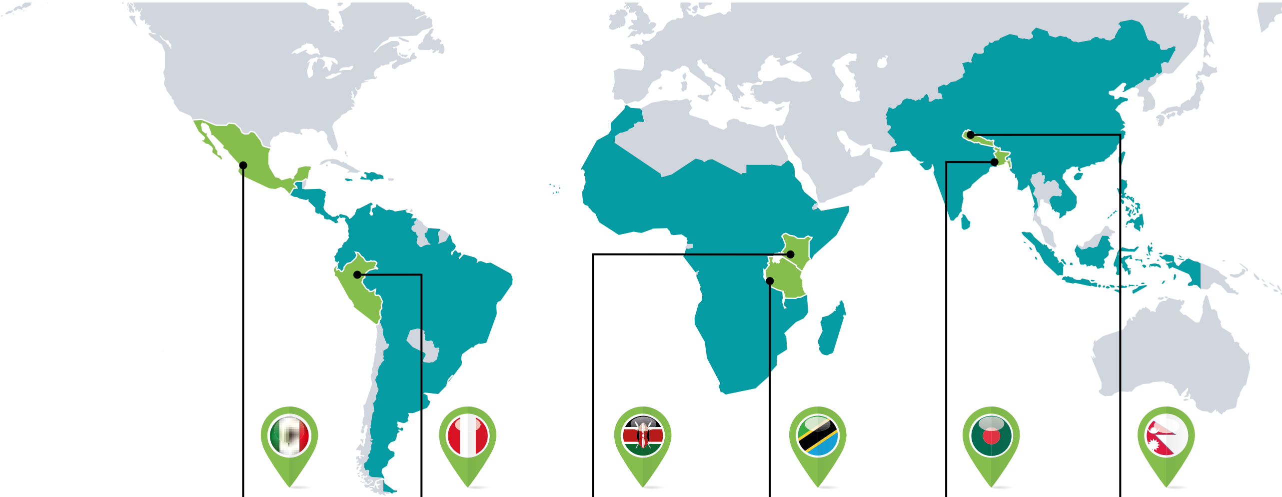
Biogas systems continued to be adopted for electricity supply in 2015, with Asia leading in total installations.[34] (→ *See Figure 31 and Bioenergy section in Market and Industry Trends chapter.)* Vegetable oil, jatropha and animal waste may be used as biogas feedstocks to substitute for diesel fuel in power generation in small-scale applications, while agricultural residues (e.g., rice husks, straw, coconut husks, shell, corn stover, etc.) may be used for commercial-scale power generation.

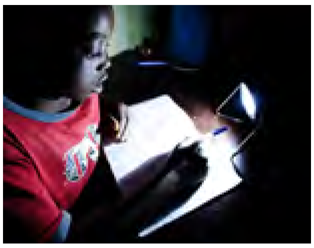
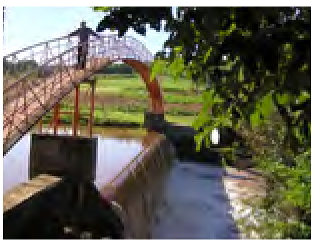
Small-scale wind turbines (≤ 100 kW) often are used to produce electricity for farms, homes and small businesses; off-grid applications include rural electrification, telecommunication and hybrid systems with diesel and solar PV.[35] Total installed capacity reached 343.6 MW in China by the end of 2014, almost 6 MW in

i The DRE Dashboard of the REN21 Renewables Interactive Map (www.ren21.net/dre) presents all DRE market data collected for 2014 and 2015.

DISTRIBUTED RENEWABLE ENERGY

Figure 28. Market Penetration of DRE Systems in Selected Countries

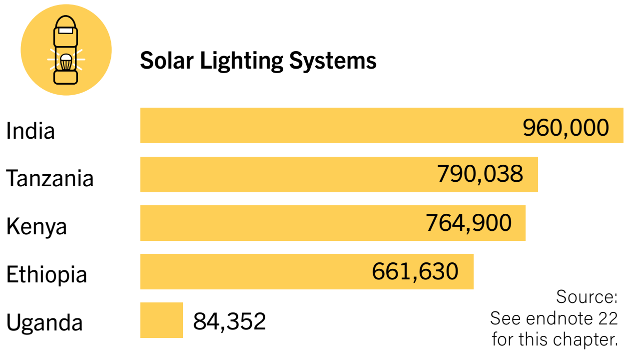


	Mexico	Peru	Kenya	Tanzania	Bangladesh	Nepal
Clean Cook Stoves	10% of households that cook with biomass use clean cook stoves	About 30% of households that cook with biomass use clean cook stoves		At least 1.2 million households use clean cook stoves	At least 1.3 million households use clean cook stoves	More than 15% of households use clean cook stoves
Solar Lighting Systems			15–20% of households use off-grid solar lighting systems	About 530,000 pico-solar products were sold during 2014–2015 under Lighting Global		
Solar Home Systems (SHS)	Residential and commercial small-scale SHS markets represent 80% of total solar PV installed	In 2015, a government contract was awarded for the installation of 500,000 SHS	More than 300,000 SHS installed and 30,000 SHS sold annually		10% of population is served by SHS	
Micro-Hydro Systems						20% of population served by micro-hydropower

Source: See endnote 18 for this chapter.

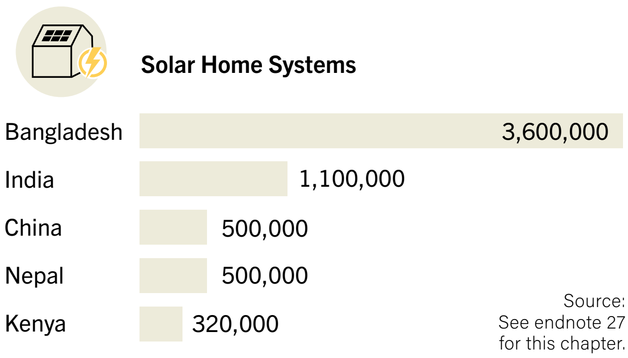
Countries presented were selected based on the availability of reliable data and do not necessarily represent the most developed DRE markets.

Figure 29. Number of Solar Lighting Systems in Top Five Countries, End-2014



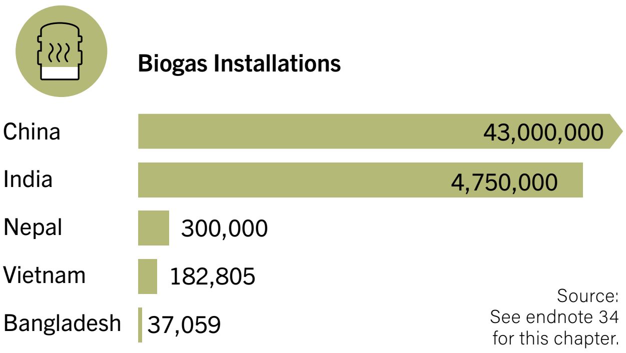
Source: See endnote 22 for this chapter.

Figure 30. Number of Solar Home Systems in Top Five Countries, End-2014



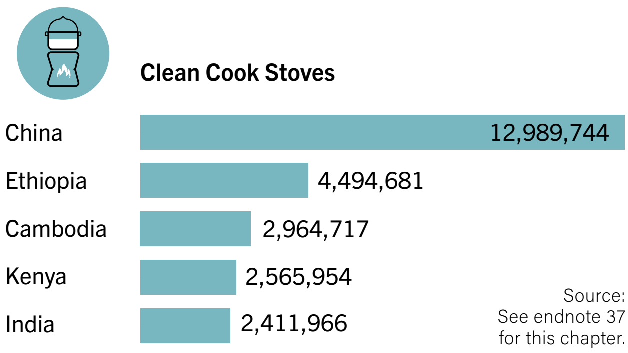
Source: See endnote 27 for this chapter.

Figure 31. Number of Biogas Installations in Top Five Countries, End-2014



Source: See endnote 34 for this chapter.

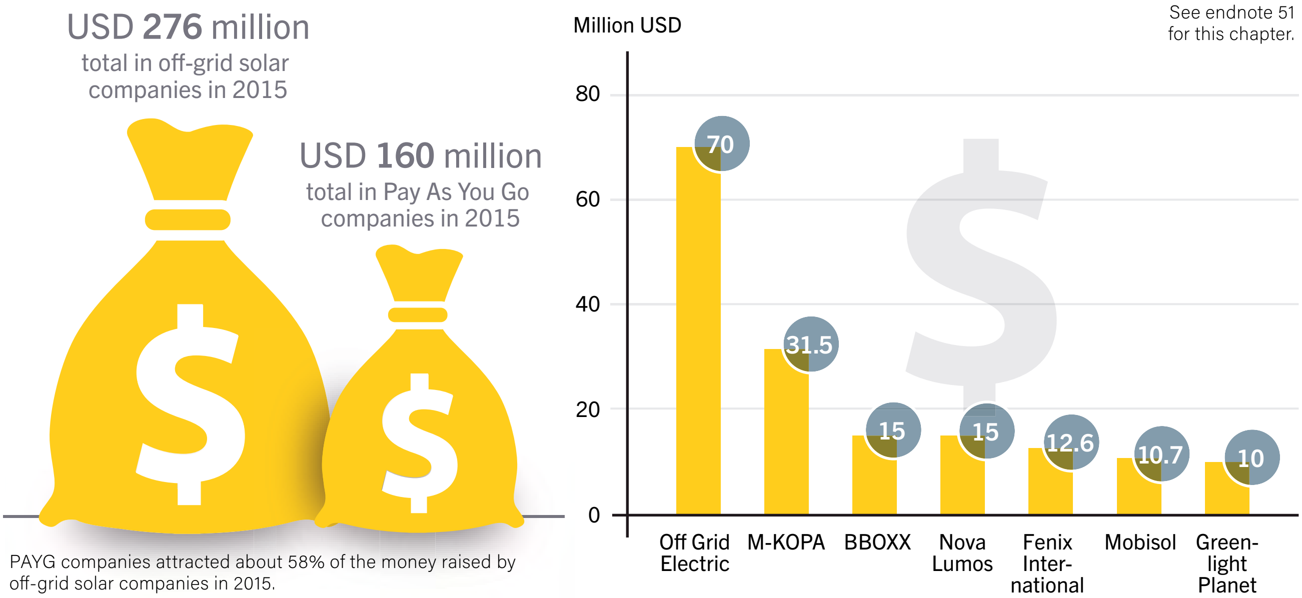
Figure 32. Number of Installed Clean Cook Stoves in Top Five Countries, 2012–2014



Source: See endnote 37 for this chapter.

Figure 33. Capital Raised by Off-Grid Renewable Energy Companies in 2015

Source: See endnote 51 for this chapter.



PAYG companies attracted about 58% of the money raised by off-grid solar companies in 2015.

THE LARGEST MARKET FOR OFF-GRID SOLAR PRODUCTS WAS SUB-SAHARAN AFRICA (1.37 MILLION UNITS), FOLLOWED BY SOUTH ASIA (1.28 MILLION UNITS SOLD)

Argentina (2011), 2.4 MW in India (2012) and 0.7 MW in Morocco (2012).[36]

The use of DRE in the cooking and heating sector also continued to flourish in 2015 due to advances in technology, increased awareness of deforestation and increased government support. At the end of 2014, it was estimated that, worldwide, some 28 million households had adopted clean cook stoves, most of which were in Asia and Africa.[37] *(→ See Figure 32.)* The social enterprise Envirofit International had sold 1 million cook stoves across 45 countries as of November 2015.[38]

In addition, the use of biogas for cooking continued to gain prominence in 2015. For example, Bangladesh installed more than 36,000 biogas cook stoves in 2015 through its domestic biogas programme, to reach a total of 90,000 in operation.[39] In Africa, nearly 60,000 bio-digesters were operating in 2015 across Burkina Faso, Ethiopia, Kenya, Tanzania and Uganda.[40]

The year 2015 also saw the continued expansion of DRE for other applications, such as energy for productive and commercial uses as well as for public services such as street lighting or health care.[41] *(→ See Table 3.)*

It is estimated that at least a few thousand mini-grids were in operation as of 2015, with primary markets in Bangladesh, Cambodia, China, India, Mali and Morocco.[42] In the Indian state of Uttar Pradesh, a 250 kW solar mini-grid powering 60 street lights and 450 buildings (homes, schools and a healthcare facility) was finished in 2015.[43] A number of mini-grid projects also were launched in Africa, including the integrated Kalangala Infrastructure Services Project in Uganda, a single solar-based 1.6 MW mini-grid.[44]

Table 3. Examples of Distributed Renewable Energy Use for Productive Energy Services

ENERGY SERVICE	INCOME-GENERATING VALUE	RENEWABLE ENERGY TECHNOLOGIES
Irrigation	Better crop yields, higher-value crops, greater reliability of irrigation systems, enabling of crop growth during periods when market prices are higher	Wind, solar PV, biomass, micro-hydro
Illumination	Reading, extension of operating hours	Wind, solar PV, biomass, micro-hydro, geothermal
Grinding, milling, husking	Creation of value-added products from raw agricultural commodities	Wind, solar PV, biomass, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value-added products, preservation of products that enables sale in higher-value markets	Biomass, solar heat, geothermal
Expelling	Production of refined oil from seeds	Biomass, solar heat
Transport	Reaching new markets	Biomass (biodiesel)
TV, radio, computer, Internet, telephone	Support of entertainment businesses, education, access to market news, co-ordination with suppliers and distributors	Wind, solar PV, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end-users (e.g., phone charging business)	Wind, solar PV, biomass, micro-hydro, geothermal
Refrigeration	Selling cooled products, increasing the durability of products	Wind, solar PV, biomass, micro-hydro

Source: See endnote 41 for this chapter.

INVESTMENT AND FINANCING

The year 2015 saw closure of a number of financing agreements to support DRE development worldwide. In India, the US Agency for International Development (USAID), the David and Lucile Packard Foundation and the Asian Development Bank agreed to invest or provide financing for USD 41 million in off-grid energy infrastructure, USD 15 million in clean energy "beyond the grid" and USD 6 million for SHS.[45] Also in Asia, the UK-based Impact Investment Fund finalised a USD 2.1 million package to support the activities of Sunlabob Renewable Energy (Lao PDR).[46] The African Development Bank launched its "New Deal for Energy in Africa", targeting 75 million off-grid connections by 2025.[47] In addition, the Millennium Challenge Corporation agreed to provide a USD 46 million grant for off-grid electrification in Benin.[48]

Investments in distributed solar systems continued to grow in 2015. Bloomberg New Energy Finance estimates that roughly USD 276 million was invested in off-grid solar companies (solar lanterns and home systems) during the year, bringing the total since 2010 to more than USD 511 million.[49] Pay As You Go (PAYG) companies received 87% of all such direct investments in 2014 and 2015.[50] For example, Off Grid Electric raised USD 70 million in debt financing in 2015 to kick-start its partnership with the Tanzanian government to provide solar electricity to 1 million households over three years. Other market leaders in off-grid solar – including M-KOPA, Nova Lumos, BBOXX, Mobisol, Fenix International and Greenlight Planet – each raised investments of USD 10 million or more in 2015.[51] (→ *See Figure 33.)* As part of the Power Africa initiative (discussed in the section on programmes, below), the US Overseas Private Investment Corporation (OPIC) also agreed to provide Kenya and Nigeria with more than USD 20 million in loans to promote solar energy in 90,000 households.

Moving away from solar to micro-grids, the company Powerhive (United States) secured a loan of USD 6.8 million to build 100 solar-powered micro-grids (which will power about 20,000 households and businesses), and Enel Green Power (Italy) announced that it will invest USD 12 million for the construction and operation of a 1 MW portfolio of mini-grids in 100 villages.[52] The International Finance Corporation (IFC) launched a USD 5 million programme to develop a market for mini-grids in Tanzania to increase access to energy, while in Mozambique, Energias de Portugal (EDP) secured USD 1.95 million to finance a 160 kW hybrid solar/biomass mini-grid to power 900 households, 33 productive users and 3 community buildings.[53]

To promote the use of clean cook stoves, more than USD 400 million has been mobilised in the past five years.[54] In 2015, under the Enhanced Livelihoods Investment Initiative (ELII) (a three-year, minimum USD 10 million investment initiative), BURN Manufacturing (Kenya) secured an investment of USD 800,000 to bring clean cook stoves to smallholder and plantation workers on tea estates in Kenya and Tanzania.[55] Early in 2016, OPIC committed to finance USD 4 million of Envirofit's activities to expand the use of clean cook stoves.[56] Carbon finance also continued to gain momentum as a commercial pathway to generate revenue to scale up the deployment of clean cook stoves; by mid-2015, 57 projects using carbon credits had distributed 6.8 million clean cook stoves in 27 countries.[57]

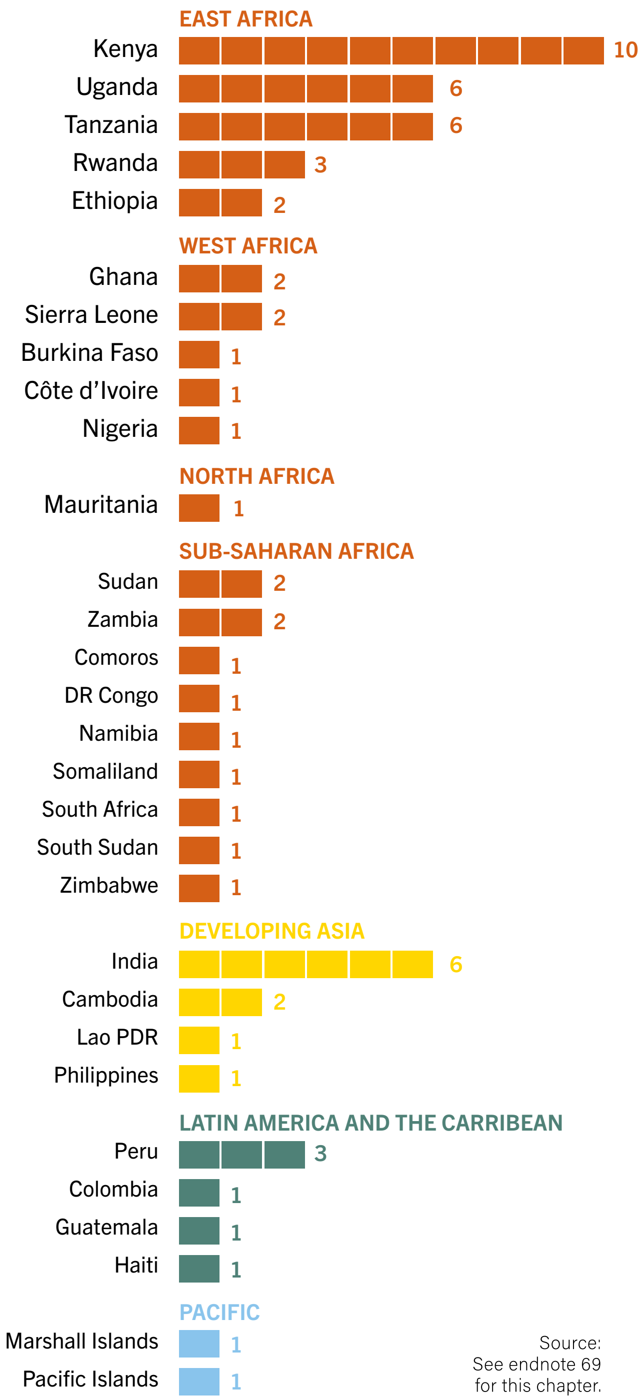
In addition to debt capital and equity financing from investment funds and development banks, crowdfunding continued to increase in popularity in 2015, with many institutions managing crowdfunding campaigns to release new products or expand into new areas.[i] Countries with low rates of energy access, such as Tanzania and Uganda, have implemented a number of micro-grids with funds from companies such as SunFunder.[58] A crowdsourcing model launched in 2015, "Gridmates", is a web-based platform that aims to expand access to DRE globally by crowdfunding[ii].[59] In Nepal, Gham Power teamed up with other local solar companies and Global Nepali Professional Network to launch a new campaign called Rebuild with Sun, which has a crowdsourced Indiegogo campaign that raised USD 150,000 for solar power systems and micro-grids.[60]

In December 2015, an array of new financing and investment initiatives was launched at the COP21 in Paris. For example, the African Renewable Energy Initiative (AREI), which aims to achieve universal energy access on the continent, plans to install 10 GW of additional renewable energy capacity by 2020, and 300 GW by 2030.[61] France will double investments across Africa in renewable energy projects – ranging from wind farms to solar power and hydroelectric projects – to USD 2.2 billion between 2016 and 2020.[62] The International Solar Alliance, with members from 120 countries, aims for large-scale solar PV expansion in the tropics and beyond, and has a goal to raise USD 400 million from membership fees and international agencies.[63] In December 2015, the European Union launched the ElectriFI Initiative, a tool with initial funding of USD 83.5 million that supports investments in clean energy services.[64]

i Crowd-sourced platforms such as SunFunder, Indiegogo, Kickstarter, RocketHub and Pozible have become increasingly accessible in recent years through the Internet.

ii Gridmate users donate hours of energy via PayPal.

Figure 34. Number of Pay As You Go Enterprises by Country/Region



Source: See endnote 69 for this chapter.

INDUSTRY DEVELOPMENT AND BUSINESS MODELS

In addition to enhanced investment and positive market trends, 2015 saw the continued maturation of innovative business models. The use of mobile payment systems and scratch cards continued to flourish, especially as energy companies began to collaborate with the telecommunications industry to design and implement solutions (such as Mobisol, a company that combines solar energy with an affordable payment plan via mobile phone) that result in modern energy services and business opportunities for people in rural areas.[65] In India, SunEdison and Omnigrid Micropower Company are electrifying rural villages by pairing commercial solar customers with telecom companies that need to power their cellular towers. A solar-powered mini-grid is first built to power the phone tower, on which additional mini-grid capacity is developed that can be sold to local villagers.

The year 2015 also saw the launch in East Africa of the "Powerhive" business model, which combines solar PV arrays, battery storage and smart metering systems with mobile telecommunications and payment applications.[66] M-KOPA uses charging outlets for mobile phones as a key part of its business model in Africa. More than 280,000 homes in Kenya, Tanzania and Uganda used M-KOPA's solar systems with mobile payment and charging configurations during the year.[67]

The market for PAYG solar – micro-payment schemes that have become more popular in recent years – continued to grow in 2015.[68] Under PAYG schemes, customers typically pay a small upfront fee for a solar charger kit, a portable system and a control unit that can be used for powering LED lights and charging devices such as mobile phones. They then pay for the energy they need, either in advance or on a regular basis depending on consumption. It is estimated that by the end of 2015, the PAYG model had been commercialised by some 32 companies operating in nearly 30 countries.[69] (→ *See Figure 34.)* It is most prominent in East African countries (Kenya, Uganda and Tanzania) and in India, but it is quickly developing in other regions as well.

Examples of successful PAYG operations include Simpa Networks (India), SolarNow (Uganda), MKOPA (Kenya), Off Grid Electric (Rwanda and Tanzania) and Azuri (spread across sub-Saharan Africa). Greenlight Planet (in East and West Africa, and South Asia), a market leader that has commercialised about 3 million solar lighting systems, launched its PAYG model in early 2015. In Tanzania, Off Grid Electric is installing off-grid solar devices for more than 10,000 households and businesses per month using this model.[70]

Another category of business model focuses on bundled packages that sell not only energy equipment but also integrated services, from simple solar lamps with radios and mobile phones to aspirational products such as televisions. In Nicaragua, Barefoot Power sells a small plug-and-play home system, which can provide lighting services to households, charge a cell phone and power a portable DVD player.[71]

POLICY DEVELOPMENTS

Government policies in developing countries are one of the most important factors for the deployment of DRE technologies.[72] Robust policy frameworks that address a wide range of market issues – from regulations and financing to business support and training – can lead to rapid transformations in energy access.[73]

Policies that support DRE deployment include auctions, dedicated electrification targets, initiatives related to clean renewable cooking, and fiscal and other incentives that focus on specific renewable energy technologies (e.g., exemptions on VAT and import duties). An array of national governments across Africa, Asia and Latin America announced the expansion of existing targets and policies for DRE systems or the creation of new ones during 2015. Kenya, Rwanda and Tanzania all removed VATs on solar products in 2014–2015. India successfully removed excise duties on off-grid solar systems in 2014, and, in 2015, Uttar Pradesh (the Indian state with the most people lacking access to energy) announced plans to waive its VAT on solar energy equipment as well.[74] (→ *See Table 3.)*

In Africa, Rwanda approved its new energy policy, which included a target of reaching 22% of its population with DRE systems by 2017/2018, thereby increasing its off-grid power generation to 22 MW. Even before this policy was approved, Rwanda had partnered with Mobisol and the EU to provide solar PV systems to 49,000 households and 1,000 schools by 2019, representing a total installed capacity of 7.9 MW.[75] Tanzania announced a target of 1 million solar installations by the end of 2017, which is expected to supply solar electricity to 10% of the nation's population and to create over 15,000 solar jobs.[76] Ghana launched a PAYG home solar programme in collaboration with Azuri Technology to provide electricity to 100,000 households.[77] Mali is promoting the sale of 1,500 solar kits with the support of local banks, which will offer special loans to users.[78]

In Asia, the Philippines announced plans to build 150 to 200 micro-hydropower plants to provide electricity to people in remote regions, with a goal of increasing the country's hydro generating capacity by 50 MW.[79] Bangladesh declared its intention to install up to 6 million SHS by 2018 and plans to finance the installation of about 1,550 solar irrigation pumps by 2017.[80] India announced plans to install some 8,960 solar agri-pumps in the state of Maharashtra by the end of 2015; in addition, 500 solar-powered mini-grids are to be installed by the end of 2016 through the state's Smart Power for Rural Development programme, financed by the Rockefeller Foundation.[81] In early 2016, the Indian state of Uttar Pradesh introduced its "Mini-grid Policy" encouraging the development of solar/biogas/biomass mini-grids of up to 500 kW with an array of incentives, including a 30% investment subsidy.[82]

In Latin America and the Caribbean, Guyana announced plans to install 6,000 SHS in its hinterland communities.[83] Under the National Photovoltaic Household Electrification programme, Peru intends to install 12,500 solar PV systems to power 500,000 households to ensure that 95% of its population has access to electricity by the end of 2018.[84]

PROGRAMME DEVELOPMENTS

Beyond policy developments of individual countries, dozens of international actors – including at least 30 programmes and around 20 global networks – were involved in deploying DRE in 2015. ***(→ See Reference Tables R12 and R13.)*** New major DRE programmes were announced in 2015, in addition to the continued operation and expansion of existing ones. Most programmes focused on the provision of electricity, although there was notable activity in the cooking and heating sectors. There also was continued momentum towards partnerships that involved either supranational actors (such as the United Nations) or multiple donor countries or sectors supporting a single programme.

Perhaps the most significant change affecting the global policy environment relates to the United Nations' announcement of new "Sustainable Development Goals" as part of a post-2015 agenda for development practitioners. Goal 7, adopted as one of the 17 key goals, states that universal access to affordable, reliable and modern energy services needs to be ensured by 2030, among other targets.[85] This is in line with the UN's other major energy platform, Sustainable Energy for All (SE4All), which also calls for universal energy access by 2030.[86]

Energising Development (EnDev), an energy access partnership that is financed by six donor countries, continued its operations into 2015.[87] Since 2005, EnDev has helped 14.8 million people obtain sustainable access to modern energy services in Africa, Asia and Latin America by training 37,000 stove builders, craftspeople, vendors and solar PV technicians.[88] In support of the Government of Rwanda's efforts, EnDev offered a subsidy of up to 70% on investments in privately owned and operated mini-grids of up to 100 kW.[89]

The Private Infrastructure Development Group (PIDG) also continued to expand its reach. PIDG mobilises private sector investment to assist developing countries in combating poverty, including through the provision of infrastructure that is vital to boosting economic growth.[90] From 2010 to 2015, it supported over 1,000 micro- and small-scale enterprises, 900 of which are actively delivering products and services to their communities. PIDG created approximately 3,000 jobs; reached over 4 million beneficiaries with energy products and services, such as improved cook stoves, briquettes, solar phone charging and solar lighting; and changed how small enterprises do business through enterprise-to-enterprise linkages, marketing and promotional events, business planning, product improvement and standardisation.[91]

In 2015, the United States continued its commitments to DRE systems through a variety of programmes and agencies. Two years after its original launch, Power Africa – a partnership between the US government, African governments, multilateral and bilateral partners, and the private sector – announced expanded commitments to increase generating capacity and electricity access across sub-Saharan Africa. OPIC mobilised an additional USD 1.4 billion in private capital directed at energy access projects in Africa and announced an additional USD 1 billion commitment through 2018.[92] In addition, USAID placed more than 25 advisors across sub-Saharan Africa to advance power sector transactions and provide technical assistance to improve the enabling environment for private sector investment.[93]

Electricity was not the only area that saw activity. The Global Alliance for Clean Cookstoves (GACC) had provided improved stoves to an estimated 24 million households – most of which are fuelled by renewable energy (although some by liquefied petroleum gas) – by the time it celebrated its five-year anniversary

in 2015. In 2014, GACC projected that it would reach 63 million households by 2016.[94] Its partner network grew from 19 in 2010 to more than 1,300 in 2015.[95] Through GACC's activities, by 2015, 28 countries were actively engaged in the development of International Organization for Standardization-approved standards for clean cook stoves; 16 GACC-supported cook stoves and fuel testing centres were operating in 14 countries around the world; and over 300 stoves had been featured in GACC's Clean Cooking Catalogue.[96] In addition, since the GACC's founding in 2010, 19 new investors have deployed more than USD 60 million, and USD 265 million in carbon finance has been directed to the sector.[97]

The year also saw the creation of entirely new multilateral programmes and networks. In late 2015, the United Kingdom announced a new multilateral programme called Energy Africa in an effort to accelerate the expansion of household solar energy throughout the continent.[98] The Energy Africa campaign, a multi-donor effort to be managed by the UK's Department for International Development, seeks to overcome financial hurdles and market failures that are preventing firms from raising capital by testing new approaches and reaching poor and rural customers. It aims to overcome the policy and regulatory barriers to household energy access, for example by drawing African countries into the compact to accelerate clean energy access.[99]

In September 2015, the international Stiftung Solarenergie (Germany) started the Solar Entrepreneur Network for Decentralized Energy Access (Sendea), which seeks to enable solar entrepreneurs to create their own companies. Operating in East Africa and Asia, Sendea intends to establish solar villages for social impact, awareness creation and training; to implement a revolving fund to finance products for end-users; and to train solar technicians in technology, management and finance.[100]

THE PATH FORWARD

The demand for DRE systems remains a matter of prime social and economic significance for billions of people around the world. In many developing countries, political instability and corruption make it difficult to access financing for DRE projects, slowing advances despite positive technology developments.[101] However, when backed by strong financing and investment, coupled with robust policy frameworks, DRE systems have proven to be both a reliable and affordable means for achieving access to modern energy services. DRE systems will only continue to grow more reliable and affordable as technological improvements and innovative business models enable them to spread to new markets. DRE systems stand at the centre of global efforts to induce a paradigm shift towards poverty eradication, green economies and, ultimately, sustainable development.

04

Citizens' involvement beyond the community's border

Vermont's first community-owned solar facility in **Putney** serves 49 customers across nine counties. The customers not only consume the renewable electricity generated by the solar PV plant, but also financially participate in the utility and collectively own the facility. The project – a joint effort with the solar developer – enables citizens without suitable roofs or spaces to engage in bringing solar energy to their community. Working together with their local utility, this community demonstrated the potential for successful partnerships with the private sector to bring renewable energy to the local level.

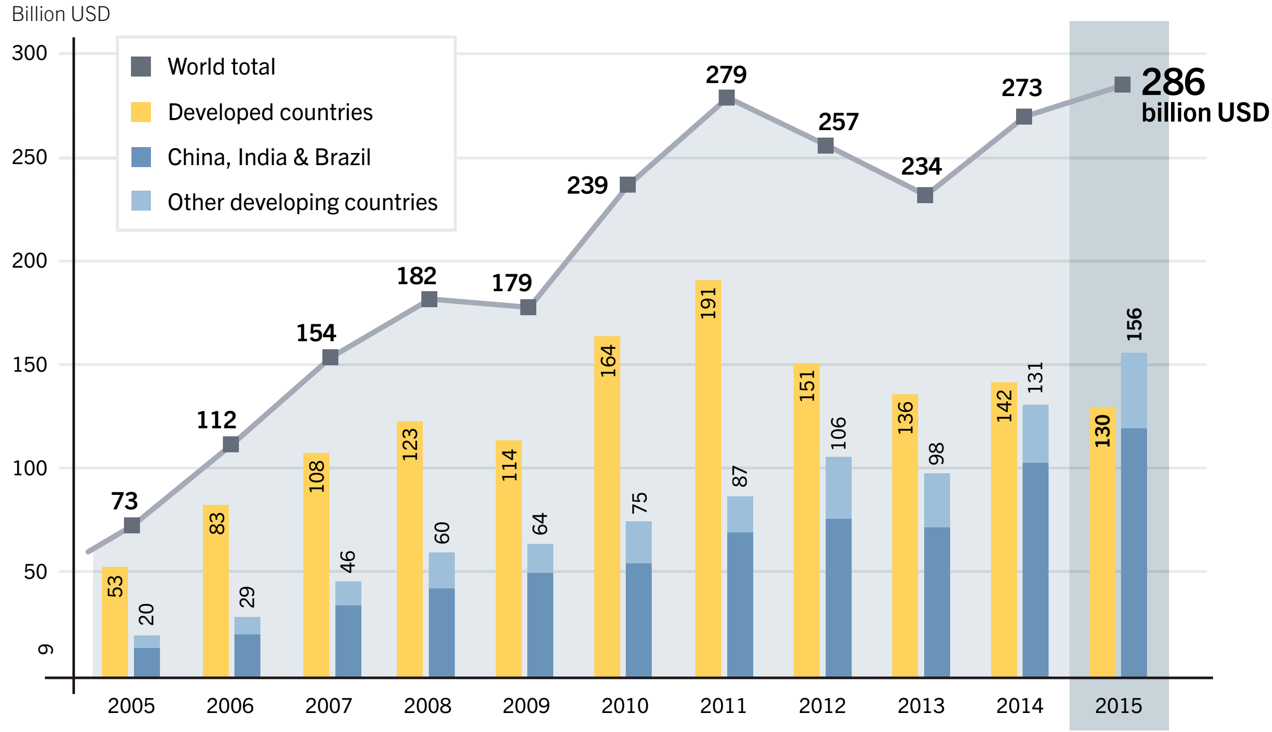
Vermont, United States | Created: 2013 | Participating utility customers: 49 | Capacity: 114kW solar PV

04 INVESTMENT FLOWS

Global new investment in renewable power and fuels (not including hydropower projects >50 MW) was USD 285.9 billion in 2015, as estimated by Bloomberg New Energy Finance (BNEF)[i]. This represents a rise of 5% compared to the previous year and exceeds the previous record of USD 278.5 billion achieved in 2011[ii]. Investment in renewable power and fuels has exceeded USD 200 billion per year for the past six years. (→ *See Figure 35.)* Including investments in hydropower projects larger than 50 MW, total new investment in renewable power and fuels was at least USD 328.9 billion in 2015[iii,1] Note that these estimates do not include investment in renewable heating and cooling technologies. ***(→ See Reference Tables R14.)***

In 2015, global investment in new renewable power capacity (excluding hydropower >50 MW), at USD 265.8 billion[iv], was more than double the USD 130 billion allocated to new coal- and natural gas-fired generation capacity. This represents the largest difference in favour of renewables to date. If hydropower projects >50 MW are considered, the spread between renewables and fossil fuel investment in new power capacity is even greater.

Figure 35. Global New Investment in Renewable Power and Fuels, Developed, Emerging and Developing Countries, 2005–2015



Source: BNEF, see footnotes i and iii for this section.

i This chapter is derived from UNEP's *Global Trends in Renewable Energy Investment 2016* (Frankfurt: 2016), the sister publication to the GSR, prepared by the Frankfurt School–UNEP Collaborating Centre for Climate & Sustainable Energy Finance (FS-UNEP) in co-operation with BNEF. Data are based on the output of the desktop database of BNEF, unless otherwise noted, and reflect the timing of investment decisions. The following renewable energy projects are included: all biomass and waste-to-energy, geothermal and wind generation projects of more than 1 MW; all hydropower projects of between 1 and 50 MW; all solar power projects, with those less than 1 MW estimated separately and referred to as small-scale projects or small distributed capacity; all ocean energy projects; and all biofuel projects with an annual production capacity of 1 million litres or more. For more information, please refer to the FS-UNEP/BNEF Global Trends report. Where totals do not add up, the difference is due to rounding.

ii Note that declining costs of some renewable energy technologies (particularly solar PV and wind power) have a decremental impact on total investment (all else being equal). Thus, growth in investment (monetary) does not reflect actual growth in installed renewable power capacity.

iii Investment in large hydropower (>50 MW) is not included in the overall total for investment in renewable energy. BNEF tracks only hydropower projects of between 1 MW and 50 MW, but it does make estimates for hydro >50 MW.

iv This number is for renewable power asset finance and small-scale projects. It differs from the overall total for renewable energy investment (USD 285.9 billion) provided elsewhere in this chapter because it excludes biofuels and some types of noncapacity investment, such as equity-raising on public markets and development R&D.

Asset finance of utility-scale[i] projects such as wind farms and solar parks dominated investment in 2015 at USD 199 billion, or 6% above 2014. Small-scale solar PV installations accounted for the remainder, at USD 67.4 billion worldwide. Distributed solar PV systems are gaining ground in many developing countries as immediate and affordable alternatives to centralised, grid-based power systems.

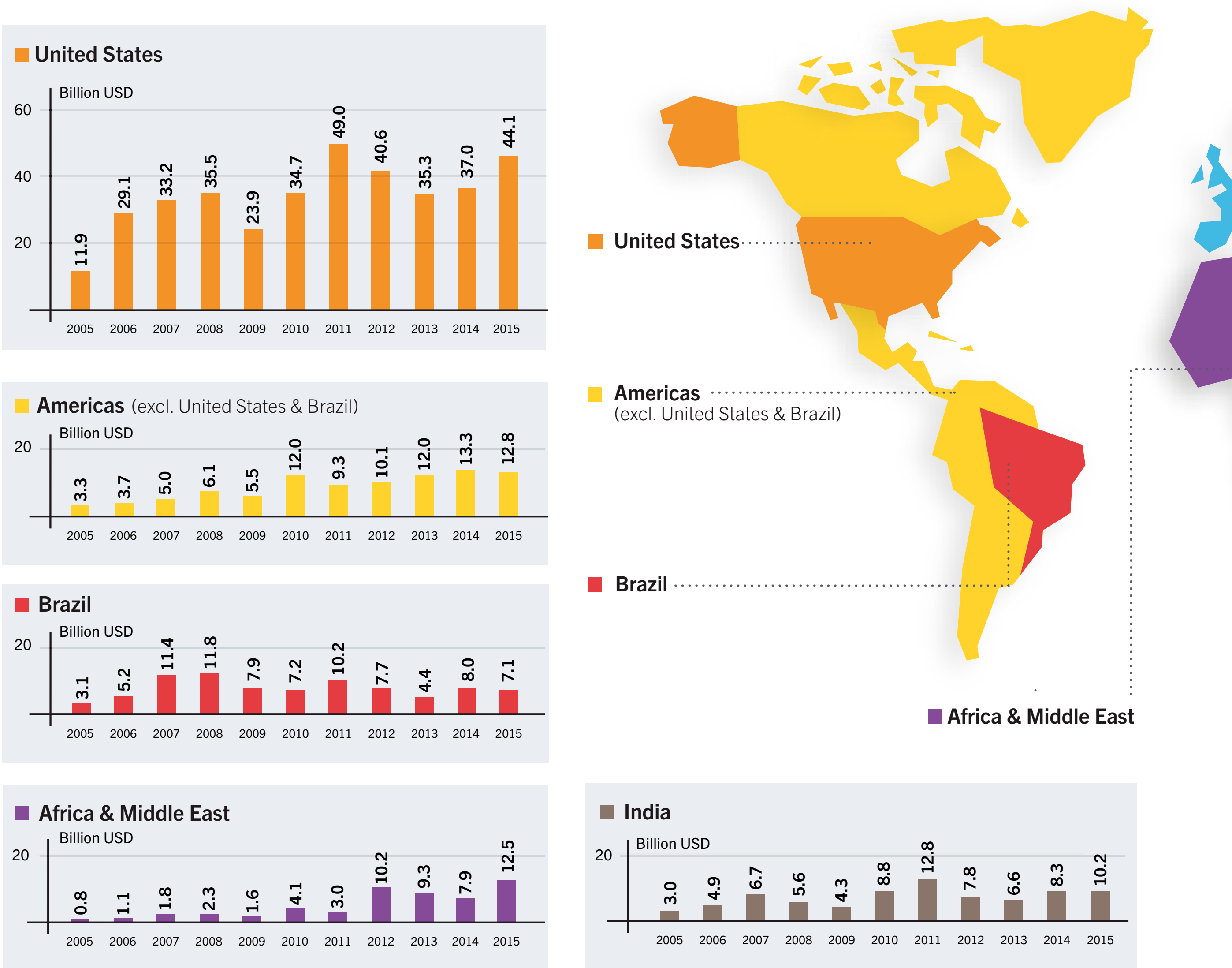
For the first time in history, total investment in renewables (excluding large hydro) in developing countries exceeded that in developed economies. The developing world, including China, India and Brazil, committed a total of USD 156 billion, up 19% compared to 2014. China played a dominant role in this turnaround, increasing investment by 17% to USD 102.9 billion, or 36% of the global total. In 2015, renewable energy investment also increased significantly in India, South Africa, Mexico and Chile. Other developing countries investing more than USD 500 million in 2015 included Morocco, Uruguay, the Philippines, Pakistan and Honduras.

By contrast, investment in developed countries as a group declined by 8% in 2015, to USD 130 billion. The most significant decrease in investment was seen in Europe, down 21% to USD 48.8 billion, despite its record year financing offshore wind (USD 17 billion, up 11% from 2014). In the United States, investment (dominated largely by solar power) increased by 19%, the country's largest increase since 2011.

Investment in renewable capacity has been weighted increasingly towards wind and solar power. In 2015, investment in solar power capacity was up 12% to USD 148.3 billion, while investment in wind power capacity advanced 9% to USD 107 billion. Investment in other renewable capacity declined in the same period: biomass and waste-to-energy dropped 46% to USD 5.2 billion, small-scale hydropower dropped 26% to USD 3.5 billion, geothermal slipped 25% to USD 1.8 billion and biofuels dropped 67% to USD 669 million.

i "Utility-scale" in this chapter refers to wind farms, solar parks and other renewable power installations of 1 MW or more in size, and to biofuel plants of more than 1 million litres' capacity.

Figure 36. Global New Investment in Renewable Power and Fuels, by Country/Region, 2005–2015



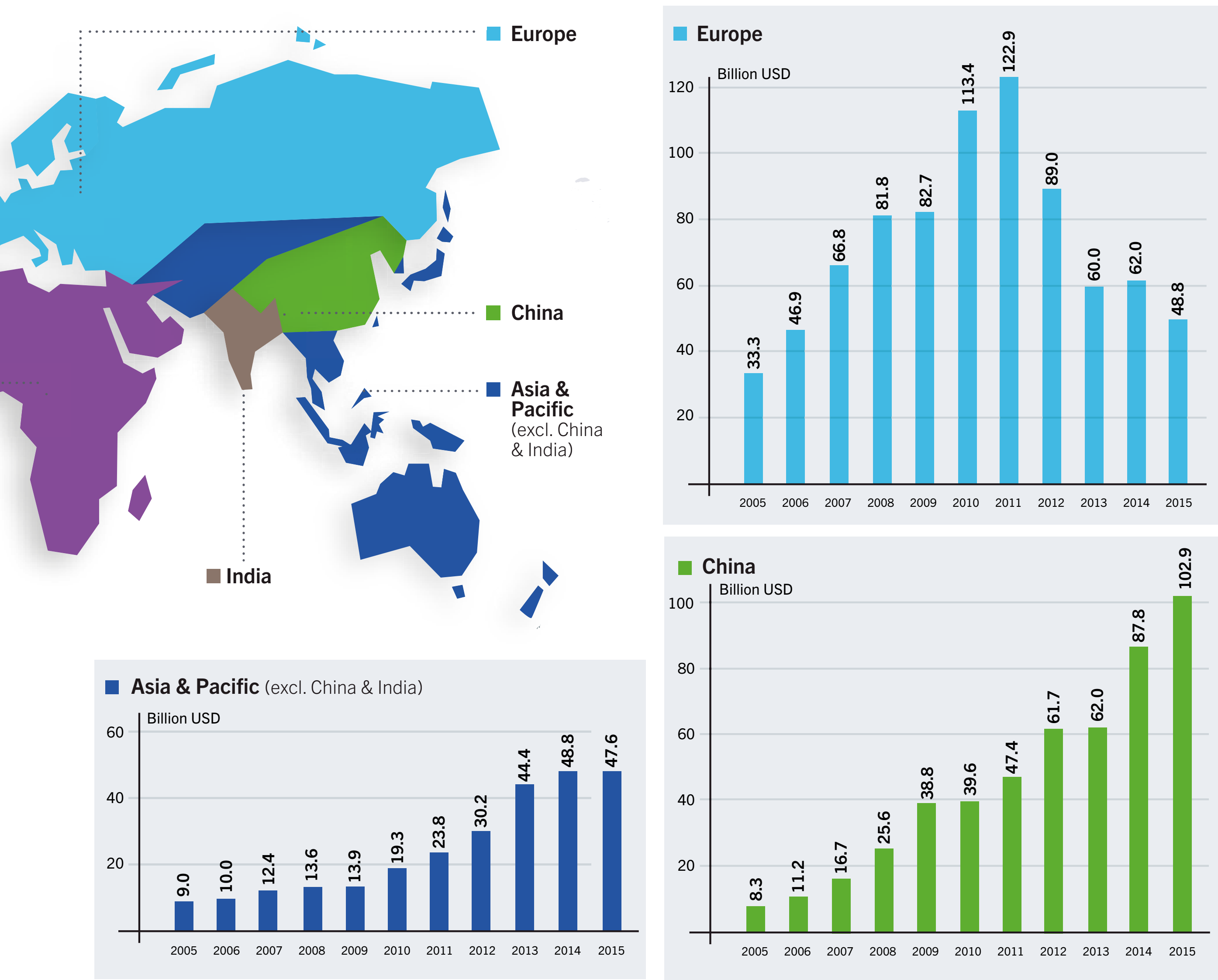
INVESTMENT BY ECONOMY

The shift in renewable energy investment from developed to developing and emerging economies is not surprising, as the latter have a rapidly rising electricity demand and need the most additional power generation capacity. Although the developed world has provided substantial financial support for the development and deployment of renewable energy technologies over the past three decades, such support has declined in many countries in recent years. At the same time, the falling costs of renewable energy technologies, mainly solar and wind power, have made projects viable in resource-rich developing and emerging economies, as well as in more locations in developed countries.

Trends in renewable energy investment varied by region in 2015, with increased investments in China, India, Africa and the Middle East, and the United States, and decreased investments in Canada and Europe. (→ *See Figure 36.)* The top 10 national investors consisted of six developing countries (four of which are BRICS[i] countries) and four developed countries. China led with more than double the investment of the next largest investor, the United States, followed by Japan, the United Kingdom and India. The next five were Germany, Brazil, South Africa, Mexico and Chile. While China, the United States, Japan and the United Kingdom maintained their positions relative to 2014, India moved up to displace Germany, which saw a sharp drop in investment. South Africa, which had slipped off the top 10 list in 2014, ranked eighth in 2015, and Mexico and Chile ranked among the top 10 for the first time in 2015.

China witnessed the strongest dollar increase (up 17%) and accounted for USD 102.9 billion (including R&D) of new investment in renewable energy. Most of this total (USD 95.7 billion) was in asset finance, with USD 5.5 billion invested in small-scale projects. Wind power led investments in utility-scale projects, attracting USD 47.6 billion of asset finance, compared with USD 44.3 billion

i The five BRICS countries are Brazil, the Russian Federation, India, China and South Africa.



Source: BNEF

Note: Data include government and corporate R&D.

for solar power. Offshore wind had a breakthrough year in China, with nine projects financed for an estimated USD 5.6 billion. The country also invested significant sums in large-scale hydropower[i], commissioning 16 GW of new projects during the year, a large portion of which was projects >50 MW.[2] (→ *See Hydropower section in Market and Industry Trends chapter.)*

The United States, which invested USD 44.1 billion (including R&D), continued to be the largest individual investor among developed economies. The increase was due primarily to utility-scale and rooftop solar PV. In terms of finance types, venture capital and private equity finance for renewables increased to USD 2.2 billion. Asset finance of utility-scale renewable energy projects rose 31% to USD 24.4 billion – solar increased 37% (USD 13 billion) and wind was up 24% (USD 10.6 billion). The rebound in wind asset finance and utility-scale solar PV investment in 2015 was driven largely by the on-off saga of national investment and production tax credits during the previous year.

Japan's investment of USD 36.2 billion (excluding R&D) remained relatively unchanged from 2014. Approximately 88% of total investment went to small-scale solar PV projects, driven by the country's generous solar feed-in tariff. Japan accounted for most of the investment in the Pacific, excluding China and India, where investment was USD 47.6 billion, slightly below the 2014 total.

The United Kingdom saw a considerable rise (25%) in renewable energy investments – particularly for solar PV and wind power (both offshore and onshore) – to USD 22.2 billion (excluding R&D). Wind power was again the country's best-performing sector, with USD 10.5 billion for offshore projects. This compared with USD 1.8 billion invested in small-scale solar PV.

Investment in India increased for the second consecutive year, for a total of USD 10.2 billion in 2015. India's increase was due to a jump in utility-scale solar power financing, which reached USD 4.6 billion, up 75% on the previous year, a direct result of the new Indian government's increased focus on renewable energy. USD 4.1 billion of asset finance was invested in wind power, an increase of 17% compared to 2014.

Apart from China, Japan and India, Thailand was the only other country in Asia to reach USD 1 billion in asset finance for renewables. Thailand was followed by the Philippines (USD 798 million), Pakistan (USD 723 million), the Republic of Korea (USD 395 million), Vietnam (USD 248 million) and Kazakhstan (USD 101 million).

Germany, which ranked sixth globally for total investment, saw overall financing fall by 46%, to USD 8.5 billion. This decline was a result of the changing policy framework. (→ *See Policy Landscape chapter.)* The total would have been even lower if not for investment in two large offshore wind projects, totalling USD 3.4 billion. Once Europe's engine of growth for small-scale distributed solar PV, Germany saw its investment in this sector contract by 57% in 2015, to USD 1.3 billion. Europe in general saw investment fall 21% to its lowest total since 2006.

Brazil invested USD 7.1 billion in renewables, with wind power asset finance up 46% over 2014 to USD 5.7 billion; solar power projects received USD 657 million.

Elsewhere in the Americas (beyond Brazil and the United States), investment fell 3% to USD 12.8 billion. However, some countries saw significant growth. Mexico and Chile saw asset finance increase to USD 3.9 billion (more than doubling) and USD 3.4 billion (up 141%), respectively, and ranked ninth and tenth globally for total investment. Chile led the region for solar power by a large margin, investing USD 2.2 billion in the sector. Other Latin American countries with significant renewable energy investment were Uruguay (USD 1.1 billion), Honduras (USD 567 million), Jamaica (USD 167 million), Peru (USD 155 million) and the Dominican Republic (USD 129 million).

The Middle East and Africa saw investment increase from less than USD 1 billion in 2004 to a record USD 12.5 billion in 2015, thanks partly to South Africa's successful Renewable Energy Independent Power Producer Programme (REIPPP). In South Africa, investment rebounded to USD 4.5 billion, up from USD 1 billion in 2014. Much of the investment in renewable energy occurred in the first quarter of 2015, which resulted from a delay in the financial close of the remaining projects from the Round 3 auction that occurred in 2014. The second largest investor in Africa was Morocco (USD 2 billion), followed by Kenya (USD 357 million), Uganda (USD 134 million) and Ethiopia (USD 100 million).

i The Chinese government estimates that China invested USD 12 billion (CNY 78 billion) in 2015, down 17% from 2014, including hydropower facilities of all sizes, per National Energy Agency of China, National Electric Power Industry Statistics, sourced from the National Energy Board, 15 January 2016, http://www.nea.gov.cn/2016-01/15/c_135013789.htm; and National Energy Administration of China, National Electric Power Industry Statistics, sourced from the National Energy Board, 16 January 2015, http://www.nea.gov.cn/2015-01/16/c_133923477.htm.

INVESTMENT BY TECHNOLOGY

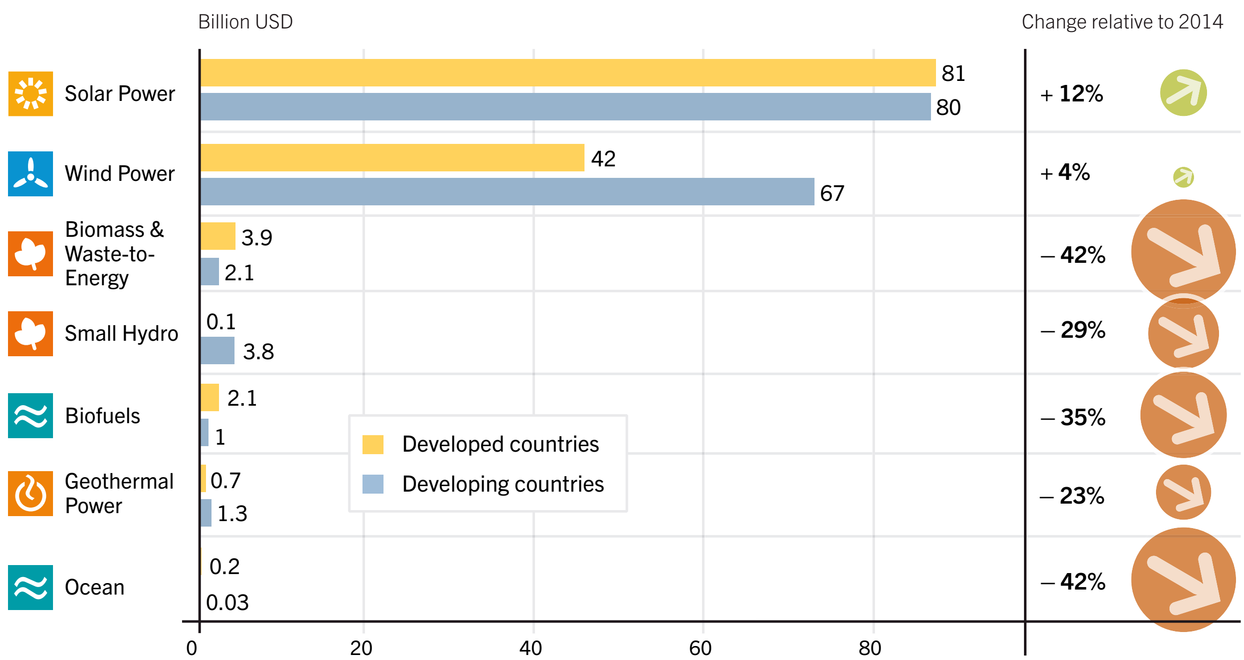
Solar power was again the leading sector by far in terms of new investment committed during 2015, accounting for USD 161 billion, or more than 56% of total new investment in renewable power and fuels (not including hydropower >50 MW). Investment in solar power was up 12% over 2014. Wind power followed with USD 109.6 billion, or 38.3% of the total (up 4%). The remaining 5.7% was made up of biomass and waste-to-energy[i] (USD 6 billion), biofuels (USD 3.1 billion), small-scale hydropower (<50 MW) (USD 3.9 billion), geothermal power (USD 2 billion) and ocean energy (USD 215 million). All technologies except solar and wind power saw investment decline relative to 2014: geothermal was down by 23%, ocean by 42%, biofuels by 35%, biomass and waste-to-energy by 42% and small-scale hydropower by 29%. (→ *See Figure 37.)*

Until 2014, developed countries (namely Germany, Italy and Japan) dominated investment in small-scale solar power. In 2015, China, India, Chile, South Africa and other developing and emerging countries ramped up deployment of both utility- and small-scale investment in solar PV, and to some extent concentrating solar power (CSP), closing the gap to less than USD 1 billion; solar power investment in developed countries was USD 80.8 billion, compared to USD 80.2 billion in developing and emerging economies.

A similar trend has been seen with wind power. In 2015, developing and emerging countries invested USD 67.4 billion in wind power, while developed countries invested only USD 42.2 billion.

Although BNEF does not track detailed statistics for large-scale hydropower (projects greater than 50 MW in size), this was the third most important sector for renewable energy investment in 2015 (after solar and wind power). Translating hydropower capacity additions into asset finance dollars per year is not straightforward because the average project takes four years to build. However, BNEF estimates that asset financing for large-scale hydropower projects reaching financial go-ahead in 2015 totalled at least USD 43 billion.

Figure 37. Global New Investment in Renewable Energy by Technology, Developed and Developing Countries, 2015



Source: BNEF

i Includes all waste-to-power technologies, but not waste-to-gas.

INVESTMENT BY TYPE

Global research and development[i] (R&D) spending was almost unchanged in 2015, at USD 9.1 billion.

Government R&D was down 3% relative to 2014, to USD 4.4 billion, and corporate R&D was up by 3% (to USD 4.7 billion). China's level of R&D spending challenged Europe's for the first time; spending in Europe fell 8% compared to 2014 while that in China rose 4%, with each investing USD 2.8 billion. In third place, the United States spent USD 1.5 billion, a modest increase of 1%.

Total R&D spending on solar power rose 1% to USD 4.5 billion. For the fifth year in a row,, R&D spending for solar power equated that for all other sectors combined, and it was approximately 2.5 times that of the next closest technology, wind power. Investments in wind power were unchanged over 2014, at USD 1.8 billion. Investment in biofuels was down 3%, to USD 1.6 billion.

Asset finance of utility-scale projects accounted for the vast majority of total investment in renewable energy. It totalled USD 199 billion during the year, an increase of 6% relative to 2014.

Small-scale distributed capacity investment, largely rooftop solar PV, was USD 67.4 billion. Falling costs and innovative financing mechanisms are putting small-scale distributed solar PV within reach of more people in developed, emerging and developing economies.

Public market investment in renewable energy companies and funds fell 21%, to USD 12.8 billion. However, it remained three times higher than the total in 2012. Funds raised by initial public offerings (IPOs) fell by 35% relative to 2014, to USD 2.3 billion. However, secondary issues and private investment in public equity (PIPE) rose by 4% to a new record of USD 6.7 billion.

Investment via public markets in "yield companies" (yieldcos) started to emerge in 2013, with investors seeing this model as providing steady dividend income at relatively low risk, at a time of record-low interest rates. The noteworthy overall figure for public markets investment in 2015 (USD 12.8 billion) hides the fact that the year saw disproportionate equity-raising by renewable energy companies, with North American yieldcos and their European equivalents accounting for nearly half of the total. The yieldco model came under closer examination in the second half of 2015 in response to a sudden reassessment by investors of whether yieldcos were really growth stocks, and to a resulting sell-off.

Venture capital and private equity investment (VC/PE) in renewable energy increased by 34% to USD 3.4 billion in 2015, the second consecutive year of growth. Investment in early-stage venture capital jumped 60%, although from a very low base. There was a more modest 28% increase in late-stage venture capital, while private equity made solid gains of 32%. As in previous years, solar power companies led the field with USD 2.4 billion in venture capital and private equity investment, representing an increase of 58% compared to 2014. Due in part to the falling costs of solar PV, venture investors have begun to shift their focus away from improving the performance of the hardware, to making solar technologies available to new markets and previously unreachable sectors of society – for example, the development of mobile-enabled solar systems for off-grid communities in developing countries. (→ *See Distributed Renewable Energy chapter.)*

Acquisition activity – which is not counted as part of the USD 285.9 billion in new investment – jumped to a record USD 93.9 billion, up 7% compared to 2014. The scale of this total is a sign of how large the renewable energy sector has grown in terms of both annual sales and installed capacity. These figures include corporate mergers and acquisitions (M&A); power infrastructure acquisitions and debt refinancing; private equity buy-outs; and the purchase of stakes in specialist companies by trade buyers.

Corporate M&A – the buying and selling of companies – increased by 63% to USD 19.2 billion. This increase represents a substantial change from 2014, when corporate M&A fell 35%. Similar to past years, the largest category of acquisition activity was asset purchases and refinancing, which totalled USD 69.3 billion in 2015, down 3% from the all-time high reached in 2014. Public market investor exits were almost unchanged, at USD 1.8 billion, but private equity buy-outs increased some 36% to USD 3.5 billion. As usual, acquisition activity was dominated by wind power (at USD 57.6 billion) and solar power (at USD 29.4 billion).

i See Sidebar 5 in GSR 2013, "Investment Types and Terminology", for an explanation of investment terms used in this section.

SOURCES OF INVESTMENT

Debt makes up the majority of the investment going into many utility-scale renewable energy projects, either at the project level in the form of non-recourse loans, bonds or leasing; or at the corporate level in the form of borrowings by the utility or project developer. In 2015, commercial banks provided most of the project-level debt for wind farms and solar parks in established markets such as Europe, North America, China and India.

Bonds have been an alternative to conventional bank project finance for many years. Issuance of green bonds hit a new record of USD 48 billion in 2015, up 28% compared to 2014. A significant proportion of the green bond issuance came from development banks, commercial banks and utilities. Project bonds accounted for a relatively small fraction of the world market for green bonds.

Apart from commercial banks and bond issues, the other major source of debt for renewable power assets is borrowing directly from the world's array of national and multilateral development banks. Aggregate figures for development bank lending to renewables in 2015 were not yet available at the time of publication. Among those that released preliminary figures in early 2016, the European Investment Bank lent USD 3.4 billion to renewable energy in 2015, down 42% from 2014; Germany's KfW indicated that its renewable energy programme provided EUR 4.5 billion (USD 4.9 billion), up from EUR 4.1 billion (USD 4.48 billion); and Brazil's BNDES provided USD 1.8 billion to wind power projects, with lending up by 85% in 2015.

Utilities continued to be an important source of equity for renewable energy projects at the development or pre-construction stage. Institutional investors such as insurance companies or pension funds tend to be more risk-averse and therefore interested in the predictable cash flows of an operating-stage project. In Europe, direct investment by institutional investors totalled USD 1.1 billion in 2014.

The year 2015 also saw several new approaches for channelling debt and equity financing into renewable power projects worldwide. This involved the establishment of platforms through which institutional investors could have exposure to the equity of clean energy assets but with the reassurance of having a technically experienced bank involved alongside them. These are akin to unquoted funds, except that the manager is an investment bank that invests its own capital, rather than a conventional private equity or infrastructure fund manager.

EARLY INVESTMENT TRENDS IN 2016

Global investment in renewable energy was USD 52.7 billion in the first quarter (Q1) of 2016, down 12.5% from Q1 in 2015 (USD 60.2 billion). There were substantial wind power investments in the United Kingdom and Norway; the decrease was due largely to a decline in investment activity in China (USD 11.8 billion in Q1), down 50% from Q4 and 37% lower than in Q1 2015. The reason for this drop in China was a pause in investment following a rush by wind and solar power developers in late 2015 to qualify for electricity tariffs that were set to expire.

Investments in Europe were strong in early 2016, bucking the trend of recent years. This was thanks largely to three billion-dollar wind power projects that boosted Q1 investment to USD 17 billion, up by 23% compared to Q4 in 2015 and up by no less than 70% compared to Q1 in 2015. Investment in the United States rose 9% compared to the first quarter of 2015 (at USD 9.4 billion), and in India it was up 6% (USD 1.9 billion). Large projects also were financed in Africa in early 2016: the 300 MW Grand Para solar PV installation in Djibouti and the 140 MW Olkaria V geothermal plant in Kenya.

Brazil (down 27% compared to Q1 in 2015 to USD 1 billion) and Japan (down 19% to USD 6.8 billion) also saw declines in early 2016. South Africa recorded almost no deals in Q1 2016, compared to USD 3.7 billion in the same quarter of 2015, due to the timing of its auction rounds. Chile, Mexico and Uruguay also had quiet starts to 2016.

Asset finance of utility-scale renewable energy projects amounted to USD 34.3 billion worldwide in Q1 2016, down 16% compared to the same quarter in 2015. Small-scale solar projects (< 1MW) represented the second-biggest category of spending, worth an estimated USD 17.4 billion in Q1, up 3% compared to Q1 in 2015.

05

Renewable energy benefits schools

As part of an Indonesia-wide Greenpeace programme, the indigenous community of **Ciptegelar village** has electrified its school building, benefiting the 150 students. Eight solar home systems were installed, providing residential lighting to the entire community, helping to modernise its schools and education system.

Indonesia, Ciptegelar School | Created: 2013 | Solar home systems | 800 W of solar PV capacity

05 POLICY LANDSCAPE

Nearly all countries worldwide now have renewable energy support policies in place. As of year-end 2015, renewable energy policies could be found in 146 countries, up slightly from the 145 countries reported in the *Renewables 2015 Global Status Report* (GSR 2015)[i]. Countries around the world continue to develop new policy measures for renewable energy that remove barriers, attract investment, drive deployment, foster innovation and encourage greater flexibility in energy infrastructure.[1] (→ *See Table 4.)*

In 2015, renewable energy technologies were highlighted as a means to mitigate emissions and to adapt to the impacts of climate change in the lead-up to the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP21) in Paris. Building on the goals of the Sustainable Energy for All (SE4All) initiative, the new Sustainable Development Goals adopted in 2015 include renewable energy and energy efficiency as important pillars of the global commitment to end poverty, protect the environment and ensure prosperity for all.[2]

Policy makers at the national and sub-national levels continued to grapple with themes that have shaped renewable energy policy discussions in recent years, including revising existing mechanisms to keep pace with changing market conditions, creating new policies that respond to the technical and non-technical challenges of higher renewable energy shares, and expanding renewable energy in the heating, cooling and transport sectors. Renewable energy for power generation continued to receive the majority of attention from policy makers in 2015.

Some notable regional policy trends – explored in more detail in this chapter – include:

- **Africa:** Several African countries increased their renewable energy targets in 2015; in many African countries, the targeted shares for renewables now rank among the highest in the world.

  The majority of the 15 ECOWAS member countries completed their National Renewable Energy Action Plans.

  South Africa garnered another impressive showing in the latest round of its renewable tendering programme and began using the same model to support biofuels.

- **Asia and the Pacific:** China and India both increased their renewable energy targets.

  Indian states were particularly active in expanding policies to promote renewable power deployment through the adoption of new net metering policies and the use of tendering.

  Multiple Pacific Island nations outlined ambitious visions for renewable energy deployment by introducing 100% renewable energy targets in 2015.

- **Europe:** The EU adopted a new regionally binding target, calling for a minimum of 27% renewable energy in final energy consumption by 2030.

  Countries began to implement the EU policy shift from feed-in tariffs (FITs) to tendering mechanisms.

  In response to sustainability concerns, the European Commission introduced regulations on the use of first-generation biofuels to meet the region's 2020 renewable transport goals.

  Support for renewable heat increased, including increased targets in France and new renewable heat incentive schemes in Eastern Europe.

- **Latin America and Caribbean:** Countries across the region continued to establish some of the world's highest targeted shares for renewable energy deployment.

  The region remains at the forefront of the use of competitive bidding for renewable energy project allocation, with many tenders attracting record-setting participation and low bid prices.

- **Middle East:** Renewable energy tendering expanded across the region, with new tenders taking place in Iraq, Jordan and the United Arab Emirates.

  New support for renewable power projects was introduced through new net metering policies and new fiscal incentives.

- **North America:** The US federal investment and production tax credits were extended.

  Many states expanded existing Renewable Portfolio Standards (RPS), including increased commitments from California and New York and the country's first 100% RPS in Hawaii.

  The roll-back of net metering incentives, which began in 2014, continued in 2015.

i All GSR estimates for the numbers of countries with policies and targets are based on the best information available to REN21 at the time. This chapter includes policy developments from calendar year 2015.

This chapter highlights various policy types – such as targets, mandates, incentives and enabling mechanisms – that were added or revised during 2015 in the power, heating and cooling, and transport sectors at the regional, national and sub-national levels; the final section focuses on local policy developments. Developments related to each type of policy mechanism are described independently, although a targeted mix of complementary policies often addresses these sectors jointly. Renewable energy policies often are one component of broader national clean energy strategies, which also may include mechanisms to promote energy efficiency. (→ *See Energy Efficiency chapter and Figure 38.)*

The new policy developments featured in this chapter are intended to provide a snapshot of 2015 developments and emerging trends in renewable energy policy. This chapter does not attempt to assess or analyse the effectiveness of specific policy mechanisms. Specific details on new policy adoptions and policy revisions are included in the policy reference tables and policy endnotes, beginning on pages 161 and 247, respectively.

TARGETS

Worldwide, targets for renewable energy continue to be a primary means for governments to express their commitment to renewable energy deployment. As of year-end 2015, renewable energy targets had been established in 173 countries at the national or state/provincial level. Targets also have been adopted at the regional level, incorporating joint commitments by several countries.

Setting ambitious, long-term renewable energy targets demonstrates political commitment and can catalyse change by providing an official mandate for action. Targets take many forms and have varying levels of specificity, and many are linked to broader development initiatives. To achieve their targets, policy makers often adopt mechanisms including regulatory measures, fiscal incentives and public financing options. Increasingly, in many countries, policy makers are tracking the success of adopted measures and, if necessary, are revising existing policies or instituting new measures to meet their goals. A number of targets adopted by developing nations have included explicit calls for international assistance to help achieve their stated goals.

Targets are adopted in a variety of ways, ranging from announcements by governments or heads of state to fully codified plans accompanied by quantifiable metrics and compliance mechanisms.[3] The lines between target and regulatory policy mechanisms are often blurred, as in the case of RPS that establish mandatory shares, or "targets", of renewable power that utilities must achieve by a specified date.

A number of regions have established targets for renewable energy deployment in recent years. Led by the EU, this trend has expanded to cover organisations in Africa (ECOWAS) and the Caribbean (CARICOM). Although no new regional commitments were established in 2015, the EU built on its 2020 targets by establishing a long-term objective of a minimum of 27% of final energy consumption by 2030; while binding at the regional level, the 2030 target lacks legally binding national mandates.[4] In ECOWAS, almost all of the 15 member countries finalised their National Renewable Energy Action Plans that were mandated under the regional energy policy.[5]

Several countries around the world set economy-wide targets for renewable energy deployment in 2015. ***(→ See Reference Tables R15 and R16.)*** They include many in Africa (Djibouti, Ghana, Guinea, Liberia and Togo), Asia and the Pacific (China, Indonesia, Lao PDR, Thailand and Vanuatu), Europe (France and Portugal), the Middle East (Jordan, Lebanon and the United Arab Emirates) and South America (Brazil and Guyana).[6] (Additional sector-specific renewable energy targets are discussed later in this chapter.) Also in 2015, 74 countries identified quantifiable renewable energy goals in their INDC submissions[i],[7] *(→ See Sidebar 4.)* Many countries have also joined international renewable energy initiatives with global targets, including SE4All.

In addition to formal regional targets, the development of new sustainable energy centres for Small-Island Developing States (SIDS) as well as regional centres in the Caribbean (CCREEE), Southern Africa (SACREEE) and East Africa (EACREEE),

i INDCs are national post-2020 climate action commitments submitted to the UNFCCC in preparation for the Paris COP. They include a mix of new and existing renewable energy targets.

spearheaded by UNIDO, is designed to further enhance regional collaboration on renewable energy as well as energy efficiency.

A number of sub-national governments also made new renewable energy commitments in 2015 both at the state/provincial and municipal levels. The Compact of States and Regions includes commitments to renewable energy from some of the world's largest sub-national actors, including the US states of California and New York; the Canadian provinces of Ontario and Québec; Rio and São Paulo in Brazil, as well as territories in Australia and Europe.[8]

While targets are an important tool, they do not guarantee success. For example, the United Kingdom confirmed in November that it would miss the EU's requirement of a 15% share of renewable energy in the country's energy consumption by 2020, citing the lack of properly designed policy mechanisms (primarily in the transport and heat sectors) to meet its goal.[9] Spain also is expected to miss its 2020 obligation.[10]

POWER GENERATION

Policy makers continued to utilise deployment targets to outline their visions for power sector development, including the expansion of electricity access. In Africa, the Republic of the Congo, Eritrea, Gabon and Namibia established renewable power targets of 70% or greater, with lower goals set in Côte d'Ivoire, Djibouti, Liberia and Sudan.[i] Policy makers in Latin America also set some of the world's highest renewable power share targets, led by Costa Rica (100% by 2030), Uruguay (95% by 2017), Belize (85% by 2027), Guatemala (80% by 2030) and Bolivia (79% by 2030). Lower shares were targeted in Brazil, Chile and Paraguay.[11] Building on past commitments, a number of SIDS committed (through their INDC submissions) to the full transformation of their power sectors. For example, Papua New Guinea, Samoa and Vanuatu all committed to achieving 100% renewable electricity by 2030, and Cabo Verde committed to 100% by 2035.[12]

New goals for lower renewable shares as well as renewable capacity targets have been set around the world. ***(→ See Reference Tables R17–R19.)***

State- and provincial-level policy makers also established new commitments to renewable power in 2015. Notably, Hawaii announced its intention to become the first US state to run entirely on renewable power, setting an RPS mandate for 100% renewables by 2045.[13] Other state/provincial targets can be found in Australia, Belgium, China, Kosovo, New Zealand, the United Arab Emirates and the United Kingdom. The state of Lower Austria in Austria achieved its goal of generating 100% of the area's power from renewable sources in November 2015.[14]

As of year-end 2015, feed-in policies (feed-in tariffs and feed-in premiums; see Glossary) remained the most widely adopted form of renewable power support, in place in 75 countries at the national level and in 35 states/provinces/territories. In 2015, with no new countries adding new feed-in policies for the first time since 2000, the rate of new adoption continues to remain far below that of the peak in the mid-2000s. (→ *See Figures 38 and 39, and **Reference Table R20.***)

Globally, feed-in policies are in the midst of a transitional period, with policy makers making significant changes to rates and design to keep pace with changing market conditions brought on by technological innovation, increasing deployment, falling prices and shifting public opinion. Some countries with mature renewable energy markets, for example, have targeted their FITs to specific technologies (e.g., smaller-scale generators or solar PV), while phasing in competitive bidding to support larger-scale projects. At the same time, countries with less-mature renewable energy markets have continued to explore the use of feed-in policies to broadly incentivise project development.

In Europe – the birthplace of the modern feed-in policy – significant changes were made to a number of national FIT frameworks in 2015. Some changes have been instituted in response to European Commission (EC) State Aid guidelines that require a shift to renewable tenders for many projects by 2017[ii]. For example, in response to EC recommendations and public opinion, Germany removed FITs for solar PV projects of 0.5–10 MW in size in favour of new tender schemes.[15] France and Poland also have used tendering to allocate large-scale renewable energy projects over 250 kW and 500 kW, respectively.[16]

While FIT rates were reduced in some countries, including the United Kingdom and Ukraine, small-scale solar PV systems saw an increase in support in other countries, including France, Malta and Poland.[17] FIT schemes were also expanded: for example, both France and Ukraine extended support to cover bio-power, with the programme in Ukraine also covering geothermal power.[18]

Feed-in rate review and revision occurred in many of Asia's largest economies, continuing a trend of the last few years. New rates were introduced in Malaysia and Pakistan, whereas policy makers in China, Japan, the Philippines and Thailand made revisions to solar PV and wind FIT rates, both positive and negative. For example, the Philippines doubled the capacity cap for wind power projects under the FIT while lowering rates.[19]

In the Middle East and North Africa (MENA) region, Algeria implemented the FIT policy adopted in 2014, offering preferential tariffs for solar PV and wind projects of 1 MW and over.[20] In sub-Saharan Africa, Ghana instituted a temporary cap on its FIT that limits utility-scale solar PV until the country can assess the impact of initial projects that are pending construction and connection.[21] Changes also were made in Tanzania, which revised tariff rates during 2015, moving from payments based on seasonally adjusted utility avoided costs to technology-differentiated tariffs that are adjusted based on the US Consumer Price Index.[22]

No new FIT policies were added in Latin America during 2015, and few changes were made to the region's existing policies during the year. Ecuador eliminated FIT support to all technologies, while regulators in Costa Rica proposed new FIT rates for solar PV systems.[23]

i Some targets include large-scale hydropower and some do not. See Reference Table R17 for additional details.

ii The guidelines include certain exemptions to the tendering requirement, including for small-scale projects (capacity ranges set by technology) and technologies in early stages of development.

Sidebar 4. Renewable Energy in Intended Nationally Determined Contributions (INDCs) and the COP21 Paris Agreement

National commitments to renewable energy deployment received global attention throughout 2015 as the international community worked to reach a global climate change agreement. In December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. In a shift from past processes, the Paris Agreement drew heavily on a bottom-up approach in which nations outlined their own concrete post-2020 mitigation commitments under Intended Nationally Determined Contributions (INDCs) submitted throughout the year [i].

Although the INDC commitments relate to all sectors of the global economy, countries around the world identified the deployment of renewable energy technologies as an effective mechanism for achieving emissions reduction goals. The new goals expressed in the INDCs draw on well-established renewable energy policies and targets that countries have enacted for decades. Although non-binding in nature, these activities outlined through the INDC process served as the basis for the Paris Agreement [ii].

A majority of the INDCs aim to decouple energy use and emissions through commitments to scaling up the deployment of renewable technologies. Of the 162[iii] INDCs submitted, 106 indicate national intentions to increase renewable energy deployment, and 74 of these outline specific goals for renewable power, heating and cooling, and transport technologies.

The scope and ambition of pledges vary greatly from country to country. Many countries indicated their intention to rely on policies and goals developed independently of the global climate negotiations to meet their international emissions commitments, while others used the INDC process as an opportunity to introduce new or more-ambitious goals and strategies.

To meet their targets, some INDC submissions include calls for specific policy mechanisms (such as feed-in tariffs or public financing schemes) to drive national advances in renewable energy and energy efficiency. Many other INDCs necessitate a concerted effort from domestic policy makers to identify and implement those policy measures that can best achieve national goals. Sierra Leone, for example, called for the adoption of specific emissions reduction actions such as a feed-in tariff and the removal of fossil fuel subsidies.

Economy-wide renewable energy goals from some of the world's largest economies include Brazil's target for renewables to meet 45% of total energy needs by 2030 and the United Arab Emirates' target of 24% by 2021. China, a country with far-reaching existing domestic renewable energy targets, committed to increasing its share of non-fossil fuel energy[iv] to 20% by 2030.

Power generation technologies received the majority of attention, with many INDCs committing to the deployment of specified capacities or shares of renewable technologies. Non-Annex I countries were primarily responsible for the highest targeted renewable power shares submitted [v].

i INDCs are a new and innovative tool submitted for the first time in the lead-up to the 2015 UNFCCC 21st Conference of the Parties (COP21) to outline post-2020 climate actions that countries intend to take under an international climate regime. INDCs were born out of the 2013 Warsaw decision, in which countries agreed "To invite all Parties to initiate or intensify domestic preparations for their intended nationally determined contribution, without prejudice to the legal nature of the contributions". Although the Paris Agreement is legally binding, it does not obligate countries to meet their individual national-level targets.

ii The Paris Agreement represents a commitment by 195 countries to limit the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels and to promote universal access to sustainable energy in developing countries.

iii The 162 individual submissions cover 189 countries, which account for approximately 95% of global emissions and 98% of the global population. The European Union submitted an INDC covering 28 Member States. A total of 160 INDCs was submitted in 2015, and Nepal and Panama submitted their INDCs in 2016, bringing the overall total to 162.

iv Non-fossil energy includes nuclear power.

v The UNFCCC divides countries into three main groups: Annex I, Annex II and Non-Annex I. Non-Annex I includes primarily developing countries. Many Non-Annex I country targets include large-scale hydropower development.

Specific commitments to renewable heating received comparatively little attention. However, examples of renewable heat goals include the INDCs of Malawi and Jordan, which include commitments to increased deployment of solar water heaters.

Approximately 75% of all countries that submitted an INDC highlighted the transport sector – which relies almost exclusively on fossil fuels – as an important target for mitigation. Although the majority of transport-focused measures sought to reduce fuel consumption through fuel efficiency standards or increased public transport, some countries – including Burkina Faso, India, Lao PDR, Liberia, New Zealand, Seychelles and Uruguay – explicitly committed to increased use of biofuels to meet their goals.

Success in meeting the most ambitious renewable energy goals may depend in part on the world's developed nations following through on their collective pledge to provide USD 100 billion per year through 2025; increasing voluntary commitments from other countries; and leveraging private sector capital to supplement public finance delivered through mechanisms such as the Green Climate Fund and the Global Environment Facility. Many developing countries have underlined the need for financial assistance by submitting "conditional" targets that call explicitly for international financial support as a requirement for meeting their stated goals. The Paris Agreement secured commitments from industrialised nations to mobilise these funds.

If fully implemented, the INDC renewable energy goals are expected to boost technological innovation and renewable energy deployment, particularly in the power sector. Several recent analyses have examined the potential impacts of the INDC commitments and the Paris Agreement. One analysis projects that wind power capacity will nearly triple and that solar power capacity will increase five-fold over the next 15 years to meet national climate commitments. These figures are very much in line with some of the most ambitious growth scenarios outlined by international organisations and agencies. Other projections paint a similarly sunny future for renewables under the new climate regime built on the INDC commitments, with new growth estimates for renewable energy in 2030 beating previous projections by 18%.

Further scaling up of the commitments made in INDCs will be necessary to hold the increase in global average temperatures to below 2 degrees Celsius. Starting in 2018, national commitments will be revisited every five years, with countries assessing progress and encouraged to submit progressively more ambitious goals.

Source: See endnote 7 for this chapter.

In North America, feed-in policies continued to exist only at the state and provincial levels. No new states/provinces/territories added feed-in policies in 2015, but two revised existing programmes. In Canada, Nova Scotia closed the Community Feed-in Tariff (COMFIT) programme to all new applicants after reaching a projected 125 MW of projects by year-end 2015, and Ontario introduced new rates for its MicroFIT programme – which supports projects 10 kW or less in size – targeting 240 MW of new projects in 2016.[24]

The use of competitive bidding, also referred to as tendering or auctioning, has gained momentum in recent years. In 2015, the number of countries utilising tendering mechanisms increased to 64, up from 60 in 2014. Many of the world's developing and emerging countries attracted record bids in terms of both low price and high volume. All BRICS countries[i] continued their interest in tendering: Brazil held several auctions throughout the year, with solar PV and wind power accounting for the majority of project allocations, followed by biomass and small-scale hydropower[ii]; the Russian Federation approved 365 MW of solar PV, wind and hydropower projects; China issued a 1 GW solar PV tender; India's new national offshore wind energy policy, introduced in 2015, includes tenders to take place in later years; and South Africa saw the first allocations under its small project window, while continuing to receive high levels of engagement under its Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)[iii, 25] ***(→ See Reference Tables R22.)***

Latin America, an early adopter of renewable energy tenders,

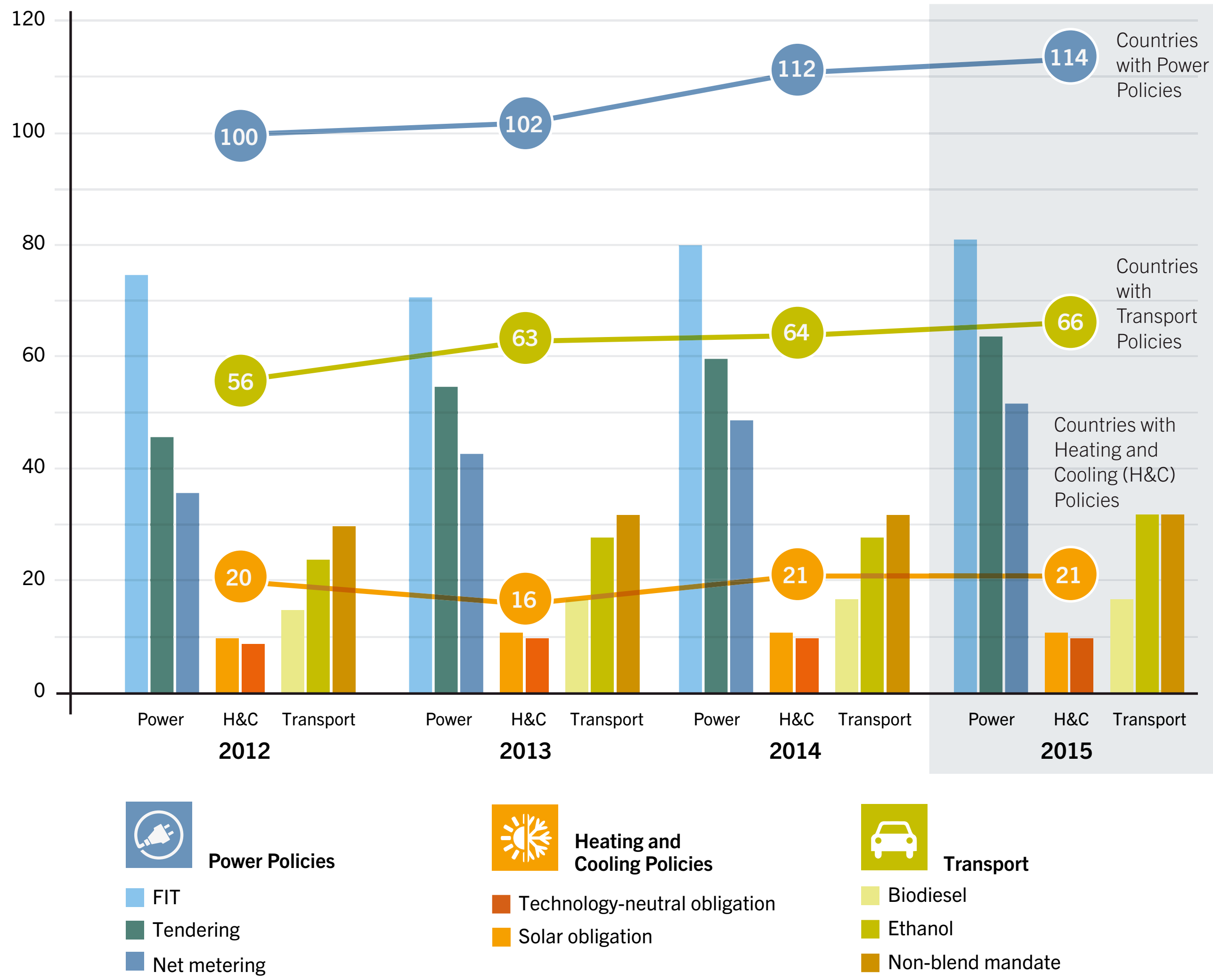
i The five BRICS countries are Brazil, the Russian Federation, India, China and South Africa.

ii Brazil's auction rules require bidders to secure guaranteed grid access prior to participating.

iii The REIPPPP programme has approved a total of 6,327 MW of new renewable energy capacity from 92 individual projects since its creation in 2011 and is now being used as a model to allocate contracts for IPPs utilising all forms of energy sources in South Africa. The programme uses weighted development criteria such as local job creation, local content, local ownership and development, etc. during bid evaluation to maximise the national development potential of selected renewable energy projects.

POLICY LANDSCAPE

Figure 38. Number of Renewable Energy Policies and Number of Countries with Policies, by Type, 2012–2015



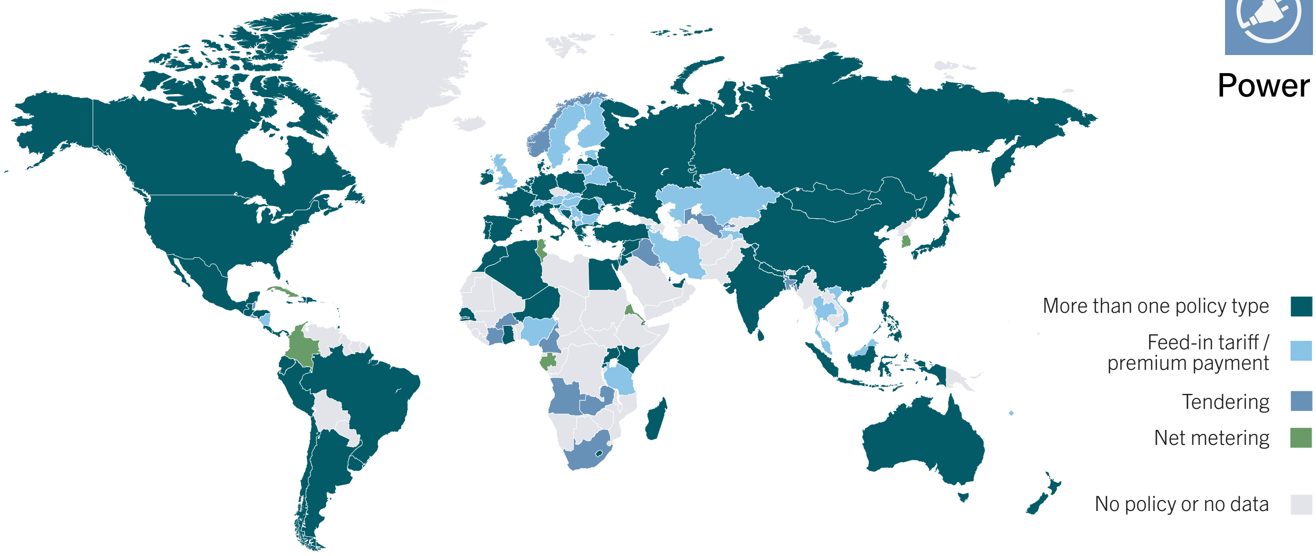
Source: REN21 Policy Database

Figure does not show all policy types in use. Countries are considered to have policies when at least one national or state/provincial-level policy is in place. Some transport policies include both biodiesel and ethanol; in this case, the policy is counted once in each category (biodiesel and ethanol).

REGULATORY POLICIES IN THE **POWER SECTOR** COVER OVER **87%** OF THE WORLD POPULATION, WHILE REGULATORY POLICIES IN THE **HEATING AND COOLING AND TRANSPORT SECTORS** COVER OVER **50%** AND **73%**, RESPECTIVELY.

Figure 39. Countries with Renewable Energy Power Policies, by Type, 2015

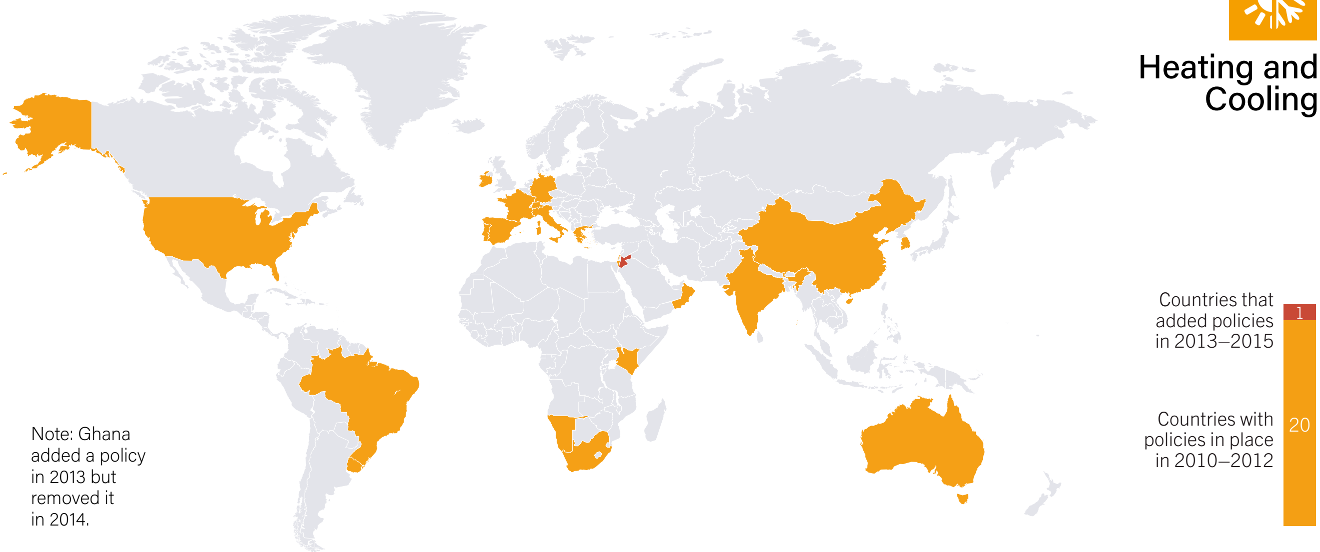
Power



Source: REN21 Policy Database

Figure 40. Countries with Renewable Energy Heating and Cooling Obligations, 2010–2015

Heating and Cooling

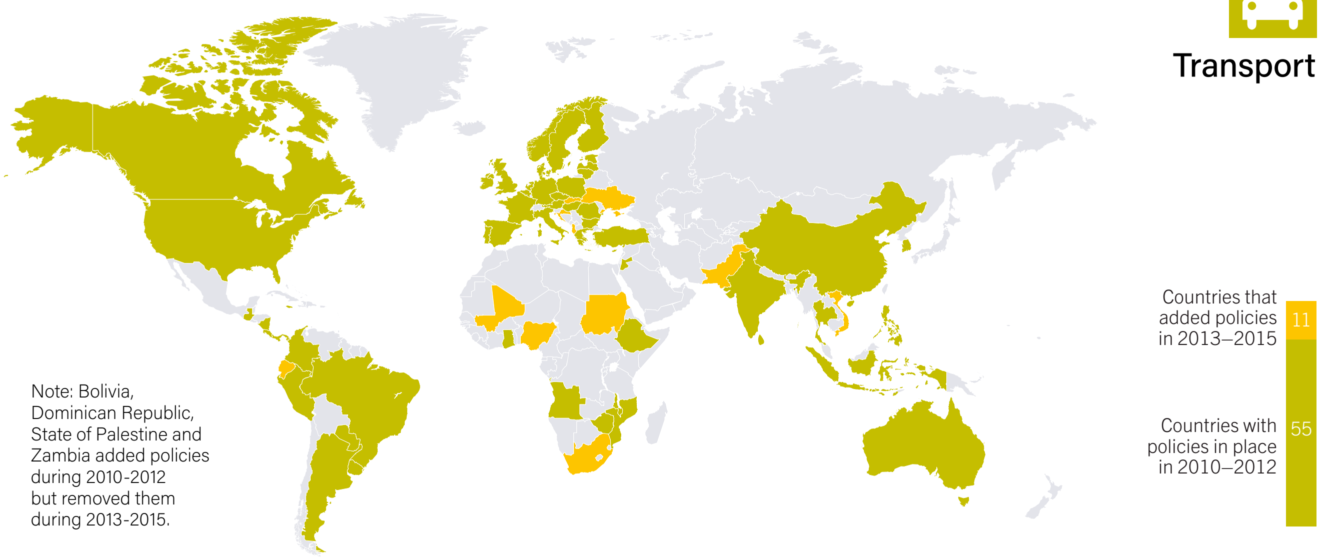


Note: Ghana added a policy in 2013 but removed it in 2014.

Source: REN21 Policy Database; see endnote 55 for this chapter.

Figure 41. Countries with Renewable Energy Transport Obligations, 2010–2015

Transport



Note: Bolivia, Dominican Republic, State of Palestine and Zambia added policies during 2010-2012 but removed them during 2013-2015.

Source: REN21 Policy Database

Countries are considered to have policies when at least one national or state/provincial-level policy is in place.

remained one of the most active regions in 2015. Argentina began preparing tenders to be launched in 2016, while Peru held its fourth round of auctions, offering 1,300 GWh of biomass, wind and solar PV power, and also awarded a power purchase agreement (PPA) to supply electricity to rural households through 150,000 solar home systems.[26] Mexico and El Salvador announced plans to hold their first and second renewable energy auctions, respectively.[27]

In the MENA region, both Iraq and Jordan held their first tenders, and Morocco awarded 850 MW of new wind projects.[28] Turkey held multiple auctions that attracted bids totalling nearly 15 times the capacity offered.[29] In Europe, tenders were held in countries including France, Germany and Spain.[30]

Although auction mechanisms have been used primarily at the national level, their adoption is expanding among sub-national jurisdictions as well. Several Indian states employed tenders in 2015 to support solar power deployment. Notable examples include Andhra Pradesh, Karnataka, Rajasthan, Telangana (which held two solar tenders for 400 MW) and Jharkhand (which announced plans to allocate 1,200 MW of small- and large-scale solar contracts).[31] In addition, the Emirate of Dubai in the UAE awarded a contract for a 200 MW solar PV park and opened its third solar PV tender (800 MW).[32] The Australian Capital Territory launched its second utility-scale wind power auction in 2015.[33]

Net metering / net billing policies were in force in 52 countries as of year-end 2015. Net metering / net billing has been utilised to support the deployment of small-scale, distributed renewable energy systems by enabling generators to receive credit or payments for excess on-site generation. In many cases, net metering policies have been adopted in conjunction with other policy mechanisms – such as FITs or auctions – that support larger-scale projects.

Although the pace of new adoption of net metering policies had slowed in recent years, this trend reversed in 2015, with four new policies announced at the national level and five added at the state/provincial level. Colombia, Ghana, Nepal and Pakistan all adopted net metering/net billing for plants no larger than 1 MW, and Brazil expanded its net metering cap from 1 MW to 5 MW.[34] In India, Himachal Pradesh and Rajasthan adopted solar PV net metering, bringing to 21 the number of Indian states with announced (although not necessarily operational) net metering policies. In North America, South Carolina became the 44th US state[i] to establish net metering, while Newfoundland and Labrador became the 4th Canadian province to do so.[35] In addition, the Emirate of Dubai established a rooftop solar PV net metering programme in 2015.[36]

Revisions to net metering policies have focused increasingly on technical standards for grid connection, as well as on the introduction of taxes or fees on self-generators participating in net metering programmes or generating their own power. As the amount of distributed renewable electricity operating under net metering has increased, policy makers in some countries have come under pressure from private citizens or electric utilities citing electric rates or revenue concerns. In response, some policy makers have revised downward the net metering payments and/or have levied new taxes or fees on renewable generators.

Notable examples introduced in 2015 include Spain's surcharge on many solar PV systems and on self-consumption of the electricity generated on the premises.[37] Generators pay grid fees plus separate capacity and generation taxes, with a second tax established for systems larger than 10 kW.[38] In the United States, Nevada revised tariffs on new and existing systems after reaching its net metering cap, and Hawaii closed its net metering programme to new applicants and introduced additional tariffs for connecting systems to the electric grid.[39] Other US states – including Arizona, California, Kansas, Oklahoma and Texas – were considering proposals for rate adjustments and charges on residential customers with solar PV systems.[40]

In addition to regulatory policies that stimulate increased renewable electricity generation, renewable obligations or mandates that require the deployment of renewable power capacity are in use worldwide. Electric utility quotas or Renewable Portfolio Standards (RPS) are the most common mandate in use at the national level to promote renewable power. RPS policies were in place nationally in 26 countries by year-end 2015. ***(→ See Reference Table R21.)*** The overall pace of new adoption at the national level has slowed significantly in recent years, and no new additions were made at the national level in 2015.

RPS policies remain popular at the sub-national level. As of year-end 2015, RPS or quota policies were in place in 74 states/provinces/territories, including in Belgium (2), Canada (3), India (27 states and 7 union territories) and the United States (29 states, the District of Columbia and three territories). State-level policy makers were by far the most active in revising existing mandates in 2015. Policy changes resulted in a wide array of new and increased obligations as well as in the removal of some existing mandates.

New RPS policies were added in one state and one territory in 2015. In the United States, Vermont upgraded its voluntary standard to mandate that all utilities in the state acquire 55% of electricity from qualifying renewable technologies by 2017, and 75% by 2032.[41] The US Virgin Islands codified the existing voluntary goal of 30% by 2025 as a mandatory RPS. In addition, Colorado's RPS survived a court challenge when the Federal Appeals Court ruled the policy constitutional because it does not impose unlawful regulations on out-of-state companies.[42]

i In addition to American Samoa, the District of Columbia, the US Virgin Islands and Puerto Rico.

Three US states took steps to expand their RPS policies. California increased its RPS from 33% by 2020 to 50% by 2030.[43] The state also set requirements for its three biggest utilities[i] to secure 600 MW of new solar capacity by 2019 under the community-shared solar programme[ii].[44] Hawaii became the first state to target a fully renewable power supply by increasing its RPS to 100% by 2045.[45] New York's RPS expired at end-2015, but the state's Public Service Commission was directed to establish a new, more ambitious mandate of 50% renewable power by 2030.[46] Elsewhere in North America, the Canadian province of New Brunswick extended its RPS to 40% by 2020, and Nova Scotia established a mandate of 25% in 2015 and 40% by 2020.[47]

Despite the new adoptions, US RPS policy roll-backs continued in 2015, with Kansas downgrading its existing mandate to a voluntary goal of 20% by 2020. A number of RPS policies in US states – including Michigan, Montana, North Dakota, Oklahoma, South Dakota, Texas and Wisconsin – also were expected to reach their maximum target date at year-end 2015.

The mandated use of renewable energy systems, such as obligations for their installation in new construction, were instituted in a few countries in 2015. France enacted a law that requires all new buildings in commercial zones to be partially covered by vegetation or solar PV panels.[48] The Czech Republic and Switzerland introduced building permit exemptions for rooftop solar PV to simplify deployment.[49]

Several countries have utilised public finance mechanisms as an attempt to drive the investment needed to increase renewable energy deployment. Many introduced renewable energy tax incentives in 2015. Notably, the United States approved multi-year extensions, the longest extensions to-date, of its production and investment tax credits in late 2015.[50] El Salvador, India, Jordan, Mongolia and Pakistan all added new policies or extended existing policies. By contrast, Japan announced plans to remove tax breaks for commercial solar installations, set to be implemented in early 2016 as a component of the upcoming electricity market liberalisation strategy.[51]

Additional public sector support, such as grants and loans, has been directed towards increasing the deployment of renewable technologies as well as research and development (R&D), including support for enabling technologies, such as energy storage. Globally, 20 countries around the world pledged to double public funding for R&D in clean energy technologies with the launch of the Mission Innovation initiative in 2015.[52] At the national level, Australia committed over USD 80 million to support energy storage projects, ranging from technology development to large-scale deployment, and the Czech Republic established a new USD 1.1 billion (CZK 27 billion) 10-year energy efficiency incentive programme that includes support for residential solar PV installations.[53] However, some countries reduced funding for renewables during 2015; Denmark, for example, lowered funding for the Energy Technology Development and Demonstration Program – which provides incentives to spur research in new green energy technologies – from USD 55 million to USD 18 million (DKK 385 million to DKK 127 million).[54]

HEATING AND COOLING

In 2015, the adoption of policies promoting the development and deployment of renewable energy technologies in the heating and cooling sector continued to lag behind policy adoption in the power and transport sectors. However, some leading jurisdictions have begun to recognise the important role that renewables can play in transforming the heating and cooling energy mix and have established regulatory and financial mechanisms to support technologies such as solar water heaters or modern biomass heat.

More policies have been directed towards renewable heating technologies than towards renewable cooling technologies. Policies have focused primarily on smaller-scale solar thermal heating options, with solar water heaters historically receiving the bulk of policy support. Policies have continued to focus primarily on residential and commercial buildings, rather than on the industrial sector. The recent attention granted to utility-scale and industrial heat in some countries – such as Austria, Denmark, Germany, India, Mexico and Tunisia – did not result in the significant expansion of policy support around the world in 2015.[55] (→ *See Figure 40.)*

As in the electricity sector, policy makers have aimed to promote renewable heating and cooling through a mix of policies including targets, rate-setting and incentives policies, regulatory mandates and public finance mechanisms. Although examples exist, comparatively little regulatory attention has been focused on renewable heating and cooling, with policy makers instead adopting public finance mechanisms to support the sector. However, building code mandates are used widely at the local level to promote renewable heat. (→ *See City and Local Governments section.)*

At least 45 countries worldwide had renewable heating and cooling targets in place by year-end 2015, with 31 of these in Europe. During 2015, France established a target for a 38% renewable heat share by 2030.[56] ***(→ See Reference Table R23.)*** A few other countries outlined goals in their INDCs to expand the deployment and manufacturing of renewable heat technologies

i The obligation applies to Pacific Gas & Electric (which must secure 272 MW of new capacity), Southern California Edison (269 MW) and San Diego Gas & Electric (59 MW).

ii California's programme defines as "community-shared" a solar electric system that provides power and/or financial benefit to multiple community members.

in order to decarbonise their heating sectors. For example, Malawi introduced a goal to manufacture 2,000 solar water heaters (no date given) and to increase the penetration of solar water heaters from the 2,000 in place as of 2015 to 20,000 by 2030.[57] Bosnia's INDC submission included the introduction of renewable energy into existing district heating systems and the construction of new district heating systems fuelled by renewable technologies.[58] Jordan's INDC included the goal to provide short-term support for the deployment of solar water heaters.[59]

In general, policy makers have adopted one of two types of mandates: solar obligations, which have been enacted in 11 countries at the national or state/provincial level, and technology-neutral renewable heat obligations, which were in place in 10 countries by year-end 2015. Mandates have advanced slowly at the national level, particularly in comparison to the municipal level (see City and Local Governments section), and no new mandates were adopted at the national level in 2015.

Financial incentives and public financing also have been extended to support the deployment of renewable heat technologies, although there were few new developments in 2015. Australia announced a new grant scheme covering 50% of project costs for renewable heat for industrial processes as one of the focus areas for investment under the Australia Renewable Energy Agency.[60] The Czech Republic expanded its residential subsidy scheme to support district heating and heat recovery and relaxed requirements for solar thermal systems to qualify for incentives.[61] France doubled the budget for its renewable heat support scheme Fonds Chaleur – first established in 2009 – to provide USD 455 million (EUR 420 million) to support renewable heat in the industrial, residential and district heating sectors.[62] Italy announced its intention to double the size of qualifying projects under its renewable heating and cooling incentive scheme from 1 MW to 2 MW.[63] Slovakia launched its long-awaited support scheme to scale up renewable technologies in residential buildings, including rebates of up to 50% of project costs for renewable heat systems.[64]

At the sub-national level, the Renewable Heat NY programme (introduced in 2014) began offering incentives in the US state of New York for the use of high-efficiency wood heating systems for residential and commercial buildings that lack access to natural gas.[65] Despite low international oil and gas prices, few incentives for solar process heat were reduced in 2015; however, Thailand halted its process heat subsidy for 2015–16.[66]

TRANSPORT

In the transport sector, renewable fuels and electric vehicles (EVs) continue to attract attention from policy makers in the form of regulatory measures and fiscal incentives. The vast majority of policies adopted in the renewable transport sector have been directed at the production and use of biodiesel and ethanol. This support has shifted increasingly towards the promotion of second-generation, advanced biofuels in new policy development, although, globally, the majority of policies adopted to date focus predominantly on first-generation biofuels. (→ *See Figure 41 and* ***Reference Table R24.****)*

Efforts to promote biofuel technologies have employed similar provisions as in the power and heating/cooling sectors – including targets, regulatory measures and tax/financial incentives – to spur growth within the transport sector. New and existing policies have focused almost exclusively on road transport rather than on aviation, rail or shipping. EVs also have received increased support, although to a much lesser degree. The number of jurisdictions that have enacted policies to promote a direct linkage between renewable energy and EVs remains very limited.

A small number of new renewable transport targets were introduced in 2015, with most of these targets in INDC submissions. France set a new target of 15% renewables in final transport energy consumption by 2030; Liberia put forward a target for blending up to 5% palm oil biodiesel by 2030 for vehicle fuels; Lao PDR seeks to increase the use of biofuels to meet 10% of its transport fuel demand by 2025; and Malawi set a goal of increasing the proportion of vehicles running on ethanol to 20% by 2020.[67] In the aviation sector, Japan aims to utilise some biofuels for air transport by the time the country hosts the Olympics in 2020.[68]

Globally, the transport sector continued to be embroiled in debate over the economic and environmental impacts of biofuels, with particularly vocal debates continuing in Europe and the United States in 2015. Critics contend that the full life-cycle emissions associated with the fuels negates the positive environmental impact of displaced fossil fuel consumption, while others challenge concerns about the impact on food crop prices and land use.[69]

Many long-running policy debates were adjudicated in 2015, with rulings made on obligations for the use of first-generation biofuels in the EU and the United States. After seven years of speculation and negotiation, the European Parliament approved revisions to the EU renewable energy act to establish a limit on the use of first-generation biofuels to meet the EU's 10% renewable fuels mandate. The new provisions limit crop-based biofuels to a 7% share of the EU's 2020 10% renewable transport energy target. They also include indicative support for second-generation biofuels through a 0.5% voluntary target and by allowing their contribution to be double-counted towards meeting the overall EU mandate.[70] At the national level in the EU, Germany reduced its required blend volumes for biodiesel from 6.25% to 3.5% to bring the requirement in line with the targeted emissions reduction goals.[71]

In the United States, a similar debate over first-generation biofuel mandates in the form of the Renewable Fuel Standard (RFS) – a national mandate for total volume of biofuel blending – occurred throughout 2015. In December, the US Environmental Protection Agency released updated biomass-based diesel volume requirements that were an increase over previous years but lower than the statutory requirements that originally were set under the RFS.[72]

Despite ongoing debates over biofuel production and use, biofuel support policies continued to be adopted during 2015. The most commonly used form of regulatory support for the renewable transport sector continues to be biofuel blend mandates, which specify a minimum share or volume of renewable fuel to be blended with traditional transport fuel. At year-end 2015, blend mandates were in place at the national level in 32 countries and 27 states/provinces/territories: 45 jurisdictions mandate specified shares of ethanol and 27 mandate biodiesel blends, with many countries having mandates for both fuels. ***(→ See Reference Table R25.)***

In 2015, Brazil began allowing voluntary biodiesel blending of B20 for road transport; for rail transport, agriculture and industrial uses, the blend ceiling was raised from B7 to B30.[73] Brazil also increased its ethanol mandate from E25 to E27.[74] Ecuador introduced an E5 blend mandate, which is set to be raised to E10 by 2017.[75] India made a number of changes to its national biofuels programme, setting supply quotas for Indian states to comply with the new E10 mandate; a proposed National Policy on Biofuels would increase blending of ethanol and biodiesel in India to 20% by 2017.[76] Indonesia raised its blend mandate for transport, household, commercial and industrial sectors from 10% to 15%; Malaysia increased its biofuel mandate from B7 to B10; and Thailand's B7 mandate came into force.[77] A biofuel bill pending adoption in Uganda at year's end would establish a national 20% biofuel blend mandate if fully adopted.[78]

The use of additional regulatory measures to promote renewables in the transport sector expanded in 2015 to incorporate auction-based mechanisms, market deregulation and additional forms of mandates. Paraguay mandated that 30% of all new purchases for public fleets be flex-fuel vehicles.[79] South Africa introduced a competitive bidding programme similar to its renewable power capacity tenders.[80] In India, state-owned oil marketing companies issued a tender to buy 2.7 billion litres of ethanol from domestic sources; additional reforms that deregulate the ethanol market in India allow farmers to produce their own corn-based ethanol.[81]

New financial incentives and public investment schemes were introduced in 2015 to promote biofuel production and consumption. India made a number of changes to its national biofuel support programme: tax reductions were established to encourage the production of E10, the national ethanol import tariff was reduced from 7.5% to 5%, the central excise tax (12.36%) on ethanol blended with gasoline was removed, and the government announced an investment of USD 1.53 billion through 2018 to support palm oil production.[82] At the sub-national level, the US state of California revised its tax code to make biodiesel a non-taxable fuel.[83]

Public financing also has been utilised to support R&D in advanced biofuels. For example, in 2015 the US Department of Agriculture announced a USD 70 million loan guarantee to support the development of a cellulosic biofuel facility.[84] The US Department of Energy also provided USD 18 million for the production of algae biofuel, aimed at reducing the cost of algae-based fuels.[85]

In some countries, support for biofuels was reduced. For example, voters in Lithuania chose to remove excise exemptions on biofuel blends that were established in 2001.[86] In addition, policies continued to be adopted to protect domestic industries; Brazil enacted an 11.25% import tariff on ethanol, the EU renewed anti-dumping duties against US biodiesel producers until 2020, Malaysia limited imports of Indonesian palm oil, and Indonesia continued to advance its case against the EU at the World Trade Organization (WTO).[87]

While electric vehicles have received support in a number of countries, policy makers continue to be slow to adopt measures that link them to renewables. A number of measures have been adopted worldwide to promote EVs, such as Jordan's commitment to install 3,000 solar PV EV charging stations; however, policies directly linking EVs and renewable energy received little to no attention in 2015.[88]

CITY AND LOCAL GOVERNMENTS

Cities and municipalities are playing a pivotal role in the global energy transition. Cities rely on a mix of regulatory policies, mandates and direct purchasing to support the deployment of renewable energy within their jurisdictions. Local-level support for renewable technologies often is included in broader initiatives to increase air quality, reduce carbon emissions or promote job creation. Support traditionally has been directed towards power generation technologies, but policies and mandates supporting renewable heat and renewable transport, as well as linkages between renewable energy and energy efficiency, have been gaining momentum at the municipal level.

Local-level policies fill the gaps in (or supplement) policy frameworks at the national or state/provincial level to drive local renewable energy growth. In addition to supplementing national frameworks, municipalities can serve a unique role as proving grounds for innovative renewable energy policies, often piloting programmes that later might be adopted by a broader set of cities or at the national level.

Cities also play a major role in adopting some of the world's most ambitious renewable goals and are leading the rapidly expanding 100% renewable energy movement.

In 2015, municipal policy makers continued to use their unique purchasing and regulatory authority to spur deployment across their jurisdictions, making cities among the most ambitious and fastest-moving governmental actors in adopting renewable technologies. The important role of municipal governments in promoting deployment of renewable energy technologies on a large scale was highlighted throughout the COP21 process. Local-level climate-based commitments to scale up renewable energy solutions became an important component of the Paris negotiations, and will be critical to meeting the goals agreed to in the Paris Agreement. This section provides an overview of actions taken by cities around the world and does not provide a comprehensive list of municipal policy actions.

Cities have assumed a leading role in the promotion of renewable energy through direct purchasing of renewable power equipment. For example, in 2015, Washington, D.C. completed a deal for one of the largest municipal on-site solar PV projects in the United States, increasing the city government's total installed solar capacity by 70%.[89] In Harare, Zimbabwe, the municipal government invested USD 15 million for the purchase and construction of solar streetlights.[90]

Regulatory measures such as feed-in tariffs and net metering policies also continue to be important tools for promoting the deployment of renewable power capacity at the municipal level. Originally adopted in developed countries in Europe and North America, these mechanisms have begun to spread to the local level in developing and emerging nations, including South Africa. In 2015, Cape Town, South Africa began allowing the sale of surplus energy from renewable energy installations into the municipal grid system through a new net metering programme.[91] Elsewhere, Banff became Canada's first municipality to offer a local FIT programme, although on a very limited scale, supporting only 26 rooftop solar PV systems.[92]

Through their direct regulatory authorities, cities have instituted obligations to drive the deployment of renewable energy technologies. Several municipalities have enacted mandates that range from utility obligations to purchase renewable power to municipal building codes that mandate the installation of renewable technologies such as solar water heaters. New obligations build on existing municipal mandates in Europe, India and the UAE. In 2015, Denman Prospect in the Australian Capital Territory became Australia's first suburb to mandate the installation of solar PV systems (of at least 3 kW each) on all new buildings within the territory.[93] Austin, Texas (United States) mandated its utility to contract an additional 600 MW of solar PV by 2019.[94]

Municipalities have a critical role to play in promoting the development of district heating and cooling networks and linking them to renewable energy. In 2015, Amsterdam committed to total decarbonisation of its district heating system and set an immediate goal of increasing connections to a total of 230,000 houses by 2040 (a 70% increase).[95] The Austrian city of Graz committed to increasing the share of solar thermal in its district heating network by 20% through the installation of up to 500 MW_{th} of new solar collectors.[96] Münster, Germany – the first German city to divest from fossil fuels – invested in hot water storage tanks in 2015 to utilise surplus grid electricity to generate heat for injection into the city's district heat network as part of a plan to increase renewable energy penetration.[97]

In the transport sector, several Chinese cities influenced national policy in 2015 by working together to reverse a national corn-based ethanol ban that has been in place since 2006, resulting in the approval of new maize-based ethanol production plants.[98] National governments often have introduced biofuel blend mandates as pilot initiatives in relatively small jurisdictions. Kenya adopted an E10 mandate in the city of Kisumu; Mexico established an E2 mandate in the city of Guadalajara, and aims to expand the programme to Mexico City and Monterrey; and Vietnam's national E5 mandate was initially rolled out in a select group of seven cities.[99]

A quickly growing list of cities – primarily in Europe, North America, Australia and Japan – are targetting the complete transformation of their energy or power sectors through on-site generation or the purchase of renewable power. In 2015, Byron Shire, Coffs Harbour and Uralla in Australia; Oxford County and Vancouver in Canada; and the US cities of Rochester (Minnesota) and San Diego (California) joined numerous cities around the world that have committed to going 100% renewable[i],[100] ***(→ See Reference Table R26.)*** Many cities already have achieved their goals, including the US cities of Burlington (Vermont), Aspen (Colorado) and Greensburg (Kansas), which all reached 100% renewable electricity during 2015.[101]

Major global and regional initiatives helped to advance the 100% renewable energy movement in 2015. The Climate Summit for Local Leaders, held in parallel with COP21, issued a declaration in support of a transition to 100% renewable energy by 2050; it was signed by nearly 1,000 mayors from around the world.[102] This non-binding commitment builds on examples of leading cities such as Copenhagen, Frankfurt, San Francisco, Sydney and Stockholm.[103]

Also in 2015, the Global 100% RE Campaign published 12 criteria to help define the concept of 100% renewable energy for local governments and to guide policy makers in initiating their transition to 100% renewables. The Campaign also launched the 100% RE Cities and Regions network to enable peer-learning and exchange among municipalities.[104] The Global 100% RE Campaign, along with Europe's 100% RES Communities and RES Champions League, has brought additional attention to municipal efforts aimed at achieving 100% renewable energy.[105]

European cities have led in the advancement of local renewable energy solutions through individual action as well as regional-level partnerships. The Covenant of Mayors began as a group of European municipalities committed to meeting and exceeding a 20% reduction in CO_2 emissions by 2020, relative to a recommended baseline year of 1990, through increased energy efficiency and renewable energy deployment; new signatories as of 2015 pledge a 40% reduction by 2030 (based on their own Baseline Emission Inventory). Nearly 500 municipalities joined during 2015, and the Covenant had 6,660 signatories by year's end.[106] The majority of the signatories also signed onto a new Covenant of Mayors for Climate and Energy, which calls for an increase in energy efficiency and renewable energy of at least 27% by 2030 over the established baseline.[107] In December 2015, both Covenant initiatives pledged to work together to advance municipal efforts to scale up their low-carbon development efforts.[108] Additionally, 2015 saw the Covenant of Mayors expanded to include cities in sub-Saharan Africa.[109]

The Compact of Mayors is a global initiative of voluntary city pledges to reduce local greenhouse gas emissions and enhance resilience to climate change. By end-2015, the Compact had received commitments from 428 cities with a combined population of 376 million residents (or over 5% of the world's population); this makes it the largest such coalition of city leaders by population.[110] Rio de Janeiro became the first city to fully align with the principles outlined in the Compact of Mayors, in August 2015, and was soon joined by Buenos Aires, Cape Town, Copenhagen, Melbourne, New York, Oslo, San Francisco, Stockholm, Sydney and Washington, D.C.[111] By year's end, 43 cities were in compliance with the Compact[ii],[112]

i 100% renewable energy targets vary by municipality, with some focused exclusively on electricity and others targeting all energy, including heating and cooling as well as transport.

ii Cities are deemed compliant according to the Compact when they register a commitment, take inventory, create reduction targets and establish a system of measurement, and establish an action plan.

Table 4. Renewable Energy Support Policies

COUNTRY	Renewable energy targets	Feed-in tariff / premium payment	Electric utility quota obligation / RPS	Net metering / net billing	Transport obligation / mandate	Heat obligation/ mandate	Tradable REC	Tendering[i]	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, VAT or other taxes	Energy production payment	Public investment, loans, or grants
		REGULATORY POLICIES							FISCAL INCENTIVES AND PUBLIC FINANCING				
HIGH INCOME COUNTRIES													
Andorra		○										○	
Argentina	R	○		○	○			○	○	○	○	○	○
Australia	R	●	○		●	●	○	★*	○				R
Austria	○	○			○		○		○	○			○
Bahrain	○												○
Barbados[1]	R			○							○		○
Belgium	○		●	●	○		○	○	●	○	○		
Canada	R*	R*	R*	●	○			○	○	○	○		○
Chile	R		○	○				○	○	○	○		○
Croatia	○	○			○								
Cyprus	○	○		○	○			○	○				
Czech Republic	○				○		○		○	○	○		R
Denmark	○	○		R	○		○	○	○	○	○		R
Estonia	○	○			○							○	○
Finland	○	○			○		○		○		○	○	
France	R	R			○	○	○	★	○	○	○		R
Germany	○	R			R	○		★	○	○	○		○
Greece	○	○		○	○	○			○	○	○		○
Hungary	○	○			○				○		○		○
Ireland	○	○			○	●	○	○					
Israel	R	○	○	○		○		○			○		○
Italy	○	R		R	R	○	○	○	○	○	○		○
Japan	R	R					○	○	○		R		○
Korea, Republic of	○		○	○	R	○	○		○	○	○		○
Kuwait	○							○					
Latvia	○	○		○	○			○			○		
Liechtenstein		○											
Lithuania	○	○	○		○						R		○
Luxembourg	○	○			○				○				
Malta	○	R		○					○		○		
Netherlands	○	○		○	○		○		○	○	○	○	○
New Zealand	○			●					○				○
Norway	○		○		○		○	○	○		○		○
Poland	○	R	○		○		○	R			○		○
Portugal	R	○	○	○	○	○		○	○	○	○		○
Russian Federation	○	○						R	○				
San Marino		○											
Seychelles	○			○						○	○		○
Singapore	R			○				○					○
Slovakia	○	○			○		○				○		★
Slovenia	○	○					○	○	○	○	○		R
Spain[2]	○			R	○	○	○	★	○	○		○	
Sweden	○	○	○		○		○		○	○	○		○
Switzerland	○	○				○			○		○		
Trinidad and Tobago	○									○	○		
United Arab Emirates	R		●	★*		●		★*				●	●
United Kingdom	○	○	○		○		○		○		○	○	○
United States[3]	R*	●	R*	R*	R	●	●		○	R	○		R
Uruguay	R	○		○	○	○		○	○		○	○	○

○ EXISTING NATIONAL (could also include subnational)
● EXISTING SUB-NATIONAL (but no national)
★ NEW (one or more policies of this type)
R REVISED (one or more policies of this type)
★* NEW SUB-NATIONAL
R* REVISED SUB-NATIONAL

i Tendering column includes all countries that have held tenders. Tenders held in 2015 are denoted with a star.

Table 4. Renewable Energy Support Policies (continued)

COUNTRY	Renewable energy targets	REGULATORY POLICIES: Feed-in tariff / premium payment	Electric utility quota obligation / RPS	Net metering / net billing	Transport obligation / mandate	Heat obligation/ mandate	Tradable REC	Tendering[i]	FISCAL INCENTIVES AND PUBLIC FINANCING: Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, VAT or other taxes	Energy production payment	Public investment, loans, or grants
UPPER-MIDDLE INCOME COUNTRIES													
Albania	○	○	○		○		○	○		○	○	○	○
Algeria	R	○						○	○			★	○
Angola					○								○
Azerbaijan	○												○
Belarus	○	○	○								○		○
Belize	R							○					
Bosnia and Herzegovina	R	○						○	○				
Botswana	○								○		○		
Brazil	R			R	R	●		★		○	R		○
Bulgaria	○	○			○								○
China	R	R	○		○	○		★	○	○	○	○	○
Colombia	○			★	○					○	○		○
Costa Rica	R	R		○	○			○			○		
Dominican Republic	○	○		○				○	○	○	○		○
Ecuador	○	R			R			○			○		○
Fiji	○									○	○		
Grenada	R			○							○		
Iran	○	○								○		○	○
Jamaica	○			○	○			○		○	○		
Jordan	R	○		○	○	○		★			R		○
Kazakhstan	○	○					○		○				
Lebanon	R			○							○		○
Libya	○										○		
Macedonia, Republic of	○	○											
Malaysia	○	R	○		R						○		○
Maldives	○	○						○					
Marshall Islands	○										○		
Mauritius	○							○	○		○		○
Mexico	R			○				★		○			○
Mongolia	R	○						○			★		
Montenegro	○	○											
Namibia	R					○							
Palau	○		○										
Panama	○	○		○	○			○		○	○	○	
Paraguay	★				○						○		
Peru	○	○	○	★	○			★			○		○
Romania	○		○		○		○						○
Serbia	○	○							○				
South Africa	○		○		R	○		★	○		○		○
St. Lucia	○			○							○		
St. Vincent and the Grenadines[1]	○			○									
Thailand	R	R			R						○	○	○
Tunisia	R			○					○		○		○
Turkey	R	○			○			★	○				○

[1] Certain Caribbean countries have adopted hybrid net metering and feed-in policies whereby residential consumers can offset power while commercial consumers are obligated to feed 100% of the power generated into the grid. These policies are defined as net metering for the purposes of the GSR.

[2] Spain removed FIT support for new projects in 2012. Incentives for projects that previously had qualified for FIT support continue to be revised.

[3] State-level targets in the United States include RPS policies.

[4] The area of the State of Palestine is included in the World Bank country classification as "West Bank and Gaza." They have been placed in the table using the 2009 "Occupied Palestinian Territory" GNI per capita provided by the United Nations (USD 1,483).

Source: See endnote 1 for this section.

Note: Countries are organised according to annual gross national income (GNI) per capita levels as follows: "high" is USD 12,736 or more, "upper-middle" is USD 4,126 to USD 12,735, "lower-middle" is USD 1,046 to USD 4,125 and "low" is USD 1,045 or less. Per capita income levels and group classifications from World Bank, "Country and Lending Groups," http://data.worldbank.org/about/country-and-lending-groups, viewed January 2016. Only enacted policies are included in the table; however, for some policies shown, implementing regulations may not yet be developed or effective, leading to lack of implementation or impacts. Policies known to be discontinued have been omitted or marked as removed or expired. Many feed-in policies are limited in scope of technology.

i Tendering column includes all countries that have held tenders. Tenders held in 2015 are denoted with a star.

Table 4. **Renewable Energy Support Policies** (continued)

COUNTRY	Renewable energy targets	REGULATORY POLICIES: Feed-in tariff / premium payment	Electric utility quota obligation / RPS	Net metering / net billing	Transport obligation / mandate	Heat obligation/ mandate	Tradable REC	Tendering[i]	FISCAL INCENTIVES AND PUBLIC FINANCING: Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, VAT or other taxes	Energy production payment	Public investment, loans, or grants
LOWER-MIDDLE INCOME COUNTRIES													
Armenia	○	○											
Bangladesh	R							○	○		○		○
Cabo Verde	R			○				○		○		○	
Cameroon											○		
Côte d'Ivoire	R							○			○		
Egypt	○	R		○				○	○		○		
El Salvador								★		○	R	○	○
Ghana	R	○	○	★	○		○		○		○		○
Guatemala	R			○	○			○		○	○		
Guyana	R										○		
Honduras	○	○		○				○		○	○		
India	R	○	○	R*	R	●	○	★	○	○	R	○	○
Indonesia	R	○	○		R			○	○	○	○		○
Iraq								★					
Kenya	○	○		○		○		○			○	○	○
Kyrgyz Republic			○						○		○		
Lesotho	R			○				○	○	○		○	○
Micronesia, Federated States of	○			●									
Moldova	○	○											○
Morocco	R			○				★					○
Myanmar	R										○		
Nicaragua	○	○			○					R	○		○
Nigeria	○	○			○				○		○		○
Pakistan	○	R		★	○		○		●		R		○
Palestine, State of[4]	○	○		○							○		
Philippines	○	R	○	○	○			○	○	○	○	○	○
Senegal	R	○	○	○				○			○		
Sri Lanka	○	○	○	○	○				○		○	○	○
Sudan	R				○								
Syria	○	○		○				○		○			
Tajikistan	○	○									○		○
Ukraine	○	R		○	○				○		R		○
Uzbekistan								○					
Vanuatu	R	○									○		
Vietnam	○	○			○		○		○	○	○		
Zambia									○		○		○
LOW INCOME COUNTRIES													
Burkina Faso								○		○	○	○	
Ethiopia	○				○						○		○
Gambia	○										○		
Guinea	R										○		
Haiti	R												○
Liberia	R										○		
Madagascar	R										○		
Malawi	R				○						○		○
Mali	○				○						○		○
Mozambique	○				○						○		○
Nepal	○	○					○	○	○	○	○		○
Niger	R										○		
Rwanda	○	○						○		○	○		○
Tanzania	○	○							○		○	○	○
Togo	R										○		
Uganda	R	○						○	○		○		○
Zimbabwe	○				○						○		○

○ EXISTING NATIONAL (could also include subnational)
● EXISTING SUB-NATIONAL (but no national)
★ NEW (one or more policies of this type)
R REVISED (one or more policies of this type)
★* NEW SUB-NATIONAL
R* REVISED SUB-NATIONAL

i Tendering column includes all countries that have held tenders. Tenders held in 2015 are denoted with a star.

06

Consumer-owned renewable district heating – the Danish cooperative model

In **Denmark**, a large majority of district heating projects are owned by non-profit consumer co-operatives. In Ringkøbing-Skern, 5,000 consumers own and hold decision-making authority over the community's solar district heating system, contributing to the community's vision of becoming 100% self-sufficient through renewable energy by 2020.

Ringkøbing-Skern, Denmark | Created: 2010 | Members: 5,000 | 15,000 m² solar thermal water collectors for district heating

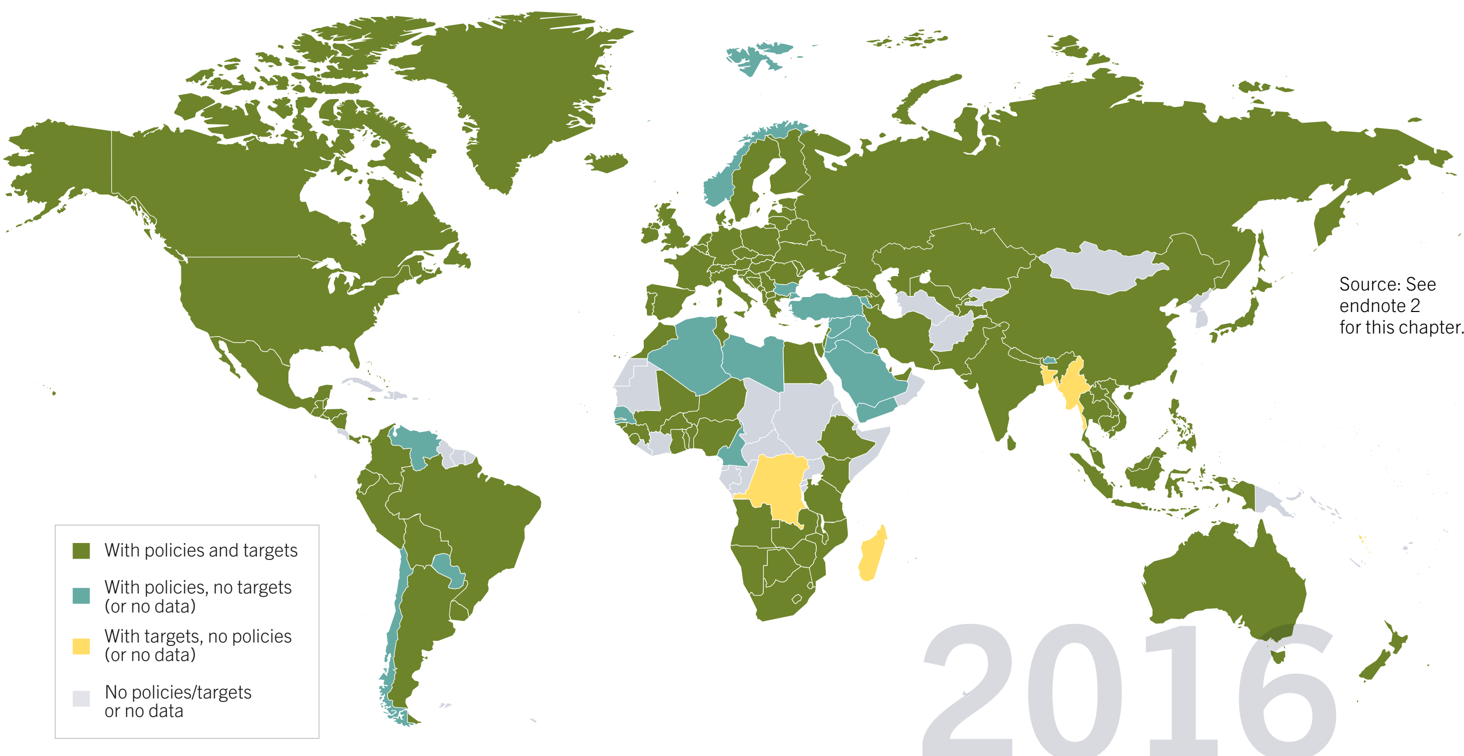
06 ENERGY EFFICIENCY

GLOBAL OVERVIEW

Energy efficiency[i] represents the opportunity to deliver more services for the same energy input, or the same amount of services for less energy input.[1] Conceptually, this is the reduction of losses at each stage of energy conversion, transport, transmission and use, from primary fuel extraction through final energy use, as well as other active or passive measures to reduce energy demand without diminishing the energy services delivered. Energy losses occur during extraction, generation, transmission, distribution and end-use in lighting, appliances, buildings, mechanical work, transport and industry contexts. Consequently, the areas for energy efficiency improvement and investment can occur anywhere along the chain of energy production and use, from primary energy to final energy required to perform the service.

The year 2015 saw an increased emphasis on energy efficiency activities at the international, regional, national and sub-national levels. This was due to the recognition of energy efficiency's key role in reducing energy-related emissions and in providing multiple economy-wide benefits – such as enhanced energy security, reduced fuel poverty and improved public health. By end-2015, at least 146 countries had enacted some kind of energy efficiency policy, while at least 128 countries had enacted one or more energy efficiency targets.[2] *(→ See Figure 42.)*

Figure 42. Countries with Energy Efficiency Policies and Targets, 2015



Source: See endnote 2 for this chapter.

i Renewable energy and energy efficiency are twin pillars of a sustainable energy future. Synergies exist between the two across numerous sectors. This means that the interaction of renewables and energy efficiency can result in an outcome greater than the sum of the parts. In recognition of the important linkages between renewable energy and energy efficiency, this topic was introduced as an annual chapter in GSR 2015. (See Feature in GSR 2012 for more on renewable energy–energy efficiency synergies.)

The international community continued to pursue energy efficiency action by engaging in various collaborative activities such as the Sustainable Energy for All (SE4All) Global Energy Efficiency Accelerator Platform, the G20's Energy Efficiency Action Plan, the Clean Energy Ministerial's energy efficiency initiatives and the European Union's Energy Union Framework Strategy.[3] International organisations initiated several additional energy efficiency activities during the year.[4]

Out of the 189 countries that outlined voluntary plans to decelerate greenhouse gas emissions in their Intended Nationally Determined Contributions (INDCs) for COP21, 147 countries mentioned renewable energy, and 167 countries mentioned energy efficiency; in addition, some countries committed to fossil fuel subsidy reform.[5] Over 50 countries had committed to phasing out fossil fuel subsidies under G20 and Asia-Pacific Economic Cooperation (APEC) processes by the end of 2015.[6] Reducing or eliminating such subsidies brings prices closer to their true economic costs, removing artificial impediments to energy efficiency improvements and renewable energy deployment.

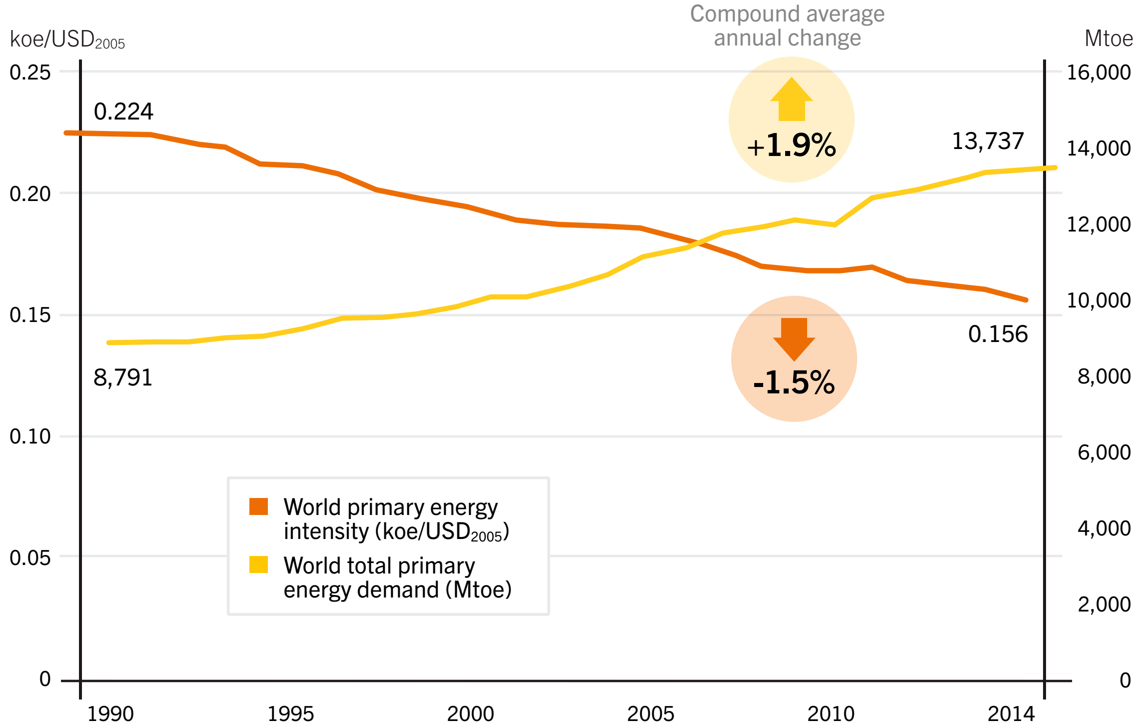
Cities, which accommodate over half of the world's population, also continued to play an increasingly prominent and active role in accelerating energy efficiency. In 2015, cities received international support from a number of initiatives and organisations, such as ICLEI, C40 and the Covenant of Mayors.[7] Commercial and financial actors also mobilised to increase global investment in energy efficiency during the year.[8]

Due to a lack of better indicators, reduction in energy intensity of national economies typically is used as a proxy for improvements in energy efficiency at the national or global level.[9] Energy intensity is calculated as units of energy consumed per unit of economic

output, or gross domestic product (GDP). Changes in energy intensity can reflect changes in energy efficiency of an economy, but they also reflect the impact of other factors, such as structural changes in the economy to less energy-intensive activities and the effect of fuel substitution, particularly to renewable energy.[10]

At the global level, primary energy intensity has decreased continuously for more than two decades. Between 1990 and 2014, primary energy intensity dropped by more than 30%; the average annual rate of decline was 1.5%. Nonetheless, global economic growth has been far greater, resulting in steady net growth in energy demand, increasing by 56% between 1990 and 2014, with an average annual growth rate of 1.9%. Global total primary energy demand (TPED) exceeded 13.7 billion tonnes of oil equivalent in 2014.[11] *(→ See Figure 43.)*

Figure 43. Global Primary Energy Intensity and Total Primary Energy Demand, 1990–2014



Source: See endnote 11 for this section.

Dollars are at constant purchasing power parities.

MARKET AND INDUSTRY TRENDS

BUILDINGS AND APPLIANCES

Buildings accounted for 33% of global total final energy consumption (TFEC) in 2013 (the most recent data available), with the largest portion of the building sector's TFEC (30%) coming from electricity, followed by traditional biomass (25%) for heating and cooking, and natural gas (21%).[12] In 2013, global TFEC of buildings had increased by 34% in relation to 1990.[13] Most of the TFEC used in buildings is for space heating, water heating and cooking.[14] Residential buildings account for almost three-quarters of global building energy use, and non-residential (service sector) buildings account for the remaining share.[15]

Total energy demand in buildings is determined by a variety of factors, including structural design (building envelope); heating, ventilation and air conditioning (HVAC); and electricity load for lighting and appliances. Various options are available for retrofitting existing buildings to improve their energy efficiency and reduce energy demand, thereby lowering operational costs and helping to attract new occupants.[16] Around the world, existing buildings are being retrofitted with improved insulation and windows, more-efficient lighting, and HVAC systems and controls, among others.

Improving the energy efficiency of EU buildings (35% of which are over 50 years old) could reduce the region's total energy consumption by an estimated 5–6%.[17] In OECD countries, the efficiency of energy use in the residential sub-sector improved by 15% between 2002 and 2012.[18]

Increasingly, energy efficiency principles – such as better building design and orientation to take advantage of natural lighting, heat gain or shading, and prevailing breezes – are being integrated along with more-efficient systems and building materials in new buildings. In the EU, for example, new buildings in 2015 consumed about half as much energy as new buildings did in the 1980s.[19]

The market for energy-efficient building technologies as of 2014 was USD 307 billion, representing a wide range of technologies and services, with USD 68 billion coming from energy efficiency retrofits.[20] The largest energy-efficient building market segment is building envelope technologies, including building materials, while mechanical and electrical systems (i.e., HVAC, lighting and controls) also represent major segments.[21] The largest market for energy-efficient buildings is Western Europe, where it is driven by high energy prices and stringent building energy codes. North America and the Asia-Pacific region are major markets as well, and energy efficiency is increasingly important for building projects.[22]

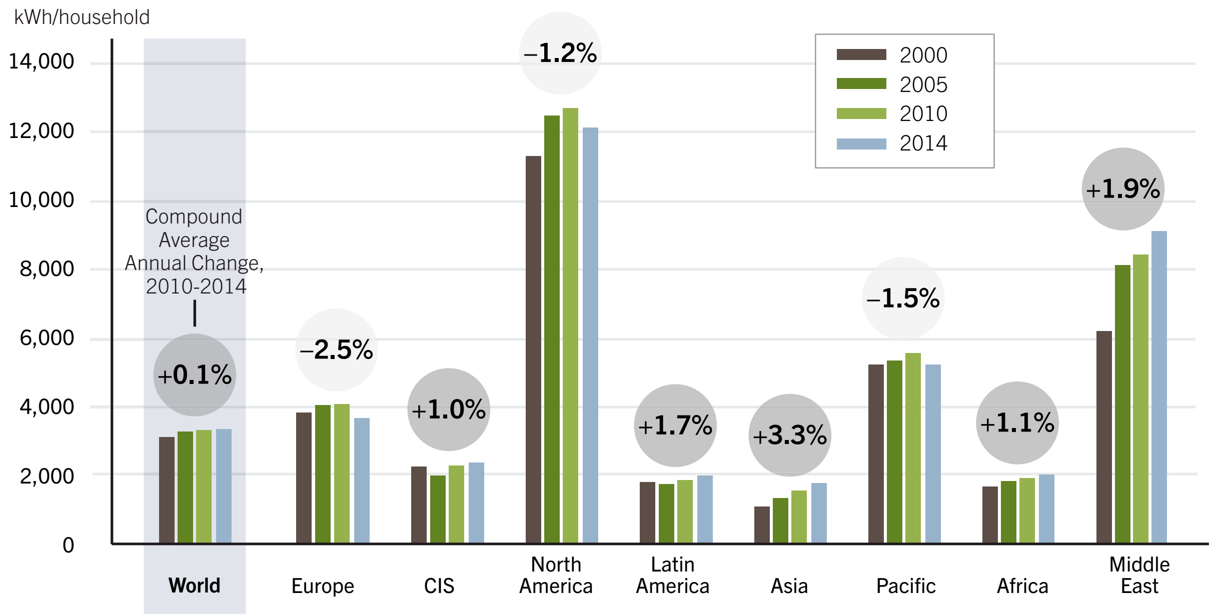
Markets for more-efficient building materials are growing worldwide, both for retrofits and for new construction. For example, China's insulation market has experienced rapid growth since 2000, with average annual growth rates exceeding 15% between 2006 and 2010; during the same period, the market share for low-emissivity glass increased from 1.3% to 7%.[23] Integrating energy-efficient technologies and equipment in buildings can further reduce the sector's energy use. For example, in the United States, the combined use of the most-efficient wall, window and HVAC equipment available on the market in 2015 could reduce the primary energy demand for residential and commercial cooling by 61% and 78%, respectively; decrease the primary energy demand for heating commercial buildings by 77%; and virtually eliminate external sources of heating for residential buildings with the contribution of waste heat from appliances and human occupants.[24]

Among environment-friendly technologies used in buildings, heat pumps offer the opportunity for efficient use of energy for space heating, cooling, and hot water supply, as well as utilisation of distributed renewable electricity (e.g., solar PV) for their operation.[25] The installed capacity of ground-source (geothermal) heat pumps worldwide increased from an estimated 1.9 GW_{th} in 1995 to 15 GW_{th} in 2005 and to 50 GW_{th} in 2015 (18% average annual growth between 1995 and 2015). The United States, China, Sweden, Germany and France were the five leading countries in installed capacity.[26] The European heat pump market is growing at about 3% annually, averaged across all energy sources (air, water, ground and waste heat). However, the ground-source component of the European heat pump market has begun to contract, with sales dropping almost 13% in 2015.[27]

The number of net zero energy buildings (NZEBs) also continued to rise in 2015, although on a limited scale, exemplifying the synergies between energy efficiency and renewable energy. The global NZEB market reached USD 629 million in 2014, and it continued to grow rapidly throughout 2015, particularly in developed regions.[28] In the United States, the number of NZE projects nearly doubled between end-2014 (213 projects) and early 2016, when there were at least 425 projects in at least 42 states.[29]

"Passive house" standards can serve as good guidelines for NZEBs and nearly zero energy buildings (nZEBs) by greatly reducing energy demand for heating and cooling.[30] In 2015, the two leading regions on passive buildings – Europe (12,000 projects) and North America (230 projects) – updated their standards to require more on-site renewable energy generation.[31]

Figure 44. Average Electricity Consumption per Electrified Household, Selected Regions and World, 2000, 2005, 2010 and 2014



Source: See endnote 32 for this chapter.

Electricity accounts for nearly one-third of global TFEC in the buildings sector. Electricity consumption per household is used as an indicator to suggest trends in the efficiency of electricity use at the global and regional levels; however, this does not isolate the effect of improved efficiency from the effect of changes in demand for electricity services.

Globally, electricity consumption per household did not change significantly between 2000 and 2014 – improvements averaged 0.5% annually over this period.[32] *(→ See Figure 44.)* However, trends varied by region. In North America, Europe and the Pacific, electricity consumption per household rose between 2000 and 2010, followed by a decline by 2014, associated in part with improved energy efficiency.[33] In the Commonwealth of Independent States (CIS) and Latin America, electricity consumption per household remained relatively unchanged over the period. In contrast, Africa and Asia saw a gradual increase in electricity consumption per household, and the Middle East experienced almost 50% growth.[34]

"Electricity intensity" is often used as an indicator of energy efficiency in the service sector[i]. The trends in the service sectors of Europe, the CIS, North America, Asia and the Pacific have shown declining electricity intensity since 2010 (and earlier in some regions). The Middle East stands apart, demonstrating a notable increase in electricity intensity in the service sector between 2000 and 2010, although it has levelled off in subsequent years. Africa's electricity intensity in the service sector declined steadily, over the 14-year period. However, as with energy intensity in general, trends in this sector are likely to be the product of a complex set of factors, such as structural changes in economies and relative energy access, in addition to the availability and use of more-efficient technology.[35] *(→ See Figure 45.)*

Appliances and equipment (e.g., computers, fans, motors, etc.) saw a steady increase in final energy demand from 1990 to 2014 and are becoming large energy end-users.[36] The increase is due largely to a rapid increase in the total number of electricity-using products per household, especially televisions and other information and communication technologies.[37]

On average in OECD countries, clothes dryers, refrigerators and freezers consumed about two-thirds as much energy in 2014 as in 1990. In North America, the efficiency of air conditioners, refrigerators and freezers improved rapidly between 1980 and 2010 and has stagnated in subsequent years.[38] In the United

i The electricity intensity of the service sector is defined as the ratio of the electricity consumption of the sector over its value added, measured in constant purchasing power parities.

States, new dishwashers use 40% less energy, and washing machines use 70% less energy, than they did in the 1990s. New refrigerators use only one-quarter of the energy that they used in the 1970s, offering 20% more capacity and a 50% reduction in purchase price.[39] In the OECD countries as a group, demand growth for such appliances has slowed significantly over the past decade, while the energy efficiency of these appliances increased.[40]

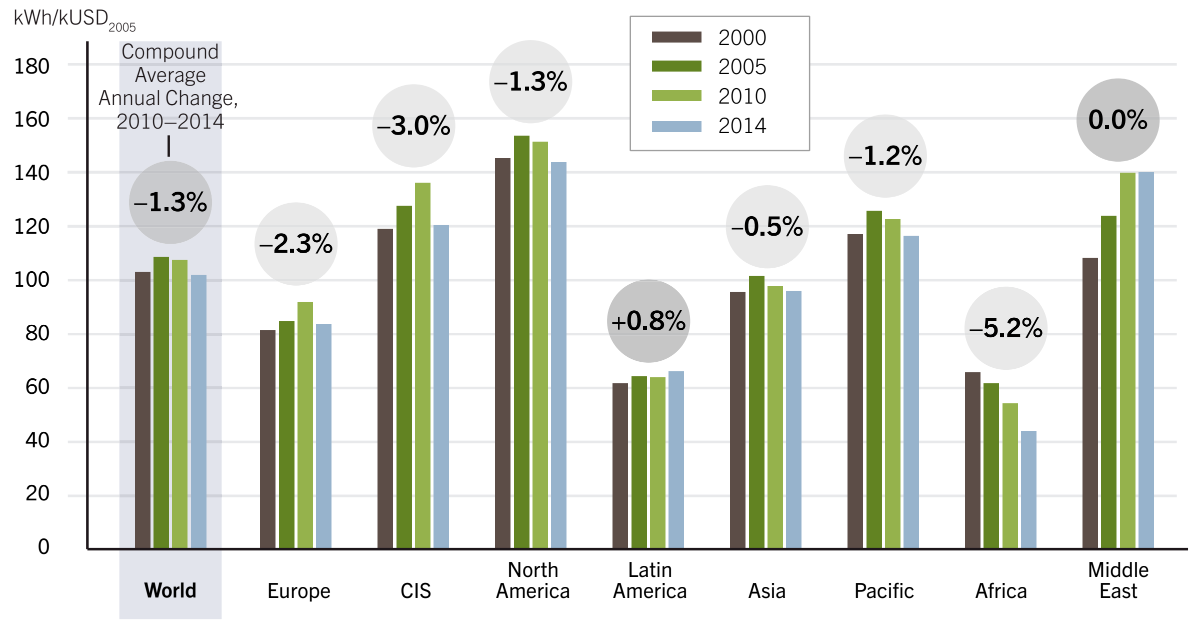
However, energy efficiency improvements have not yet been able to cancel out the effect of growing demand for certain appliance categories, such as televisions and network devices. The average energy intensity of televisions[i] more than doubled between 2000 and 2012 in Australia, Canada, Denmark, France and the Netherlands.[41] This growth reflects a rapid increase in screen size, which has been mitigated to some extent in recent years by more-efficient screen technologies.[42]

In the lighting market, the share of incandescent bulbs continues to decrease, driven largely by phase-out regulations. In several OECD countries, where such regulations are in place, the market share of incandescent bulbs has dropped to a range of 10–20%.[43] Across all developed countries, light-emitting diodes (LEDs) command 3–15% of the market.[44] Even so, the market share of efficient lighting solutions at the global level is still very limited, but it is growing rapidly as prices drop.[45]

Among developing countries, China and India lead in LED manufacturing and usage. While China is already well-established as the world's largest manufacturer, in India, governmental support, accelerated private sector engagement and declining prices are driving demand.[46] In response to the government's LED lamp distribution programme, the number of LEDs produced in India soared from 12 million in 2014 to about 360 million in 2015.[47]

Alongside advances in lighting technology, increased use of "smart" and cloud-based lighting controls is improving the technical efficiency of lighting systems. Such controls provide the opportunity for aggregating data from multiple lighting systems and enabling remote monitoring and control over their usage, resulting in energy savings.[48]

Figure 45. Electricity Intensity of Service Sector (to Value Added), Selected Regions and World, 2000, 2005, 2010 and 2014



Source: See endnote 35 for this chapter.

Dollars are at constant purchasing power parities

i Total energy consumption divided by overall stock.

06

TRANSPORT

Energy intensity of the global transport sector, defined as the ratio of energy consumption of transport to GDP, declined by an average of 1.8% per year between 2000 and 2014, reflected mostly in road transport.[49] *(→ See Figure 46.)* While transport energy intensity declined over this period in most regions, it remained virtually unchanged in Latin America and the Middle East.

Fuel economy of road transport improved at an average annual rate of 2% between 2008 and 2013. Improvement rates were higher on average in OECD countries (2.6%) than in non-OECD countries (0.2%) due to national policies and programmes – particularly fuel economy standards – in the former.[50] By 2013, eight countries (Japan, the United States, Canada, China, the Republic of Korea, Mexico, Brazil and India) and the EU had proposed or established fuel economy standards for passenger and light-commercial vehicles as well as light trucks.[51]

Although their contribution remains quite small, one of the factors driving improvements in fuel economy on a final energy basis is rising sales of electric vehicles (EVs) and plug-in hybrid (electric and natural gas) vehicles[i].[52] By one estimate, global sales of plug-in EVs were up more than 70% in 2015, and by year's end, more than 1 million plug-in EVs were estimated to be on the world's roads, with the largest number operating in the United States.[53] Despite federal and state subsidies, sales of plug-in EVs in the United States fell by more than 5% in 2015 due to the drop in gasoline prices.[54] By contrast, EV sales rose in some countries, including China and Norway, due to aggressive incentives, and EV registration in Europe more than doubled in 2015, while new hybrid vehicle registration increased by 23%.[55]

Because, the share of EVs is less than 0.1% of the global vehicle market, continuing advances in internal combustion efficiency constitute a critical component of energy efficiency improvements in road transport.[56]

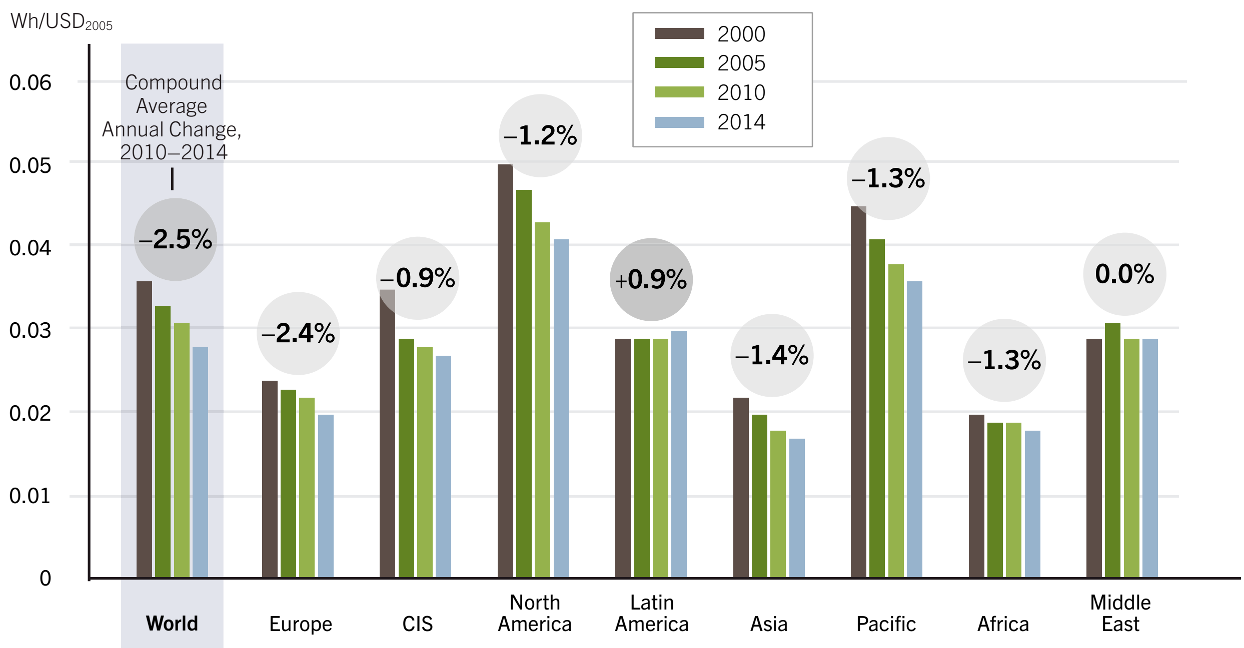
Efficiency of transport also is increasing through the promotion of more-sustainable mobility practices, such as bus rapid transit (BRT). BRT systems continue to spread, and by early 2016 were located in at least 200 cities on all continents, transporting more than 33 million passengers per day – up from 150 cities and 28 million passengers in 2013.[57]

Fuel efficiency is improving for other types of transport, such as aviation and shipping, both of which still have large potential for energy savings. Aviation accounts for about 13% of fossil fuel use in global transport.[58] Between 1990 and 2000, the average fuel efficiency of new aircraft of similar size improved by about 10%, while aviation activity for both passenger travel and freight transport grew by a factor of 2.5, but it levelled off thereafter.[59] Fuel efficiency can be increased further through improved infrastructure; operational measures, such as reducing the weight of on-board equipment; and improved aircraft design and materials.[60]

The shipping industry consumes about 250–325 million tonnes of fuel per year (4% of the total share of transport use).[61] The efficiency of individual ships varies greatly based on design, fuel and power sources, and operations. The efficiency of ships built during the 1970s was consistently poor, followed by improvements across all ship types and size categories in the 1980s (by 22–28%) due to a combination of rapidly increasing fuel prices and constant or declining freight rates.[62] Between

Figure 46. Energy Intensity in Transport, Selected Regions and World, 2000, 2005, 2010 and 2014

Source: See endnote 49 for this chapter.



Dollars are at constant purchasing power parities.

i Except in the context of renewable power, EVs are not necessarily more energy-efficient than internal combustion engine vehicles on a primary energy basis (and emissions may be higher), depending on the energy source. As the shares of non-thermal renewables increase in the power mix, the contribution of these vehicles to overall (primary) energy efficiency will only increase.

1990 and 2008, design-related efficiency of new ships declined by about 10% because cargo capacity or capital costs were given higher priority than fuel efficiency, but thereafter it began to improve again.[63]

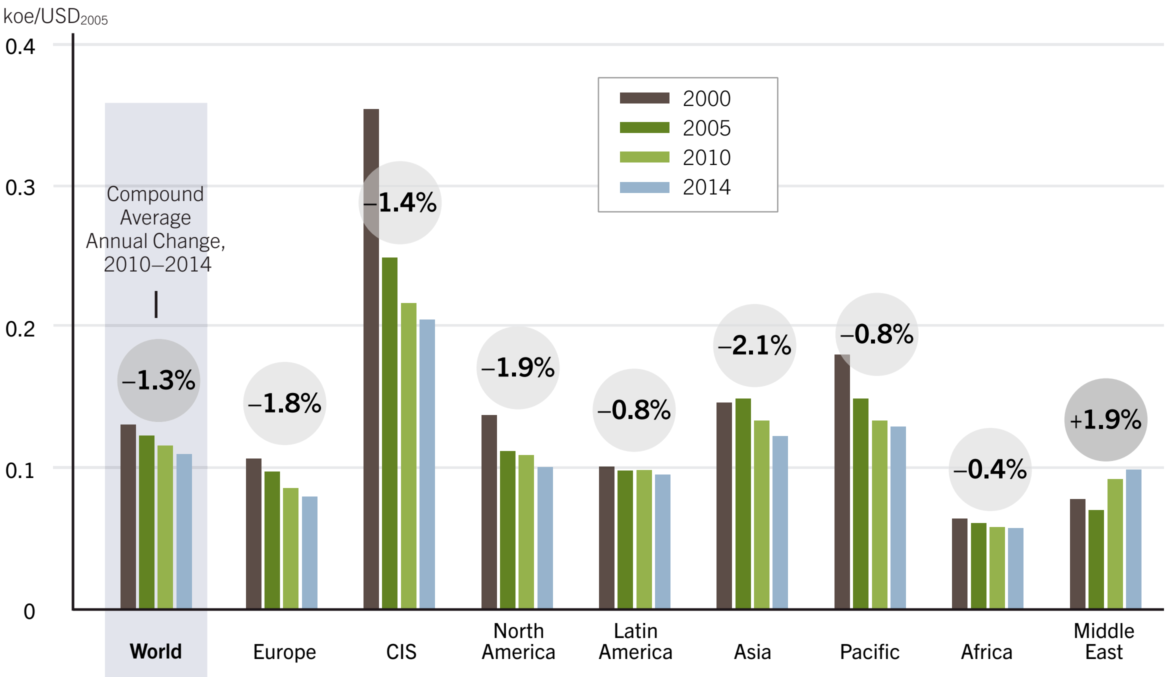
INDUSTRY AND POWER

Industry accounted for approximately 29% of global TFEC in 2013, including electricity demand, and for almost 40% of TFEC when certain metals smelting and non-energy uses are included.[64]

Between 2000 and 2014, global energy intensity in industry[i] decreased by an average of 1.2% annually and declined across all regions except the Middle East.[65] *(→ See Figure 47.)* Energy intensity of industry declined by an average of almost 4% annually in the CIS, while in Latin America and Africa the rate of decline averaged below 1% a year.[66] However, because this indicator is influenced largely by structural changes in the economy, it is unclear what portion of these reductions reflects improvements in energy efficiency. For instance, in OECD countries, reductions in industrial energy intensity were driven by a combination of changes in economic activities (e.g., caused by economic recession, energy efficiency improvements, and structural effects (e.g., displacement of energy-intensive manufacturing), with the latter taking a prevailing role.[67]

In the power sector, energy efficiency is affected mostly by energy losses in generation at thermal power plants and through transmission and distribution losses. Fossil fuel power plants convert only about one-third of their primary energy inputs into electricity, while conversion losses for non-thermal renewables are either relatively low or otherwise insignificant. Therefore, achieving greater shares of non-thermal renewable power increases primary energy efficiency by reducing conversion losses.

Figure 47. Energy Intensity in Industry, Selected Regions and World, 2000, 2005, 2010 and 2014



Source: See endnote 65 for this chapter.

Dollars are at constant purchasing power parities.

i The energy intensity of industry is defined as the ratio of the final energy consumption of industry over the value added, measured in constant purchasing power parities.

The average primary energy efficiency of electricity generation[i] increased between 2000 and 2014 across all regions but Latin America, where it declined by 0.5%.[68] The efficiency of power generation ranges from about 30–35% in the CIS (a region heavily reliant on coal) and the Middle East (heavily reliant on oil), to almost 60% in Latin America, where a significant share of electricity is generated by hydropower. Efficiency of thermal power plants, which account for most of the world's generating capacity, increased between 2000 and 2014 in all regions, with average improvements of around 9% in the Americas, 6% in Asia and under 5% in other regions.[69] Efficiency of coal-fired power plants, specifically, increased during this period in most regions, with the greatest improvements seen in Asia (12%) and the CIS (8%). Among different types of thermal power plants mentioned above, gas-fired plants experienced the highest levels of improvement between 2000 and 2014, with the increase in average efficiency exceeding 20% in North America and Africa.[70]

About 8% of the world's electricity generating capacity is in combined heat and power (CHP) facilities, with a total global installed electric capacity of 325 GW. CHP captures waste heat and utilises it to meet thermal energy demand. CHP systems, which capture and re-use waste heat from power generation, are generally 75–90% efficient in their overall use.[71]

The rate of transmission and distribution (T&D) losses, incurred through resistance and voltage conversion losses on the grid, varies across regions, ranging between 5% and 15% in 2014, with lower losses occurring generally in more-efficient power grids in developed regions.[72] Efficient and superconducting transformers and high-temperature superconducting cables, including direct current and ultra-high-voltage transmission, are considered promising solutions for increasing electrical energy efficiency and reducing T&D losses.[73] Other solutions may involve advanced demand monitoring and management to reduce losses; automation to measure and control the flow of power and improve system reliability; and movement towards smart grids[ii] to manage loads, congestion and supply shortages.[74] The increased use of distributed energy also reduces T&D losses by producing electricity closer to where it is utilised.

Smart grids offer a potential to improve energy efficiency and reliability, better integrate high shares of renewable energy and improve the responsiveness of both supply and demand to conditions in real time.[75] The global market for smart grid technologies – such as transmission upgrades, substation automation, distribution automation, smart metering, etc. – is growing rapidly; between 2010 and 2015, the market more than tripled (from USD 26 billion to USD 88 billion), while respective annual investments more than doubled (from USD 81 billion to USD 187 billion).[76]

INVESTMENT

Investment in energy efficiency can be defined as the monetary value of public expenditure, private funds, public-private ventures and commercial commitments to technologies and assets that lead directly and indirectly to energy savings relative to business-as-usual scenarios (energy productivity improvements not undertaken). It is estimated that investments in energy-efficient assets and technologies yield two- to four-fold returns in lifetime cost savings.[77] In 2013, global investments in energy efficiency totalled an estimated USD 130 billion. This figure covers the end-user categories of buildings, transport and industry (but not fuel switching). It also includes associated costs, e.g., taxes, shipping and labour.[78]

Green bonds have emerged as one of the most substantial sources of capital for energy efficiency projects, especially in the transport sector. Energy efficiency improvements in industry and buildings (including efficient lighting and appliances) also source financing through debt. As of September 2015, an estimated 27% of all labelled green bond issuances was for energy efficiency projects (including low-carbon buildings).[79]

Historically, development banks dominated the green bond market in all categories, including those issued for energy efficiency; however, green bonds are being issued increasingly by corporations, municipalities and commercial banks, with additional activity from niche sources, such as universities.[80] Bonds issued for energy efficiency categories increased considerably during 2013 through 2015. Specifically, debt issues covering certain categories of transport reached USD 418.8 billion in 2015 (16.8% average annual increase from 2013). Efficient buildings- and industry-related bonds, including appliances, surged to USD 19.6 billion in 2015 (nearly 58% average annual increase from 2013). In total, energy efficiency-related bonds reached USD 438.4 billion in 2015 (as of early December 2015; 17.8% average annual increase from 2013).[81]

Development finance institutions (DFIs), or multilateral development banks, have played a critical role in energy efficiency investments by providing loans, credit lines, partial risk guarantees and other products to both public recipients and private parties. Between 2012 and 2014, investments in energy efficiency leveraged through multilateral development banks climbed by almost 45%, from USD 3.5 billion to USD 5 billion.[82] Among the initiatives undertaken by DFIs in 2015 was the launch of the Partial Risk Sharing Facility for Energy Efficiency project by the Global Environment Facility, the World Bank and the Government of India. This USD 43 million initiative is designed to help energy service companies mobilise investment by banks in India for energy efficiency opportunities by protecting against potential loss, which can inhibit upfront investment.[83]

The German development bank KfW continues to be a leader in energy efficiency investment; in 2015, it invested more than USD 4.1 million in its Energy Efficiency programme, up from approximately USD 3.4 million the previous year. Between 2006 and 2014, KfW invested more than USD 202.7 billion in its Energy-Efficient Construction and Refurbishment Funding programmes.[84]

i The efficiency of power generation is the net electricity production divided by energy inputs.

ii According to the European Technology Platform, a smart grid is an electricity network that can intelligently integrate the actions of all users connected to it in order to efficiently deliver sustainable, economic and secure electricity supplies.

The Green Climate Fund included in its initial set of investments (in November 2015) an allocation of USD 217 million for an energy efficiency green bond in Latin America and the Caribbean with the Inter-American Development Bank.[85] Meanwhile, Goldman Sachs announced in late 2015 that it would expand its clean energy investment target – which includes energy efficiency opportunities – to USD 150 billion by 2025.[86]

Some innovative investment mechanisms have emerged that enhance financial activity in energy efficiency. For example, yieldcos, an investment instrument used for certain renewable energy assets, were employed for energy efficiency projects in the United States and Europe from the second half of 2013 to mid-2015; however, their role in the growth of renewable power mergers and acquisitions activity tapered off in the second half of 2015 due to a significant decline in the value of several publicly traded yieldcos.[87] In addition, Property-Assessed Clean Energy (PACE) financing, a form of on-bill financing that was first developed in the early 2000s, continues to expand in the United States in both commercial and residential markets.[88] PACE financing was designed to address one of the most significant barriers to energy efficiency and renewable energy retrofits: upfront costs.

In September 2015, 70 financial institutions from more than 20 countries – including national, regional and global banks – committed to increase financing for energy efficiency investments.[89] In November 2015, 20 countries (including France, Germany, Japan, the Republic of Korea and the United States) formed the Mission Innovation initiative to double R&D investment in low-carbon technologies, including end-use energy efficiency.[90] In parallel to the Mission Innovation, the Breakthrough Energy Coalition was launched by 28 private capital investors to invest in clean technologies, including energy efficiency.[91]

POLICIES, PROGRAMMES AND PLANS

An increasing number of governments worldwide – at the regional, national, state and local levels – have enacted policies to improve energy efficiency in the buildings, transport and industry sectors. Drivers for such policies include increasing energy security, advancing economic growth and competitiveness, reducing fuel poverty and mitigating climate change.[92] In developing countries, increased efficiency can make it easier to provide energy services to those who lack access.[93] Policies – including targets, regulations, standards and labelling, and fiscal incentives – aim to address a number of barriers to accelerating energy efficiency actions. These include a lack of capacity and knowledge, misplaced incentives[i] across different stakeholders, energy subsidies and regulatory barriers.[94]

Additionally, some policies attempt to harness the synergies between energy efficiency and renewable energy, despite limited new examples addressing the two in concert. However, there are numerous examples of policies and programmes that are focused on renewable energy and energy efficiency simultaneously.

Targets to improve energy efficiency have been established at all levels of government, including the regional level. A large portion of existing targets is aimed at a particular sector or sub-sector. In late 2014, the EU updated its economy-wide efficiency improvements target (relative to 1990 levels) from 20% by 2020 to 27% by 2030, although the 2030 targets were adopted as non-binding.[95] During the period 2014–2015, several EU Member States revised targets that they established in 2013 through National Energy Efficiency Action Plans (NEEAPs) under the EU Energy Efficiency Directive.

Although most of the absolute targets for 2020 remained unchanged in 2015, three countries (Bulgaria, Croatia and Slovakia) reduced their targets, while several others (including Cyprus, France, Greece, Hungary, Malta, Spain and Sweden) made their targets more ambitious.[96]

Some countries have defined both energy efficiency and renewable energy targets through roadmaps and national action plans. In late 2015, Chile adopted an Energy Roadmap to 2050 that includes the reduction of energy poverty, improvements in energy efficiency (i.e., equipment standards, new buildings standards) and an increase in renewable energy generation (to 70% by 2050) throughout the period.[97] In 2014, Japan adopted its Strategic Energy Plan, which describes the need for energy-efficient construction and renovation, LED lighting, Intelligent Transportation Systems (ITS) and energy management systems in industrial facilities, while also planning for accelerating deployment of renewables and achieving grid parity over the mid to long term.[98] Also adopted in 2014, Indonesia's National Energy Plan aims to transform the country's energy mix by 2025 by improving energy efficiency and increasing the renewable energy share in the energy mix from 2% up to 23%.[99]

In Africa, some countries furthered their efforts to advance renewables and energy efficiency in national initiatives in 2015. Algeria adopted its Renewable Energy and Energy Efficiency Program, which includes a strategy to develop and expand the

i Misplaced incentives occur if those who make decisions about investing in energy efficiency improvements are different from those who benefit from the resulting energy savings.

integration of renewable energy in the long term, while emphasising the important role of energy savings and energy efficiency.[100] Tanzania issued a draft plan to promote energy efficiency in various sectors and increase the contribution of renewable energy to the electricity generation mix.[101] Additionally, a Demand Side Management Campaigns Unit was created within TANESCO (Tanzania Electric Supply Company Limited) to build awareness of peak load management among large power consumers and to install power factor correctors.[102] Rwanda's grid system loss-reduction plan proposes an investment of USD 60 million to reduce losses from 23% to 15% (which would produce capacity savings equivalent to constructing a 15 MW power plant). The country's Energy Sector Strategic Plan (ESSP) also calls for the development of solar water heater regulations and a dedicated demand-side management unit within its power utility.[103]

A few countries also developed national roadmaps and plans focusing specifically on energy efficiency. For example, the Philippines' Energy Efficiency Roadmap 2014–2030 aims for a 40% reduction in energy intensity over that period, calling for a 1.6% annual reduction in energy consumption against baseline forecasts and energy savings of approximately 10.7 million tonnes of oil equivalent per year by 2030 (all relative to a 2010 baseline). This was followed by the Philippines' National Energy Efficiency and Conservation Action Plan 2016–2020, which outlines initiatives to expand on those in the Roadmap.[104]

To achieve their energy efficiency targets, governments are introducing new regulations or updating existing ones to drive efficiency improvements. In order to comply with the EU target for energy efficiency improvement, a number of EU Member States are implementing various regulatory measures. For example, Luxembourg modified existing regulations on building energy performance to comply with directive 2010/31/EU.[105] Hungary adopted a National Building Energy Performance Strategy 2015–2020 that established primary energy-saving targets to be achieved through buildings refurbishment and introduced stricter requirements for the cumulative primary energy performance for buildings – while also promoting the use of renewable energy sources for heating and cooling in buildings (e.g., solar collectors, biomass and heat pumps).[106]

In late 2015, the Energy Community Ministerial Council adopted EU Directive 2012/27/EU, setting a 20% energy efficiency target for 2020 within the Energy Community[i] and paving the way for additional improvements in the future, while also including consideration of increasing renewables. As in the EU, the Energy Community Directive requires Contracting Parties to adopt energy savings obligation schemes for energy distribution and retail companies; to enact policies to improve efficiency in heating and cooling and to advance co-generation; and to establish annual targets for the renovation of central government buildings. Notably, efficient heating and cooling in the Directive includes the use of renewable energy sources and the reduction of non-renewable primary energy.[107]

Also in 2015, Belarus updated its energy efficiency legislation to improve data, monitoring, education, training and international collaboration.[108] Kazakhstan amended its Law on Energy Efficiency (2012) to provide more legal details on the functioning of energy service companies.[109] In Kenya, Energy Management Regulations (2012) mandate that consumers of more than 180,000 kWh annually conduct energy audits every three years.[110]

In 2014, Austria adopted the Federal Energy Efficiency Act, setting the national target for the country's final energy consumption not to exceed 1.05 PJ in 2020.[111] As of January 2015, energy suppliers in Austria are required to implement demonstrable measures to increase energy efficiency to achieve the targeted annual increase in efficiency of 0.6% through an energy-savings obligation system; large-scale consumers must implement an energy management system or otherwise face an energy audit every four years, while small and medium consumers can participate voluntarily.[112]

A number of new policies in the United States focused on the buildings sector. The national-level Energy Efficiency Improvement Act was enacted into law in 2015, promoting energy efficiency in commercial buildings; establishing new regulations for smart grid-enabled water heaters; ensuring public disclosure of building energy performance and usage; and establishing efficiency requirements for building space leased by any federal agency.[113] Atlanta (Georgia) and Portland (Oregon) became the 12th and 13th US cities to adopt energy efficiency benchmarking through policies to improve building energy performance.[114]

Standards and labelling programmes are the primary tools used to improve the efficiency of a variety of appliances and other energy-consuming products. As of end-2015, such programmes were operational in at least 80 countries and covered more than 50 types of commercial, industrial and residential appliances and equipment.[115] Developments in 2015 include an update to the EU Minimum Energy Performance Standards (MEPS) for low-voltage motors and transformers, with the enactment of more-stringent energy efficiency requirements.[116]

Kenya adopted its Energy Bill to (among other things) establish a designated agency that is responsible for energy efficiency improvements, including the adoption or development of standards (notably, the Energy Bill is also designed to clarify issues related to the ownership of renewable energy sources and licensing and to establish a feed-in-tariff system).[117] Kenya's standards and labelling programme proposes MEPS for a range of

i Members of the Energy Community include the EU and eight Contracting Parties: Albania, Bosnia and Herzegovina, Kosovo, the former Yugoslav Republic of Macedonia, Moldova, Montenegro, Serbia and Ukraine. As of April 2016, Armenia, Georgia, Norway and Turkey participated as Observers.

appliances, and the country also has set a standard for improved biomass cook stoves.[118] Additionally, Uganda developed MEPS for several appliances, and its National Bureau of Standards has a testing laboratory to support appliance quality monitoring.[119]

Many of the new standards set in 2015 were in the transport sector. For example, a new EU mandate requires that all new passenger cars registered from 2015 onwards consume no more than 5.6 litres per 100 km (l/km) of petrol or 4.9 l/100 km of diesel. By 2021, this requirement will be further tightened to 4.1 l/100 km of petrol or 3.6 l/100 km of diesel.[120] Japan also increased its performance requirements under existing fuel-efficiency regulations for light- and heavy-duty vehicles.[121] Saudi Arabia set new regulations for light-duty vehicles to improve vehicle performance by 4% annually, increasing from an average fuel economy of 8.3 l/100 km in 2015 to 5.3 l/100 km by 2025.[122] Uganda's Fuel Efficiency Initiative Programme supports the development of policies and regulations that promote the use of fuel-efficiency vehicles.[123]

Fiscal incentives – including rebates, tax reductions and low-interest loans – also have been employed to stimulate improvements in energy efficiency. Italy is offering USD 382 million (EUR 350 million) of soft financing for energy efficiency improvements in public school and university buildings.[124] Lithuania is using structural funds from the EU to provide investment incentives for industry to implement efficiency measures between 2014 and 2020.[125] In 2015, Germany began encouraging municipalities, municipal companies, religious communities and small and medium-sized enterprises (SMEs) to implement energy performance contracting through the provision of grants for consulting on related matters.[126]

Spain introduced several programmes and allocated funds to support fiscal incentives in 2015. Through its National Energy Efficiency Fund (established in 2014), Spain allocated USD 184 million (EUR 168 million) for energy renovation of buildings, efficiency improvements in the transport and industrial sectors, and more-efficient street lighting.[127] In addition, Spain initiated the Efficient Vehicle Incentives Program, with a budget of USD 191 million (EUR 175 million), to encourage the purchase

of new energy-efficient vehicles.[128] The country also launched a subsidy scheme, allocating USD 219 million (EUR 200 million) for energy efficiency improvements, including improving the thermal insulation of buildings and advancing the efficiency of heating and lighting systems.[129] Beyond Europe, Canada started to offer a number of rebates for energy-efficient equipment in 2015, such as ductless heat pumps, cold-climate ductless heat pumps, Energy Star-certified refrigerators and efficient clothes washers.[130]

In terms of financing, energy efficiency and renewable energy actions often are considered within a broader area of clean or sustainable energy, and, therefore, both types of projects can be eligible under the same financing scheme. For example, in 2015, the US Environmental Protection Agency introduced the Clean Energy Incentive Program (CEIP) to reward early investments in renewable energy generation and demand-side energy efficiency measures that generate carbon-free energy or reduce end-use energy demand by 2020 and/or 2021.[131] In terms of financial incentive programmes that explicitly target both renewables and efficiency, Nigeria's National Renewable Energy and Energy Efficiency Policy, adopted in April 2015, provides incentives for selling, manufacturing and importing energy-efficient products, while also promoting policies for renewable energy sources.[132]

07

Scaling-up community energy

The Belgian co-operative **Ecopower** is demonstrating how to initiate and scale up local community energy initiatives to create a wider community energy movement. Ecopower develops and funds renewable energy projects and now supplies 1.1% of all households in Flanders, Belgium with electricity. These projects enable citizens to invest in the generation and use of renewable electricity, which has resulted in the co-operative's EUR 48 million in equity. Rather than focus on an individual community, Ecopower aims to spread community energy projects across the region.

Flanders, Belgium | Created: 1991 | Members: 50,000 | Concept: universal local renewable energy projects

07 FEATURE: COMMUNITY RENEWABLE ENERGY

Citizens' involvement in the energy transition

The concept of community renewable energy (community power, energy democracy[i], prosumer and energy citizenship[ii]) revolves around the idea of community ownership, participation and shared interest in renewable energy initiatives, although there is no widely agreed definition.[1] In community energy initiatives, citizens, social entrepreneurs and/or community organisations participate directly in the energy transition by investing in, producing, selling and distributing renewable energy or delivering energy services.

Community energy may describe a geographic community or a community of interest, and may be in the form of shared renewable energy projects or small locally controlled grid-connected systems.[2]

Common characteristics include:

- Citizens running projects through communities, such as co-operatives or development trusts;
- A co-operative, democratic or non-corporate structure in which individuals participate actively in decision making;
- Tangible local benefits to people living or working close to projects; and
- Profits returning to the community or being re-invested in other community energy schemes.[3]

Community energy initiatives have existed since the middle of the 19th century. Such projects enable communities to share their resources and can be used to power small-scale industrial activities. It was not until the late 1970s, however, that community energy initiatives began to become more associated with modern renewables, beginning in Denmark with the Danish Wind Turbine Owners' Association in 1978.

Now many communities are turning to local renewable energy production. Most projects are focused on electricity generation, although examples also exist for heating and transport. Project feasibility and the choice of technology depend on the regulatory framework; the potential to export the power, heat or fuel produced (determined by regulations and the available infrastructure); and possible remuneration.[4] A wide range of services may be delivered, including the provision of infrastructure, energy distribution and grid management, renewable energy generation and energy provision to end-users.

The extent of public participation in community renewable energy projects varies. Generally, the form that the initiative takes is determined by local needs and resources and the policy and regulatory environment.

Consolidated data on community initiatives are very limited, particularly in the developing world, as information is decentralised and often is not collected at the local level. Nonetheless, community energy networks to share data and strategies are slowly being established at the national and regional levels in some countries.

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i Energy democracy goes beyond national security of the energy supply to bringing energy resources and infrastructure under public or community ownership or control, from Gegenstrom 2012, www.gegenstromberlin.net, cited in http://rosaluxeuropa.info/userfiles/file/Energy-democracy-in-Europe.pdf.

ii Energy citizenship refers to the idea that citizens and communities can contribute more broadly to energy transitions when a wider consciousness of energy issues has been initiated. This encompasses the prosumer and community energy, but also citizens beginning to own or operate distribution grids, as well as supply and energy service companies, from ClientEarth, "Model Legal Frameworks for citizen-owned renewable energy," http://www.clientearth.org/reports/community-power-report-250614.pdf.

STATUS AND TRENDS

Since 2008, there has been a marked rise in initiatives focused on community renewable energy, especially in Europe.[5] In industrialised countries, particularly over the past decade, community renewable energy initiatives have tended to rely on government incentive schemes and market mechanisms, whereas in the developing world, initiatives often rely on additional government and NGO support or on partnerships with private enterprises.[6] To some degree, community energy projects across the world have tended to develop in more affluent communities, often where there is greater energy literacy and interest in environmental issues.[7] The role and potential of community renewable energy projects in larger urban areas is, as yet, underdeveloped.[8] Projects historically have relied on wind power, small-scale hydropower and micro-hydro (typically 5-100 kW), biogas and solar PV technologies.

In Europe, more than 2,800 energy co-operatives were in operation as of 2015.[9] In Germany, the number of renewable energy co-operatives increased from 67 to 772 between 2008 and 2014.[10] Although almost half (46%) of the installed renewable energy capacity in Germany is owned by private individuals and farmers, the growth of renewable energy co-operatives has decelerated, due largely to recent changes in energy policy.[11] The Netherlands has experienced similar growth, with the number of energy co-operatives increasing from 19 in 2008 to 500 in 2015.[12] In Scotland, an estimated 508 MW of community and locally owned capacity began operation in 2015, already exceeding the government's 2020 target of 500 MW.

In Australia, 45 community energy projects had been deployed by 2015, and 70 more were in planning phases.[13] However, projects in Australia have faced difficulties in the form of investment regulations (limiting small-scale projects to no more than 20 investors per project within a 12-month period) and financial constraints.[14]

Community renewable energy projects are beginning to play an important role in many parts of the United States and Canada, where individual states and provinces are free to set their own policies governing co-operatives and local energy policy.[15] Several US states – including Colorado, Massachusetts, Minnesota and Vermont – and the Canadian provinces of British Columbia and Ontario have supported community renewable energy projects through tax credits, net metering and other policy measures.[16]

Some countries in Asia have a history of community energy projects, particularly in micro-hydro generation. For example, in India, community energy projects (largely micro-hydro) have existed since the 1950s. In Nepal, roughly 15% of electricity is produced by community-owned micro-hydro installations.[17]

In Latin America, renewable energy co-operatives are playing an important role in the electrification of rural areas.[18] Costa Rica, with its ambitious goal of becoming carbon-neutral in 2021, is home to four energy co-operatives with over 180,000 members, controlling almost 15% of the energy market.[19] In Chile, new co-operative initiatives are emerging out of a period of intensive opposition to proposed large-scale coal-fired and hydroelectric generation. Recent legislative changes are allowing the entry of small-scale generators to the electricity market for the first time.[20]

In Africa, existing community energy projects have been initiated largely by international NGOs, governments, and educational and religious institutions, such as the SharedSolar initiative developed by Columbia University. In poor, rural parts of Africa, formal recognition such as bank accounts or official holdings are rare for individuals and small businesses. Without such recognition, initiating community energy projects is difficult.[21] Nonetheless, there are some successful examples of more localised initiatives, for example in East Africa, where community energy projects have driven energy access efforts in areas that lack a centralised electricity grid.[22] (→ *See Sidebar 5.*)

ORGANISATIONAL STRUCTURES

Organisational structures of community energy initiatives may be in the form of partnerships, co-operatives, community trusts and foundations, limited liability companies, non-profit customer-owned enterprises and housing associations.[23] The choice of structure often is determined by the interest or goal of the particular community as well as the regulatory framework. There is a general lack of analyses about organisational structures of community energy, especially in developing countries.

Partnerships generally are governed by a management board, with the ownership rights linked to the financial stake of each partner. In Germany, partnerships with a private limited company are a commonly used legal entity for community renewable energy ownership. In Denmark, partnerships also are referred to as co-operatives, because of their role as a typical form of "association", and come with different liabilities and tax implications.

Co-operatives are democratic structures that follow a set of internationally agreed principles and make decisions on a "one-member-one-vote" basis; day-to-day operation is governed by an elected board. Renewable energy co-operatives exist in Europe, North America, Africa and parts of Asia and Latin America.[24] Although the structure varies from one country to another, co-operatives tend to be the most common structure for community renewable energy initiatives.[25] In the developing world, co-operatives historically have played a role in other sectors as well, such as in the agricultural sector.

Community trusts and foundations share benefits from community renewable energy projects with citizens that do not have enough money to invest, ensuring that returns on investments are used for specific local or community purposes. In the United Kingdom, "Development Trusts" may take a number of different legal forms: a charity, a company limited by guarantee, a community interest company (CIC) or an industrial and provident society (IPS). In Scotland, Development Trusts have become a popular form of community ownership of wind projects.[26] In Denmark, the community foundation model has been used to create a community pot of money where generous profits from renewable energy production can go towards funding local development.[27]

Public and private limited liability companies (LLCs) are based on a legal framework that limits the liability of investors, protecting their private assets from losses. LLCs are becoming increasingly common instruments for implementing community energy projects, particularly in Europe and North America.[28] One example is the University Park Community Solar LLC, formed by residents in the US state of Maryland to reduce their reliance on local utilities. Their efforts were facilitated by the state's net metering policy and tradable renewable energy certificates, which created revenue-generation opportunities for the local community.[29]

Non-profit, customer-owned enterprises are similar to co-operatives in structure but add particular rules: for example, ownership might require grid connection, or votes may be capped to limit the power of individuals who own multiple properties. This type of structure is ideal for community power projects that rely on grid networks that are small or independent.[30] It is particularly popular in Denmark's district heating sector.[31]

Housing associations are private, non-profit organisations that can finance community renewable energy projects by adjusting tenant rents. They are highly regulated in many countries and can form a number of different legal structures. In the United Kingdom, for example, housing associations may be in the form of an IPS, a co-operative society or a company limited by guarantee. In Denmark, tenants living in the social housing estate are members of a housing association and are in charge of managing the estate. Usually such community energy projects succeed only if there is a high degree of acceptance among local tenants.

Local governments also are important actors in community renewable energy. Under municipalisation (as it is called in the United States), or Stadtwerke (Germany), local governments – often in collaboration with community co-operatives – manage and operate local power utilities to provide a not-for-profit electricity service. In Germany, local governments own and operate 1,428 utility companies. Similar efforts are being undertaken in South Asia by panchayats (rural local governments). For example, the Indian village of Odanthurai has been investing in renewables since 2005. It has installed 65 solar street lights, a biomass gasifier to pump drinking water and a 350 kW wind turbine, creating a power surplus that allows the village to sell excess power back to the state electricity board.[32]

DRIVERS AND BENEFITS

There are multiple reasons for the upward trend of renewable energy-based community initiatives. Drivers include potential economic benefits, increased control over energy generation, and social and environmental benefits. In most cases, the rationale for a given project involves a combination of drivers.

The cost of renewable energy technologies (especially solar PV and wind power) has fallen to such a degree that implementation has become economically viable in many locations. For some community groups, the potential for revenue generation is a key reason to become involved in a renewable energy project.

This revenue can be spent on other projects within a community, helping to make it more resilient and its future more sustainable. Renewable energy projects also can provide a second revenue stream for local farmers, offering them sustainable and profitable investment options. As seen with community solar projects in the United States and with onshore wind in Denmark, community ownership has been able to protect consumers from volatile energy prices, while guaranteeing a long-term return.[33]

Another driver is the growing interest in citizen control over energy production, which enables communities to choose the technologies and resources used, and to keep investments local.[34] In an increasing number of communities, people have become dissatisfied with the inflexibility of the traditional centralised model of energy production, which provides them with little-to-no influence over the sustainability of their energy supply and generally does not reinvest profits locally.[35] For some communities, sending a political message is a key motivation.[36]

Environmental concerns – ranging from local air pollution and health impacts to global climate change – often are important drivers for community energy initiatives. Community projects can

Sidebar 5. Community Energy Initiatives Using Renewable Energy

Communities around the world are mobilising to address their energy needs with renewable energy. Community-based renewable energy initiatives have manifested in different ways across regions. Selected examples include:

- The Belgian co-operative, Ecopower, was founded in 1992 and has financed several projects including 12 wind turbines, 323 solar PV installations, 3 hydropower installations and 1 co-generation plant. Its roughly 43,000 members, who are shareholders and decision makers, invest in and own the projects within their communities. The equivalent of 1.3% of all Belgian households are supplied with electricity from Ecopower.
- Residents of Germany's Jühnde village united in 2005 to construct a biogas unit using the local corn harvest as feedstock. The village's 195 co-operative members decided to recover waste heat and improve project efficiency, which resulted in the construction of a district heat network. The project created several permanent jobs in the village and additional revenue for local farmers.
- In Scotland, the community of Fintry organised itself into the Fintry Development Trust in 2007 and negotiated with a developer to buy into a commercial wind farm planned near the town. The community now receives profits by means of partial ownership and sales to the electric grid.
- Bangladesh's women-owned Coastal Electrification and Women's Development Cooperative (CEWDC) was formed in 1999. Members of the co-operative manufacture and sell solar lamps and charge controllers for solar home systems (SHS), as well as batteries, and they provide energy to the off-grid rural community of Char Montaz and four surrounding islands. The local women are both providers and users of the solar energy and earn a monthly wage for assembling the SHS.
- In the United States, University Park Community Solar LLC, made up of 30 community investors, began its operations in 2010. It installed a 22 kW solar PV system on the roof of a local church, which generates electricity that the church purchases at a discounted rate. The system provides additional revenue for community members through the sale of solar renewable energy credits.
- The Brazilian co-operative CRELUZ was formed in 1966 and has grown to 87 full-time staff and 20,000 members. Its members comprise families (with one member per family) who play an active role in decision making regarding the investment of the co-operative's profits. CRELUZ invests in and installs local mini-hydropower plants, providing electricity to households that previously were off-grid. It now operates 4,500 kilometres of power lines that reach 36 unicipalities and approximately 80,000 beneficiaries.
- The Energy for Development network has set up six local solar PV mini-grid projects in Uganda, Kenya and Cameroon, which supply electricity to off-grid villages. A co-operative manages and maintains the local projects, re-investing all profits into the project and the community. The network also provides micro-financing to support the local community's ability to purchase rechargeable battery kits for lighting, radios, televisions, etc., and provides loans for business development.
- SharedSolar provides electric infrastructure and service to off-grid communities through a combination of renewable energy, smart metering and storage management, and has built micro-grids for communities in Mali (since 2010) and Uganda (since 2011). Local energy co-operatives and community-owned partnerships are established under a pay-as-you-go model.
- Comet-ME, an Israeli-Palestinian non-governmental organisation, provides renewable electricity to more than 1,600 off-grid Palestinian residents across 28 communities in the West Bank. Electricity is generated by hybrid wind-solar PV mini-grids. Comet-ME's model is based on community participation, ownership, training and capacity building (technicians train local community members in basic maintenance and diagnostics), and the organisation makes a strong effort to procure materials from local sources.

Source: See endnote 22 for this chapter.


Ecopower


Comet-ME

be a successful means for addressing and raising awareness about environmental issues, as these projects are at a scale where people can engage, and the projects can be appropriately adapted to the local context.[37] Ownership in community energy projects has been shown to shift mindsets from energy consumption to the balance between consumption and production. Local ownership builds a constituency for distributed renewable energy in a way that buying renewable-derived electricity as a commodity may not.[38]

Other social benefits – including improved energy access, security and reliability of supply, a strengthened sense of community, and local job creation and related capacity building – also drive community renewable energy projects.[39] Energy (power or heat) that a community produces and uses locally is not subject to the same level of transmission and distribution losses that occur with more centralised systems. In addition, in some remote, off-grid areas, the presence of community-owned energy access initiatives has led to a leapfrogging to renewables.[40]

ENABLING ENVIRONMENT AND OUTLOOK

The main challenges and barriers for community energy initiatives worldwide include: uncertainty and risk caused by changes or fluctuations in regulations, support systems and available financing; continued government support of existing energy players (including fossil fuels); a lack of local skills, knowledge, confidence and engagement of local populations; and local opposition.[41] Community energy projects in Europe, in particular, have been inhibited by legal and administrative bottlenecks, rather than by financial barriers.[42]

Many of these risks have a greater impact on local community efforts than on large corporations that can draw from a larger network and spread risk across numerous projects and regions.[43] In countries with strong, centralised monopolies, the energy market may not be equipped for, or open to, small bottom-up initiatives. Even in countries with state support for community energy initiatives, it can be an enormous challenge for local communities to access the funding (either through grants, loans or the sale of shares), necessary skills, time and other resources to organise and construct a project. For these reasons, community projects often are slow to come to fruition or may even fail during the development process.[44]

An enabling environment for community energy involves stable and long-term political support from governments at the local, regional, national and even supra-national (e.g., EU) levels, as well as dependable provision of credit and capacity-building frameworks.[45] The policy framework plays a crucial role in fostering community renewable energy projects, even more so than overcoming technical barriers, and regions that have supporting policies have seen a proliferation of community energy initiatives.[46]

Several countries (mostly within Europe) and local governments (e.g., US states) have enacted policies that have either directly or indirectly supported community energy. Denmark and Scotland have specific policy frameworks for local participation. Project developers in Denmark are legally required (with some exceptions) to offer 20% ownership of schemes to local communities through the country's Promotion of Renewable Energy Act.[47] The Scottish Government set a target of 500 MW by 2020 for community energy, implemented financial support mechanisms and provided clear guidance on Good Practice Principles for Shared Ownership of Onshore Renewable Energy Developments.[48]

Stable feed-in tariff schemes (e.g., in Germany) have enabled and encouraged investments from communities and individual citizens, supporting the emergence of a variety of business models based on community energy. Important policy elements have included the purchase obligation and the guaranteed price for the electricity produced. Other policy measures – such as tax credits, net metering or small-scale incentive schemes – have helped to support community energy initiatives in the United States, Latin America and Asia.

The movement for 100% renewable energy among local governments also has enabled community energy projects. City governments such as Copenhagen, Frankfurt, San Francisco and Vancouver, and regional governments such as Fukushima prefecture and Lower Austria, have developed locally appropriate models for community energy, which support the goals to achieve a full transition to renewable energy.[49]

Micro-credit also has been used as a model for initiating community energy projects (particularly in Latin America, Africa and South Asia), while at the same time addressing poverty by increasing energy access.

Because many projects are led by volunteers or community members that have limited capabilities compared with commercial developers, the success of community energy often relies on the long-term commitment and perseverance of key individuals. Capacity-building efforts often play an important role in community energy initiatives. The Belgian co-operative Ecopower uses some of its profits to provide the local municipality with an energy expert on staff, building capacity from the bottom up.[50] New types of energy co-operatives are emerging – such as Sharenergy (UK), Energy4All (UK) and Bürgerwerke (Germany) – that work with communities, helping to set up new energy co-operatives, building capacity of community energy groups and offering administrative support.[51]

Although the number of community energy projects is increasing worldwide, driven by an ever-diversifying set of possible models, challenges persist. A coherent and comprehensive policy framework that integrates community energy across governance levels and sectors, as well as building capacity and expertise, is needed to realise the full potential of community renewable energy.[52]

Table R1. Global Renewable Energy Capacity and Biofuel Production, 2015

	ADDED DURING 2015	EXISTING AT END-2015
POWER GENERATION (GW)		
Bio-power	5.5	106
Geothermal power	0.3	13.2
Hydropower	28	1,064
Ocean power	~0	0.5
Solar PV	50	227
Concentrating solar thermal power (CSP)	0.4	4.8
Wind power	63	433
HEATING / HOT WATER (GW_{th})		
Modern bio-heat	10	315
Geothermal direct use	1.2	22
Solar collectors for water heating[1]	27	435
TRANSPORT FUELS (billion litres / year)		
Ethanol production	3.8	98
Biodiesel production	-0.3	30
Hydrotreated vegetable oil (HVO)	0.9	4.9

[1] Additions are net and do not include air collectors. Data are preliminary estimates.

Note: Numbers are rounded to nearest GW/GW_{th}/billion litres, except for numbers <15, which are rounded to nearest decimal point; where totals do not add up, the difference is due to rounding. Rounding is to account for uncertainties and inconsistencies in available data. Data reflect adjustments to year-end 2014 capacity data (particularly for bio-power and hydropower). For more precise data, see Reference Tables R2–R9, Market and Industry Trends chapter and related endnotes.

Source: See endnote 1 for this section.

Table R2. Renewable Electric Power Global Capacity, Top Regions/Countries, 2015

TECHNOLOGY	Global	EU-28	BRICS[1]	China	United States	Germany	Japan	India	Italy	Spain
	GW			GW						
Bio-power	106	36	31	10.3	16.7	7.1	4.8	5.6	4.1	1
Geothermal power	13.2	1	0.1	~0	3.6	~0	0.5	0	0.9	0
Hydropower	1,064	126	484	296	80	5.6	22	47	18	17
Ocean power	0.5	0.3	~0	~0	0	0	0	0	0	~0
Solar PV	227	95	50	44	26	40	34	5.2	18.9	5.4
Concentrating solar thermal power (CSP)	4.8	2.3	0.4	~0	1.7	~0	0	0.2	~0	2.3
Wind power	433	142	180	145	74	45	3	25	9	23
Total renewable power capacity including hydropower	**1,849**	**402**	**746**	**496**	**202**	**97**	**65**	**83**	**51**	**49**
Total renewable power capacity (not including hydropower)	**785**	**276**	**262**	**199**	**122**	**92**	**43**	**36**	**33**	**32**
Per capita capacity (kilowatts per inhabitant, not including hydropower)	0.1	0.5	0.1	0.1	0.4	1.1	0.3	0.03	0.5	0.7

[1] The five BRICS countries are Brazil, the Russian Federation, India, China and South Africa.

Note: Global total reflects additional countries not shown. Table shows the top seven countries by total renewable power capacity, not including hydropower; if hydropower were included, countries and rankings would differ somewhat (the top seven would be China, United States, Brazil, Germany, Canada, India and Japan). Numbers are based on best data available at time of production. To account for uncertainties and inconsistencies in available data, numbers are rounded to the nearest 1 GW, with the exception of the following: capacity totals below 20 GW and per capita totals are rounded to the nearest decimal point (except for India, which is rounded to the nearest 0.01 kW). Where totals do not add up, the difference is due to rounding. Capacity amounts of <50 MW (including pilot projects) are designated by "~0." For more precise capacity data, see Global Overview chapter and Market and Industry Trends chapter and related endnotes. Numbers should not be compared with prior versions of this table to obtain year-by-year increases, as some adjustments are due to improved or adjusted data rather than to actual capacity changes. Hydropower totals, and therefore the total world renewable capacity (and totals for some countries), reflect an effort to omit pure pumped storage capacity. For more information on hydropower and pumped storage, see Methodological Notes on page 262.

Source: See endnote 2 for this section.

Table R3. Biofuels Global Production, Top 16 Countries and EU-28, 2015

COUNTRY	ETHANOL	BIODIESEL	HVO[1]	TOTAL	CHANGE RELATIVE TO 2014
			billion litres		
United States	56.1	4.8	1.2	**62.1**	+2.0
Brazil	28.2	4.1		**32.3**	+2.6
Germany	0.9	2.8		**3.8**	-0.6
Netherlands	0.4	1.5	1.7	**3.5**	+0.8
France	0.9	2.4	0.1	**3.4**	+0.3
China	2.8	0.4		**3.1**	-0.4
Argentina	0.8	2.1		**2.9**	-0.7
Thailand	1.2	1.2		**2.4**	+0.2
Singapore	~0	1.0	1.2	**2.2**	+0.3
Canada	1.7	0.3		**2.0**	no change
Indonesia	0.1	1.7		**1.8**	-1.2
Spain	0.5	0.6	0.2	**1.3**	no change
Colombia	0.5	0.6	1.0	**1.0**	no change
Belgium	0.6	0.4		**1.0**	no change
India	0.7	0.1		**0.8**	+0.3
Malaysia	~0	0.7		**0.7**	+0.2
EU-28	**4.1**	**11.5**	**2.5**	**16.1**	**+0.6**
World	**98.3**	**30.1**	**4.9**	**130.7**	**4.5**

[1] Hydrotreated vegetable oil

Note: All figures are rounded to the nearest 0.1 billion litres; comparison column notes "no change" if difference is less than 0.05 billion litres; ~0 denotes production below 50 million litres. Ethanol numbers are for fuel ethanol only. Table ranking is by total volumes of biofuel produced in 2015, and not by energy content. Where numbers do not add up, it is due to rounding. Ethanol data were converted from cubic metres to litres using 1,000 litres/cubic metre; biodiesel data were converted from units of 1,000 tonnes using a density value for biodiesel to give 1,136 litres per tonne based on U.S. National Renewable Energy Laboratory, *Biodiesel Handling and Use Guide*, Fourth Edition (Golden, CO: 2009), http://www.biodiesel.org/docs/using-hotline/nrel-handling-and-use.pdf?s-fvrsn=4. HVO data were converted from tonnes to litres using a conversion factor of 780 kg/m^3, from Neste Oil, *Hydrotreated Vegetable Oil (HVO) – Premium Renewable Biofuel for Diesel Engines* (Espoo, Finland: February 2015), https://www.neste.com/sites/default/files/attachments/hvo_handbook_original_2014.pdf. Data can vary considerably across sources. For more information, see Bioenergy section in Market and Industry Trends chapter and related endnotes.

Source: See endnote 3 for this section.

REN21 Renewable Energy Policy Network for the 21st Century

Table R4. Geothermal Power Global Capacity and Additions, Top Six Countries, 2015

	ADDED 2015	TOTAL END-2015
	MW	GW
TOP COUNTRIES BY ADDITIONS		
Turkey	159	0.6
United States	71	3.6
Mexico	53	1.1
Kenya	20	0.6
Japan	7	0.5
Germany	6	0.04
TOP COUNTRIES BY TOTAL CAPACITY		
United States	71	3.6
Philippines	–	1.9
Indonesia	–	1.4
Mexico	53	1.1
New Zealand	–	1.0
Italy	–	0.9
World Total	**315**	**13.2**

Source: See endnote 4 for this section.

Table R5. Hydropower Global Capacity and Additions, Top Six Countries, 2015

	ADDED 2015	TOTAL END-2015
	GW	GW
TOP COUNTRIES BY ADDITIONS		
China	16.1	296
Brazil	2.5	92
Turkey	2.2	26
India	1.9	47
Vietnam	1.0	15
Malaysia	0.7	5
TOP COUNTRIES BY TOTAL CAPACITY		
China	16.1	296
Brazil	2.5	92
United States	0.1	80
Canada	0.7	79
Russian Federation	0.1	48
India	1.9	47
World Total	**28**	**1,064**

Note: Capacity additions are rounded to the nearest 0.1 GW, and totals are rounded to the nearest 1.0 GW. For more information and statistics, see Hydropower section in Markets and Industry Trends chapter and related endnotes.

Source: See endnote 5 for this section.

REN21 Renewable Energy Policy Network for the 21st Century

Table R6. Solar PV Global Capacity and Additions, Top 10 Countries, 2015

	TOTAL END-2014	ADDED 2015	TOTAL END-2015
		GW	
TOP COUNTRIES BY ADDITIONS			
China	28.3	15.2	43.5
Japan	23.4	11	34.4
United States	18.3	7.3	25.6
United Kingdom	5.4	3.7	9.1
India	3.2	2	5.2
Germany	38.2	1.5	39.7
Republic of Korea	2.4	1.0	3.4
Australia	4.1	0.9	5.1
France	5.6	0.9	6.6
Canada	1.9	0.6	2.5
TOP COUNTRIES BY TOTAL CAPACITY			
China	28.3	15.2	43.5
Germany	38.2	1.5	39.7
Japan	23.4	11	34.4
United States	18.3	7.3	25.6
Italy	18.6	0.3	18.9
United Kingdom	5.4	3.7	9.1
France	5.6	0.9	6.6
Spain	5.4	0.1	5.4
India	3.2	2	5.2
Australia	4.1	0.9	5.1
World Total	**177**	**50**	**227**

Note: Country data are rounded to the nearest 0.1 GW; world totals are rounded to the nearest 1 GW. Rounding is to account for uncertainties and inconsistencies in available data; where totals do not add up, the difference is due to rounding. Data for Canada, Japan and Spain are converted to direct current (DC) from official data reported in alternating current (AC). Data reflect a variety of sources, some of which differ quite significantly, reflecting variations in accounting or methodology. For more information, see Solar PV section in Market and Industry Trends chapter and related endnotes.

Source: See endnote 6 for this section.

Table R7. Concentrating Solar Thermal Power (CSP) Global Capacity and Additions, 2015

COUNTRY	TOTAL END-2014	ADDED 2015	TOTAL END-2015
		MW	
Spain	2,300	0	2,300
United States	1,628	110	1,738
India	225	0	225
Morocco	20	160	180
South Africa	0	150	150
United Arab Emirates	100	0	100
Algeria	25	0	25
Egypt	20	0	20
Australia	12	0	12
Thailand	5	0	5
World Total	**4,335**	**420**	**4,755**

Note: Table includes all countries with operating commercial CSP capacity at end-2015. Several countries with commercial capacity also have pilot or demonstration facilities that are not included in the table. Additional countries that had small pilot or demonstration plants in operation by year's end include Canada (1.1 MW), China (5 MW), France (1.6 MW), Germany (1.5 MW), Israel (6 MW), Italy (7 MW), Oman (7 MW) and Turkey (5 MW). National data are rounded to the nearest MW, and world totals are rounded to the nearest 5 MW. Rounding is to account for uncertainties and inconsistencies in available data; where totals do not add up, the difference is due to rounding. For more information, see CSP section in Market and Industry Trends chapter and related endnotes.

Source: See endnote 7 for this section.

Table R8. Solar Water Heating Collectors Total Capacity End-2014 and Newly Installed Capacity 2015, Top 18 Countries

	TOTAL END-2014 (GW_{th})			GROSS ADDITIONS 2015 (MW_{th})		
COUNTRY	**Glazed**	**Unglazed**	**Total**	**Glazed**	**Unglazed**	**Total**
China[1]	289.5	0	289.5	30,450	0	30,450
Turkey	12.7	0	12.7	1,467	0	1,467
Brazil	5.2	2.5	7.7	555	427	982
India[2]	5.2	0	5.2	826	0	826
United States	2.1	14.9	17	119	585	704
Germany	12.4	0.4	12.8	564	0	564
Australia	2.4	3.5	5.9	143	280	423
Israel	3.1	~0	3.2	300	1	301
Mexico	1.3	0.7	2	169	73	242
Denmark	0.7	~0	0.7	194	0	194
Poland	1.2	0	1.2	194	0	194
Greece	3.0	0	3	189	0	189
Spain	2.3	0.1	2.4	166	2	168
Italy	2.8	~0	2.8	161	0	161
Austria	3.3	0.4	3.6	95	0	95
France	1.7	0.1	1.8	71	0	71
Switzerland	0.9	0.1	1	61	4	64
Japan	2.6	0	2.6	59	0	59
Total 18 Top Countries	352.3	22.8	375.1	35,782	1,371	37,153
World Total	**383**	**26**	**409**	**38,100**	**1,500**	**39,600**

[1] In 2014, China settled on a new methodology for calculating cumulative capacity, which assumes a 10-year lifetime for Chinese-made systems. China and world data reflect this change.

[2] India data are by fiscal year rather than by calendar year.

Note: Countries are ordered according to newly installed glazed water collector capacity in 2015. Data are for glazed and unglazed water collectors excluding air collectors, which add almost 1.64 GW_{th} to the year-end world total for 2014. Numbers are rounded: end-2014 data for individual countries and total top 18 countries are rounded to nearest 0.1 GW_{th}, and world totals are rounded to nearest 1 GW_{th}; additions in 2015 for individual countries and total top 18 countries are rounded to nearest 1 MW_{th}, and world additions are rounded to nearest 100 MW_{th}. "~0" denotes capacity below 50 MW_{th}. Where totals do not add up, the difference is due to rounding. By accepted convention, 1 million square metres = 0.7 GW_{th}. The year 2014 is the most recent one for which firm global data on total capacity in operation are available. It is estimated, however, that 435 GW_{th} of solar thermal capacity (water collectors only) was in operation worldwide by end-2015. For more information, see Solar Thermal Heating and Cooling section in Market and Industry Trends chapter and related endnotes.

Source: See endnote 8 for this section.

Table R9. Wind Power Global Capacity and Additions, Top 10 Countries, 2015

	TOTAL END-2014	ADDED 2015	TOTAL END-2015
		GW	
TOP COUNTRIES BY ADDITIONS			
China[1]	97.3/114.6	33/30.8	129.3/145.4
United States	65.4	8.6	74
Germany[2]	39.2	6	45
Brazil	6	2.8	8.7
India	22.5	2.6	25.1
Canada	9.7	1.5	11.2
Poland	3.8	1.3	5.1
France	9.3	1.1	10.4
United Kingdom	12.6	1	13.6
Turkey	3.7	1	4.7
TOP COUNTRIES BY TOTAL CAPACITY			
China[1]	97.3/114.6	33/30.8	129.3/145.4
United States	65.4	8.6	74
Germany[2]	39.2	6	45
India	22.5	2.6	25.1
Spain	23	0	23
United Kingdom	12.6	1	13.6
Canada	9.7	1.5	11.2
France	9.3	1.1	10.4
Italy	8.7	0.3	9
Brazil	6	2.8	8.7
World Total	**370**	**63**	**433**

[1] For China, data to the left of the "/" are the amounts officially classified as connected to the grid and operational (receiving FIT premium) by year's end; data to the right are total installed capacity, most, if not all, of which was connected to substations by year's end. The world totals include the higher figures for China. (See Wind Power section and related endnotes for more details.)

[2] For Germany, some onshore capacity was decommissioned in 2015, for a net increase of about 5.7 GW. (See Wind Power section and related endnotes for more details.)

Note: Additions represent gross capacity. Country data are rounded to nearest 0.1 GW; world data are rounded to nearest 1 GW. Rounding is to account for uncertainties and inconsistencies in available data; where totals do not add up, the difference is due to rounding or repowering/removal of existing projects. Data reflect a variety of sources, some of which differ quite significantly, reflecting variations in accounting or methodology. For more information, see Wind Power section in Market and Industry Trends chapter and related endnotes.

Source: See endnote 9 for this section.

BACK

Table R10. Electricity Access by Region and Country, 2013 and Targets

WORLD/REGION/COUNTRY	ELECTRIFICATION RATE IN 2013	PEOPLE WITHOUT ACCESS TO ELECTRICITY IN 2013	TARGETS
	Share of population with access	Millions	Share of population with access
Africa	**43%**	**635**	
North Africa	**99%**	**1**	
Sub-Saharan Africa	**32%**	**634**	
Developing Asia	**86%**	**526**	
Latin America	**95%**	**22**	
Middle East	**92%**	**17**	
Africa			
Algeria	99%	0.4	
Angola	30%	15	
Benin	31%[1]	7	
Botswana	66%	1	→ 80% by 2016
Burkina Faso	18.5%[1]	14	
Burundi	5%	10	
Cabo Verde	93.6%[1]	0.2	
Cameroon	55%	10	
Central African Republic	3%	5	
Chad	4%	12	
Comoros	69%	0.2	
Congo	42%	3	
Côte d'Ivoire	26%	15	
Democratic Republic of the Congo	9%	61	→ 60% by 2025
Djibouti	50%	0.4	
Egypt	99.6%	0	
Equatorial Guinea	66%	0.3	
Eritrea	32%	4	
Ethiopia	24%	71	
Gabon	89%	0.2	
Gambia	36%	1	
Ghana	72%	7	→ 100% by 2020
Guinea	26%	9	
Guinea-Bissau	21%	1	
Kenya	20%	35	→ 70% by 2020
Lesotho	28%	2	→ 40% by 2020
Liberia	10%	4	
Libya	99.8%	0	
Madagascar	15%	20	
Malawi	9%	15	
Mali[2]	26%	11	→ 61% by 2033 (rural)
Mauritania	28%	3	
Mauritius	100%	0	
Morocco	99%	0.4	
Mozambique	39%	16	

Table R10. **Electricity Access by Region and Country, 2013 and Targets** (continued)

WORLD / REGION / COUNTRY	ELECTRIFICATION RATE IN 2013	PEOPLE WITHOUT ACCESS TO ELECTRICITY IN 2013	TARGETS
	Share of population with access	Millions	Share of population with access
Africa (continued)			
Namibia	32%	2	
Niger	14%	15	→ 15% by 2020
Nigeria	64%[1]	95	→ 75% by 2020
Rwanda	21%	9	
São Tomé and Príncipe	59%	0.1	
Senegal	55%	6	→ 60% by 2016 → 62% by 2022 (rural)
Seychelles	99%	0	
Sierra Leone[2]	5%	6	→ 75% by 2025 → 100% by 2030
Somalia	15%	9	
South Africa	85%	8	→ 100% by 2019
South Sudan	1%	11	
Sudan	35%	25	
Swaziland	27%	1	
Tanzania	24%	37	→ 75% by 2035
Togo	27%	5	
Tunisia	100%	0	
Uganda	15%	32	
Zambia	26%	11	
Zimbabwe	37%[1]	8	→ 66% by 2030 → 90% (urban) → 51% (rural)
Developing Asia			
Bangladesh	61%	60	→ 100% by 2021
Brunei	100%	0	
Cambodia	34%	10	
China[2]	99.8%	1	→ 100% by 2022
India	81%	237	
Indonesia	81%	49	
Korea, Democratic People's Rep. of	26%	18	→ 90% by 2017
Lao PDR	87%	1	
Malaysia	100%	0	
Mongolia	90%	0.3	
Myanmar	32%	36	
Nepal	76%	7	
Pakistan	73%	50	
Philippines	80%[1]	21	
Singapore	100%	0	
Sri Lanka	94%	1	
Thailand	99%	1	
Vietnam	97%	3	

Table R10. **Electricity Access by Region and Country, 2013 and Targets** (continued)

WORLD/REGION/COUNTRY	ELECTRIFICATION RATE IN 2013	PEOPLE WITHOUT ACCESS TO ELECTRICITY IN 2013	TARGETS
	Share of population with access	Millions	Share of population with access
Latin America			
Argentina	96%	1.5	
Barbados	98%	0.0	→ 100% by 2021
Bolivia[2]	88%	1.2	→ 100% by 2025 (rural)
Brazil	99.5%	1.0	
Chile	98%	0.4	
Colombia	98%	1.2	→ 97.45% by 2017
Costa Rica[2]	99%	0.0	
Cuba	98%	0.2	
Dominican Republic	97%	0.3	
Ecuador	97%	0.5	→ 98.9% by 2022 (urban) → 96.3% by 2022 (rural)
El Salvador	94%	0.4	
Guatemala	90%	1.6	
Haiti	28%	7.4	
Honduras	89%	0.9	
Jamaica	93%	0.2	
Mexico	98%	3.7	
Nicaragua	82%[1]	1.5	
Panama	91%	0.3	
Paraguay	99%	0.1	
Peru	90%	3	
Suriname	90%	0.1	
Trinidad and Tobago	97%	0.1	
Uruguay	99%	0.0	
Venezuela	99.7%	0.1	

Table R10. Electricity Access by Region and Country, 2013 and Targets (continued)

WORLD / REGION / COUNTRY	ELECTRIFICATION RATE IN 2013	PEOPLE WITHOUT ACCESS TO ELECTRICITY IN 2013	TARGETS
	Share of population with access	Millions	Share of population with access
Middle East			
Bahrain	100%	0.0	
Iran	99%	1.1	
Iraq	98%	0.6	
Jordan	100%	0.0	
Kuwait	100%	0.0	
Lebanon	100%	0.0	
Oman	98%	0.1	
Palestine, State of[3]	99%		
Qatar	100%	0.0	
Saudi Arabia	99%	0.2	
Syria	93%	1.6	
United Arab Emirates	100%	0.0	
Yemen	46%	13.3	
Pacific			
Federated States of Micronesia[1]	55%	0.0	→ 90% by 2020 (Rural)
All Developing Countries	**76%**	**1,200**	
World[4]	**83%**	**1,201**	

[1] Data are for 2014.
[2] Country had a renewable energy target for 2015.
[3] The State of Palestine rate is defined by the number of villages connected to the national electricity grid.
[4] Includes countries in the OECD and economies in transition.
Disclaimer: The tracking of data related to energy access and DRE systems is a challenging process. Discrepancies or inconsistencies with past reporting may be due to improvements in data collection.
Source: See endnote 10 for this section.

REN21 Renewable Energy Policy Network for the 21st Century

Table R11. Population Relying on Traditional Use of Biomass for Cooking, 2013

REGION / COUNTRY	SHARE OF POPULATION IN 2013	POPULATION (MILLIONS)
	Share of population	Millions
Africa	**68%**	**754**
Sub-Saharan Africa	**80%**	**753**
North Africa	**0.5%**	**1**
Developing Asia	**51%**	**1,895**
Latin America	**14%**	**65**
Middle East	**4%**	**8**
Africa		
Angola	54%	12
Benin	94%	10
Botswana	37%	1
Burkina Faso	95%	16
Burundi	98%	10
Cabo Verde	31%	0.2
Cameroon	78%	17
Central African Republic	97%	4
Chad	95%	12
Comoros	74%	1
Congo	74%	3
Côte d'Ivoire	79%	16
Democratic Republic of the Congo	95%	64
Djibouti	16%	0.1
Equatorial Guinea	44%	0.3
Eritrea	63%	4
Ethiopia	95%	89
Gabon	21%	0.3
Gambia	95%	2
Ghana	83%	21
Guinea	98%	11
Guinea-Bissau	98%	2
Kenya	84%	37
Lesotho	62%	1
Liberia	98%	4
Madagascar	98%	22
Malawi	93%[1]	16
Mali	98%	15
Mauritania	57%	2
Mauritius	0%	0
Morocco	3%	1
Mozambique	96%	25
Namibia	54%	1
Niger	97%	17
Nigeria	70%	121
Rwanda	98%	12
São Tomé and Príncipe	71%	0.1
Senegal	61%	9
Sierra Leone	98%	6
Somalia	95%	10
South Africa	11%	6
South Sudan	11%	6
Sudan	98%	11

Table R11. Population Relying on Traditional Use of Biomass for Cooking, 2013 (continued)

REGION / COUNTRY	SHARE OF POPULATION IN 2013	POPULATION (MILLIONS)
Africa (continued)		
Swaziland	61%	1
Tanzania	96%	47
Togo	95%	6
Uganda	98%	37
Zambia	82%	12
Zimbabwe	71%	10
Developing Asia		
Bangladesh	89%	140
Cambodia	89%	13
China	33%	450
India	67%	841
Indonesia	39%	98
Korea, Democratic People's Rep. of	47%	12
Lao PDR	65%	4
Mongolia	63%	2
Myanmar	93%	49
Nepal	80%	22
Pakistan	58%	105
Philippines	54%	53
Sri Lanka	74%	15
Thailand	24%	16
Vietnam	47%	42
Latin America		
Argentina		0.3
Bolivia	14%	7
Brazil	5%	10
Colombia	7%	0.8
Costa Rica	9%	0.9
Cuba	3%	0.5
Dominican Republic	19%	1.2
Ecuador	64%	9.8
El Salvador	92%	9.5
Guatemala	50%	4.1
Haiti	11%	0.3
Honduras	53%	3.2
Jamaica	15%	0.6
Nicaragua	42%	3
Panama	34%	10
Paraguay	46%	3.1
Peru	36%	10.7
Middle East		
Iraq	1%	0.3
Yemen	32%	8
All Developing Countries	**50%**	**2,722**
World[2]	**38%**	**2,722**

[1] Malawi share is for 2014.
[2] Includes countries in the OECD and economies in transition.

Disclaimer: The tracking of data related to energy access and DRE systems is a challenging process. Discrepancies or inconsistencies with past reporting may be due to improvements in data collection.

Source: See endnote 11 for this section.

REN21 Renewable Energy Policy Network for the 21st Century

Table R12. **Programmes Furthering Energy Access: Selected Examples**

NAME	BRIEF DESCRIPTION
ACP-EU Energy Facility	A co-financing instrument that works to increase access to sustainable and affordable energy services in impoverished rural and peri-urban areas of African, Caribbean and Pacific (ACP) countries by involving local authorities and communities.
Africa-EU Renewable Energy Cooperation Programme (RECP)	A programme that contributes to the African EU Energy Partnership's political targets of increasing renewable energy use and bringing modern access to at least an additional 100 million people by 2020. It provides policy advice, private sector co-operation, project preparation support activities and capacity development.
African Renewable Energy Fund (AREF)	A private equity fund that invests in small to medium-sized renewable energy projects in sub-Saharan Africa, excluding South Africa. It aims to assist governments in meeting their renewable energy and carbon emission targets, while creating jobs.
Asian Development Bank – Energy for All Initiative	An initiative that strengthens ADB's investments in energy access. From 2008 to 2015, ADB's aggregate investment in energy access was around USD 6.4 billion, which is expected to benefit 104.5 million people.
Capital Access for Renewable Energy Enterprises Programme (CARE2)	A USD 7 million programme that aims to expand renewable energy markets in Kenya, Rwanda, Tanzania and Uganda through interventions designed to increase the supply of capital to businesses. CARE2 is supported by the Swedish International Development Cooperation Agency.
Central America Clean Cooking Initiative (CACCI)	An initiative that aims to help scale up clean cooking solutions in countries such as Guatemala, Honduras, Nicaragua and possibly El Salvador. Activities to be financed by the grant include development of a roadmap to achieve universal clean cooking access by 2030. The roadmap will build on the regional Sustainable Energy Strategy 2020.
CleanStart	Developed by the UN Capital Development Fund and UNDP to help poor households and micro-entrepreneurs access micro-financing for low-cost clean energy. It aims to help lift at least 2.5 million people out of energy poverty by 2017, in ways that can be replicated and scaled up by others.
Energising Development (EnDev)	A multilateral initiative supported by the governments of Australia, Germany, the Netherlands, Norway, Switzerland and the United Kingdom. It operates in 24 countries in Asia, Africa and Latin America with the aim of facilitating the sustainable access to modern energy services for at least 15 million people by the end of 2018. So far, EnDev has facilitated energy access for 14.8 million people.
Energy Environment Resiliency in Africa (EERA)	A project that supports energy decision makers in assessing national energy policy frameworks and in identifying how energy policies can support climate resilience and sustainable energy objectives in Benin, Mali and Togo.
EU-Africa Infrastructure Trust Fund (ITF)	A fund that combines grants and loans from the EU and its Member States and banks to support local infrastructure projects, notably in electricity generation. By end-2013, 36 grants had been approved for projects totalling EUR 240 million in investments.
GIZ – HERA Basic Energy Supply	A project that works on facilitating the access of poor households, social institutions and small businesses to renewable energy and its sustainable and efficient use. HERA develops and disseminates strategies and concepts for poverty-oriented basic energy services and assists energy access projects conducted by GIZ on behalf of the German government worldwide.
Global Alliance for Clean Cookstoves (GACC)	A public-private partnership created with the goal of enabling the adoption of 100 million clean and efficient cook stoves and fuels by 2020. GACC uses a market-based approach to bring together diverse groups of actors across government, development, NGOs, academia and the private sector to save lives, improve livelihoods, empower women and protect the environment through initiatives designed to catalyse and champion the sector, mobilise resources, promote standards and testing, and co-ordinate sector knowledge and research.
Global Energy Efficiency and Renewable Energy Fund (GEEREF)	A sustainable development tool sponsored by the EU, Germany and Norway, advised by the European Investment Bank Group. It aims to mobilise public and private capital to support small and medium-sized renewable energy and energy efficiency projects.
Global LEAP Awards for Outstanding Off-Grid Products	An international competition to identify the world's best-quality low-voltage, direct current appliances for off-grid use (including LED appliances for room lighting and flat-panel colour televisions). The first round was awarded in May 2014.

Table R12. Programmes Furthering Energy Access: Selected Examples (continued)

NAME	BRIEF DESCRIPTION
Global Lighting and Energy Access Partnership (Global LEAP)	An initiative of the Clean Energy Ministerial that includes more than 10 governments and development partners. It provides support for quality assurance frameworks and programmes that encourage market transformation towards super-efficient technologies for off-grid use.
Global Sustainable Energy Islands Initiative (GSEII)	An initiative that works with NGOs and multilateral institutions to help small-island developing states (SIDS) address energy security and climate change issues. It has helped nine SIDS to build human capacity, increase awareness and implement energy efficiency and renewable energy projects. It has spent about USD 1 million on the preparation of national energy plans, biofuel feasibility studies, energy efficiency training and renewable energy projects.
Green Climate Fund (GCF)	A fund emerging from the COP climate change discussions in Copenhagen, Denmark and Durban, South Africa, to co-ordinate and consolidate funding on climate change mitigation and adaptation. It attempts to harmonise ongoing global financing efforts related to energy and transport infrastructure (among others) from the World Bank, the GEF, the Adaptation Fund, the CDM of the Kyoto Protocol and the G8.
IDEAS – Energy Innovation Contest	A contest that supports the implementation of innovative projects in the areas of renewable energy, energy efficiency and energy access in Latin America and the Caribbean by promoting innovative energy solutions that can be replicated and scaled up in the region.
IRENA – Abu Dhabi Fund for Development (ADFD)	A fund to support renewable energy projects that offer innovative and replicable approaches to broaden energy access; address several socio-economic issues identified in the Millennium Development Goals and SE4All objectives; and address energy security issues.
Lighting a Billion Lives	A global initiative launched in 2008, steered by The Energy and Resources Institute (TERI), to facilitate access to clean lighting and cooking solutions for energy-starved communities. The programme operates on an entrepreneurial model of energy service delivery to provide innovative, affordable and reliable off-grid solar solutions. As of March 2015, it had facilitated access to clean lighting and cooking solutions for more than 3.5 million people in India, sub-Saharan Africa and South Asia.
Lighting Africa	An IFC and World Bank programme to accelerate the development of sustainable markets for affordable, modern off-grid lighting solutions for low-income households and micro-enterprises across Africa. As of early 2014, Lighting Africa had provided access to clean, safe lighting for more than 7.7 million people.
Lighting Asia	An IFC market transformation programme aimed at increasing access to clean, affordable energy in rural Bangladesh and India by promoting modern off-grid lighting products, systems and mini-grid connections. The programme works with the private sector to remove market entry barriers, provide market intelligence, foster business to business linkages and raise consumer awareness on modern lighting options. It aims to reach 3 million people in India and 2.3 million people in Bangladesh by 2016.
The OPEC Fund for International Development (OFID)	A development aid institution with a 40-year standing and a presence in over 130 countries. It works in co-operation with developing country partners and the international donor community to stimulate economic growth and alleviate poverty. Since 2008, the year that OFID launched its Energy for the Poor Initiative (EPI), energy poverty alleviation has been the primary strategic focus. In June 2012, the OFID Ministerial Council committed a minimum of USD 1 billion to bolster activities under the EPI, and in 2013 it turned this commitment from a one-time obligation to a revolving pledge.
Power Africa	A US government initiative to address access to electricity in sub-Saharan Africa. It has a target to double energy access in sub-Saharan Africa, using renewable energy, by adding more than 60 million new household and business connections. In August 2014, an additional combined USD 12 billion was pledged by Norway, Sweden and the United Kingdom.
Readiness for Investment in Sustainable Energy (RISE)	A World Bank Group project providing indicators that compare the investment climate of countries across the three focus areas of the SE4All initiative: energy access, energy efficiency and renewable energy.

Table R12. **Programmes Furthering Energy Access: Selected Examples** (continued)

NAME	BRIEF DESCRIPTION
Renewable Energy and Energy Efficiency Partnership (REEEP)	A partnership that invests in clean energy markets in developing countries to reduce CO_2 emissions and build prosperity. Based on a strategic portfolio of high-impact projects, it works to generate energy access, improve lives and economic opportunities, build sustainable markets and combat climate change. REEEP has formed partnerships with more than 120 governments, banks, businesses, NGOs, and inter-governmental organisations, and has invested about USD 20 million (EUR 16.4 million) in more than 145 projects.
Scaling Up Renewable Energy in Low Income Countries (SREP)	A Strategic Climate Fund (SCF) programme that was established to expand renewable energy markets and scale up renewable energy deployment in the world's poorest countries. It initially piloted in Ethiopia, Honduras, Kenya, Liberia, the Maldives, Mali, Nepal and Tanzania, and added 14 additional countries in 2014.
SNV Netherlands Development Organisation – Biogas Practice	A multi-actor sector development approach that supports the preparation and implementation of national biogas programmes throughout the world. In co-operation with its partners, SNV had installed 579,000 biogas plants in 18 developing countries in Asia, Africa and Latin America by end-2013 (with 74,000 in 2013 alone).
Sustainable Energy for All Initiative (SE4All)	A global initiative of UN Secretary-General Ban Ki-moon with three objectives for 2030: achieving universal access to electricity and clean cooking solutions; doubling the share of the world's energy supplied by renewable sources; and doubling the rate of improvement in energy efficiency.
Sustainable Energy Fund for Africa (SEFA)	A fund administered by the African Development Bank and anchored by a Danish government commitment of USD 57 million to support small and medium-scale clean energy and energy efficiency projects in Africa through grants for technical assistance and capacity building, investment capital and guidance.

Table R13. Networks Furthering Energy Access: Selected Examples

NAME	BRIEF DESCRIPTION
African Bioenergy Development Platform	A platform launched by UNCTAD to help interested African countries develop their bioenergy potentials for advancing human and economic development through interactive, multi-stakeholder analytical exercises.
African Center for Renewable Energy and Sustainable Technologies (ACREST)	A centre established in 2005 for information, demonstration, awareness, production and research on renewable energy and sustainable technologies in Africa. Its mission is to promote renewable energy technologies and sustainable technologies to improve people's living conditions and to fight poverty.
African Renewable Energy Alliance (AREA)	A global multi-stakeholder platform to exchange information and consult about policies, technologies and financial mechanisms for the accelerated uptake of renewable energy in Africa.
AKON Lighting Africa	An initiative launched in February 2014 that seeks to provide a concrete response at the grassroots level to Africa's energy crisis and to lay the foundations for future development. It aims to develop an innovative solar-powered solution that will provide African villages with access to a clean and affordable source of electricity.
Alliance for Rural Electrification (ARE)	An international business association that represents the decentralised energy sector and works towards the integration of renewables into rural electrification markets in developing and emerging countries. It has more than 90 members along the whole value chain of off-grid technologies.
Alliance of CSOs for Clean Energy Access (ACCESS)	A loose coalition of more than 50 local and international civil society organisations (CSOs) operating in developing countries to increase the participation and engagement of civil society in sustainable energy access initiatives globally. The group is coordinated by WWF, CAFOD, Practical Action, Greenpeace, IIED, ENERGIA, WRI, TERI and HIVOS.
Clean Energy for Africa (CLENA)	A five-year action plan (2012–16) to promote sustainable energy and alleviate energy poverty in Africa.
Climate Technology Initiative Private Financing Advisory Network (CTI PFAN)	A multilateral, public-private partnership initiated by the Climate Technology Initiative (CTI) in co-operation with the UNFCCC Expert Group on Technology Transfer. PFAN operates to bridge the gap between investments and clean energy businesses. It is designed to be an "open source" network to fit seamlessly with existing global and regional initiatives and to be inclusive of all stakeholders with an interest in clean energy financing.
Climate Technology Centre and Network (CTCN)	The operational arm of the UNFCCC Technology Mechanism, hosted by UNEP and UNIDO. CTCN promotes the accelerated transfer of environmentally sound technologies for low-carbon and climate-resilient development at the request of developing countries. It provides technology solutions, capacity building and advice on policy, legal and regulatory frameworks tailored to the needs of individual countries.
Consultative Group to Assist the Poor (CGAP)	A global partnership of 34 leading organisations, housed at the World Bank, that seeks to advance financial inclusion. It develops innovative solutions through practical research and active engagement with financial service providers, policy makers and funders to enable approaches at scale.
CTI – Private Financing Advisory Network	A network that identifies promising clean energy projects at an early stage and provides mentoring for development of a business plan, investment pitch, growth strategy, etc.
ENERGIA International	An international network focused on gender issues, women's empowerment and sustainable energy. By early 2014, it included 22 organisations working in Africa and Asia.
Energy Access Practitioner Network	A 2,000-strong global network of businesses and non-profits operating in 170 countries that focuses on decentralised low-carbon household and community-level electrification. It supports innovative financial and business models in predominantly market-based applications that help address development issues such as income generation, health, agriculture, education, small business and telecommunications.
Energy & Environment Partnership (EEP)	A challenge fund that promotes renewable energy, energy efficiency and clean technology investments in Southern and East Africa. EEP supports projects that aim to provide sustainable energy services to the poor and to combat climate change. The EEP Programme is jointly funded by the Ministry of Foreign Affairs of Finland, the Austrian Development Agency and the UK Department for International Development.

Table R13. Networks Furthering Energy Access: Selected Examples (continued)

NAME	BRIEF DESCRIPTION
Energy for All Partnership (E4ALL)	A regional platform for co-operation, knowledge, technical exchange and key project development. It brings together key stakeholders from the private sector, financial institutions, governments, bilateral, multilateral and non-governmental development partners. The Partnership – led by ADB – aims to provide access to safe, clean and affordable modern energy to 100 million people in the Asia-Pacific region by 2015.
Global Network on Energy for Sustainable Development (GNESD)	A South-South network comprising 10 member centres of excellence in Africa, Asia and Latin America. It produces policy-relevant knowledge products on clean energy for sustainable development targeted at decision makers and energy practitioners. It also conducts outreach activities and policy dialogue panels with senior members of governments, academia and NGOs.
Global Renewable Energy Islands Network (GREIN)	A network created to help islands accelerate their renewable energy uptake. It will serve as a platform for pooling knowledge, sharing best practices and seeking innovative solutions for the accelerated update of clean and cost-effective renewable energy technologies in island states and territories.
HEDON Household Energy Network	A network aimed at empowering practitioners to unlock barriers to household energy access by addressing knowledge gaps, facilitating partnerships and fostering information sharing.
International Network for Sustainable Energy (INFORSE)	A network of 140 NGOs operating in 60 countries that was established as part of the Rio Convention. It is dedicated to promoting sustainable energy and social development and is funded by a mix of national governments, multilateral institutions and CSOs. INFORSE focuses on four areas: raising awareness about sustainable energy use; promoting institutional reform among national governments; building local and national capacity on energy-related issues; and supporting R&D.
La Via Campesina (LVC)	Informally known as the "international peasants' movement", LVC is a group of about 150 organisational members that co-ordinate migrant workers, farmers, rural women and indigenous communities on rural development issues. The "sustainable agriculture", "water" and "women and human rights" programmes deal with various aspects of rural energy use, especially the connections between food security and biofuels.
RedBioLAC	A multinational network of institutions involved in research and dissemination of anaerobic bio-digestion and the treatment and management of organic waste in Latin America and the Caribbean.
Small-Scale Sustainable Infrastructure Development Fund (S3IDF)	A fund that promotes a Social Merchant Bank approach to help local entrepreneurs create micro-enterprises that provide infrastructure services to the poor. As of early 2015, it had a portfolio of almost 200 small investments and associated enterprises in India, and an additional 100 projects in the pipeline.
Wind Empowerment	A global association for the development of locally built small-scale wind turbines for sustainable rural electrification.

Table R14. Global Trends in Renewable Energy Investment, 2005–2015

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	Billion USD										
NEW INVESTMENT BY STAGE											
Technology Research											
Government R&D	1.9	2.0	2.2	2.7	2.8	5.3	4.7	4.6	4.5	4.9	5.1
Corporate R&D	3.2	2.9	3.1	3.5	4.0	4.1	4.2	5.1	5.0	6.6	6.6
Development / Commercialisation											
Venture capital	0.6	1.2	2.1	3.2	1.6	2.5	2.5	2.4	0.8	1.0	1.3
Manufacturing											
Private equity expansion capital	1.0	3.1	3.6	6.7	2.9	5.4	2.4	1.6	1.4	1.6	2.1
Public markets	3.6	9.3	21.4	10.9	12.9	11.2	10.0	3.8	10.1	16.2	12.8
Projects											
Asset finance	52.6	84.5	109.8	135.8	120.2	152.9	181.4	163.3	158.0	188.4	199.0
(re-invested equity)	0.1	0.7	3.2	3.6	1.9	4.4	3.4	2.8	1.9	3.7	5.8
Small distributed capacity	10.2	9.4	14.1	22.3	33.5	62.6	75.7	79.3	53.9	60.4	67.4
Total New Investment	**72.8**	**112.0**	**154.0**	**182.2**	**178.7**	**239.2**	**278.5**	**257.3**	**234.0**	**273.0**	**285.9**
Merger & Acquisition Transactions	26.2	35.9	58.7	59.4	64.2	58.5	73.5	67.6	67.1	87.3	93.9
Total Transactions	**99.1**	**147.9**	**212.7**	**241.6**	**242.9**	**297.6**	**352.0**	**324.9**	**301.1**	**360.4**	**379.8**
NEW INVESTMENT BY TECHNOLOGY											
Solar power	16.1	22.2	38.9	61.6	64.4	103.7	154.8	146.2	119.1	143.8	161.0
Wind power	29.0	39.8	61.2	75.4	79.8	98.7	84.2	81.9	90.6	105.7	109.6
Biomass and waste-to-energy	9.7	11.9	16.2	17.1	14.7	15.7	18.0	13.5	10.5	10.4	6.0
Biofuels	7.3	7.6	6.7	7.6	6.2	7.9	7.2	6.4	5.5	5.5	3.9
Hydropower <50 MW	9.6	28.2	28.3	18.5	10.4	10.1	10.3	7.2	5.7	4.7	3.1
Geothermal power	1.0	1.5	1.9	1.7	2.9	2.8	3.7	1.8	2.4	2.6	2.0
Ocean energy	0.1	0.9	0.8	0.2	0.3	0.3	0.3	0.3	0.2	0.4	0.2
Total New Investment	**72.8**	**112.0**	**154.0**	**182.2**	**178.7**	**239.2**	**278.5**	**257.3**	**234.0**	**273.0**	**285.9**

Source: See endnote 12 for this section.

Table R15. Share of Primary and Final Energy from Renewable Sources, Targets and 2013/2014 Shares

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	PRIMARY ENERGY		FINAL ENERGY	
	Share	Target	Share	Target
EU-28			16%	→ 20% by 2020 → **27% by 2030**
Albania		→ 18% by 2020		→ 38% by 2020
Algeria				→ **37% by 2030** [40% by 2030]
Armenia	16% (2015)	→ 21% by 2020 → 26% by 2025		
Austria[1]			33.1%	→ 45% by 2020
Azerbaijan	0.5%			
Bangladesh				→ 10% by 2020
Barbados	2.3%			
Belarus			5.7%	→ 28% by 2015 → 32% by 2020
Belgium		→ 9.7% by 2020	8%	→ 13% by 2020
Wallonia				→ *20% by 2020*
Bosnia and Herzegovina		→ 20% by 2016		→ 40% by 2020
Botswana				→ 1% by 2016
Brazil			39.4%	→ **45% by 2030**
Bulgaria			18%	→ 16% by 2020
Burundi				→ 2.1% by 2020
China[2]			11.1%	→ **20% by 2030** [11.4% by 2015; 13% by 2017]
Côte d'Ivoire		→ 5% by 2015 → 15% by 2020 → 20% by 2030		
Croatia			27.9%	→ 20% by 2020
Cyprus			9%	→ 13% by 2020
Czech Republic[1]			13.4%	→ 13.5% by 2020
Denmark			29.2%	→ 35% by 2020 → 100% by 2050
Djibouti		→ **17% by 2035**		
Ecuador	13.3%			
Egypt		→ 14% by 2020		
Estonia			26.5%	→ 25% by 2020
Fiji				→ 23% by 2030
Finland			38.7%	→ 25% by 2015 → 38% by 2020 → 40% by 2025
France			14.3%	→ **23% by 2020** → **32% by 2030**
Gabon				→ 80% by 2020
Germany[1]			13.8%	→ 18% by 2020 → 30% by 2030 → 45% by 2040 → 60% by 2050

Table R15. Share of Primary and Final Energy from Renewable Sources, Targets and 2013/2014 Shares (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	PRIMARY ENERGY		FINAL ENERGY	
	Share	Target	Share	Target
Ghana				**Increase 10% by 2030 (base year 2010)**
Greece[1]			15.3%	→ 20% by 2020
Grenada		→ 20% by 2020		
Guatemala				→ 80% by 2026
Guinea				**→ 30% by 2030**
Guyana			0%	**→ 20% by 2025**
Hungary[1]			9.5%	→ 14.65% by 2020
Iceland			77.1%	→ 64% by 2020
Indonesia		→ 25% by 2025		
Ireland			8.6%	→ 16% by 2020
Israel				**→ 13% by 2025** **→ 17% by 2030** [10% by 2020]
Italy			17.1%	→ 17% by 2020
Jamaica			7.8%	→ 20% by 2030
Japan	5.8%	→ 14% by 2030		
Jordan		[7% by 2015; 10% by 2020]		**→ 11% by 2025**
Korea, Republic of		→ 4.3% by 2015 → 6.1% by 2020 → 11% by 2030		
Kosovo[3]				→ 25% by 2020
Lao PDR				**→ 30% by 2025**
Latvia				→ 40% by 2020
Lebanon				**→ 15% by 2030** [12% by 2020]
Liberia				**→ 10% by 2030**
Libya		→ 10% by 2020		
Lithuania		→ 20% by 2025		→ 23% by 2020
Luxembourg				→ 11% by 2020
Macedonia				→ 28% by 2020
Madagascar				→ 54% by 2020
Malawi		→ 7% by 2020		
Mali		→ 15% by 2020		
Malta				→ 10% by 2020
Mauritania		→ 15% by 2015 → 20% by 2020		
Moldova		→ 20% by 2020		→ 17% by 2020
Mongolia		→ 20–25% by 2020		
Montenegro			31.1%	→ 33% by 2020
Nauru				→ 50% by 2015
Nepal		→ 10% by 2030		
Netherlands[1]			5.5%	→ 16% by 2020
Niger		→ 10% by 2020		
Norway			69.2%	→ 67.5% by 2020

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Table R15. Share of Primary and Final Energy from Renewable Sources, Targets and 2013/2014 Shares (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	PRIMARY ENERGY		FINAL ENERGY	
	Share	Target	Share	Target
Palau		→ 20% by 2020		
Palestine, State of				→ 25% by 2020
Panama		→ 18.3% by 2023		
Poland		→ 12% by 2020	11.4%	→ 15.5% by 2020
Portugal			27%	→ **40% by 2030** → 31% by 2020
Romania			24.9%	→ 24% by 2020
Samoa		→ 20% by 2030		
Serbia				→ 27% by 2020
Slovakia			11.6%	→ 14% by 2020
Slovenia			21.9%	→ 25% by 2020
Spain[1]	14.4%		16.2%	→ 20.8% by 2020
St. Lucia	0.2%	→ 20% by 2020		
Sweden[1]			52.6%	→ 50% by 2020
Switzerland		→ 24% by 2020		
Syria		→ 4.3% by 2030		
Thailand				→ **30% by 2036** → 25% by 2021
Togo				→ **4% (no date)**
Ukraine	2.7%	→ 18% by 2030		→ 11% by 2020
United Arab Emirates			<1%	→ **24% by 2021**
United Kingdom			7%	→ 15% by 2020
Uruguay	55%	→ 50% by 2015		
Vanuatu				→ **65% by 2020**
Vietnam		→ 5% by 2020 → 8% by 2025 → 11% by 2050		

[1] Final energy targets for all EU-28 countries are set under EU Directive 2009/28/EC. The governments of Austria, the Czech Republic, Germany, Greece, Hungary, Spain and Sweden have set higher targets, which are shown here. The government of the Netherlands has reduced its more ambitious target to the level set in the EU Directive.

[2] The Chinese target is for share of "non-fossil" energy. All targets include nuclear power.

[3] Kosovo is not a member of the United Nations.

Note: Actual percentages are rounded to the nearest whole decimal for numbers over 10% except where associated targets are expressed differently. Historical targets have been added as they are identified by REN21. Only bolded targets are new/revised in 2015. A number of nations have already exceeded their renewable energy targets. In many of these cases, targets serve as a floor setting the minimum share of renewable energy for the country. Some countries shown have other types of targets (see Reference Tables R13, R14, R15 and R18).

Source: See endnote 13 for this section.

Table R16. Renewable Energy Targets for Technology-Specific Share of Primary and Final Energy

COUNTRY	TECHNOLOGY	TARGET
Guinea-Bissau	Solar PV	2% of primary energy by 2015
Indonesia	Hydropower, solar PV, wind power	1.4% share in primary energy (combined) by 2025
Samoa	Final energy	Increase by 20% the share of final energy supply by 2030 (base year 2007)
Spain	Bioenergy from solid biomass, biogas and organic MSW[1]	0.1% of final energy by 2020
	Geothermal energy, ocean power and heat pumps[2]	5.8% of final energy by 2020
	Hydropower	2.9% of final energy by 2020
	Solar PV	3% of final energy by 2020
	Wind power	6.3% of final energy by 2020

[1] It is not always possible to determine whether municipal solid waste (MSW) data include non-organic waste (plastics, metal, etc.) or only the organic biomass share.

[2] The energy output of heat pumps is at least partially renewable on a final energy basis, which is why they are included in this table. For more information, see Sidebar 4, GSR 2014.

Note: All shares are from 2013/2014 unless otherwise noted. Actual percentages are rounded to the nearest whole decimal for numbers over 10% except where associated targets are expressed differently. Some countries shown have other types of targets (see Reference Tables R13, R14, R15 and R18).

Source: See endnote 14 for this section.

BACK

Table R17. Share of Electricity Generation from Renewable Sources, Targets and 2014 Shares

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	SHARE[1]	TARGET
EU-28	27.5%	
Algeria		→ **27% by 2030**
Antigua and Barbuda		→ 5% by 2015 → 10% by 2020 → 15% by 2030
Argentina	0.45%	→ **8% by 2016** [8% by 2016] → **20% by 2025**
Australia		→ **23% by 2020** [20% by 2020]
South Australia		→ *50% by 2020*
Tasmania		→ *100% by 2020*
Victoria		→ ***20% by 2020***
Austria	70%	→ 70.6% by 2020
Azerbaijan		→ 20% by 2020
Bahamas, The		→ 15% by 2020 → 30% by 2030
Bahrain		→ 5% by 2030
Bangladesh		→ 5% by 2015 → 10% by 2020
Barbados		→ **65% by 2030** → 29% by 2029
Belgium	13.4%	→ 20.9% by 2020
Belize		→ **85% by 2017** → 50% (no date)
Bolivia		→ **79% by 2030**
Brazil[1]		→ **23% by 2030**
Brunei Darussalam		→ 10% by 2035
Bulgaria	18.9%	→ 20.6% by 2020
Cabo Verde		→ **100% by 2035** → 50% by 2020
Cambodia	61%	→ **25% by 2035** → 15% by 2015
Canada	59%	No national target
British Columbia		→ *93% (no date given)*
New Brunswick		→ ***40% by 2020***
Nova Scotia		→ ***25% by 2015*** → ***40% by 2020***
Saskatchewan		→ ***50% by 2030***
Chile		→ 20% by 2025
Comoros		→ **43% by 2030**
Congo, Republic of		→ **85% by 2025**
Costa Rica	99%	→ **100% by 2021** [100% by 2021]
Côte d'Ivoire		→ **42% by 2020**
Croatia	45.3%	→ 39% by 2020
Cuba		→ 24% by 2030
Cyprus	7.4%	→ 16% by 2020
Czech Republic	13.9%	→ 14.3% by 2020

COUNTRY	SHARE[1]	TARGET
Denmark[2]	48.5%	→ 50% by 2020 → 100% by 2050
Djibouti	65%	→ **35% by 2035** [100% by 2020]
Dominica		→ 100% (no date)
Dominican Republic		→ 10% by 2015 → 25% by 2025
Ecuador	47.9%	→ 85% by 2017
Egypt		→ 20% by 2020
Eritrea		→ 70% by 2030 [50% (no date)]
Estonia	14.6%	→ 17.6% by 2020
Fiji	60%	→ 100% by 2030
Finland	31.4%	→ 33% by 2020
France	18.3%	→ **40% by 2030** → 27% by 2020
Gabon		→ **80% by 2025** → 70% by 2020
Gambia		→ 35% by 2020
Germany	28.2%	→ 40–45% by 2025 → 55–60% by 2035 → 80% by 2050
Ghana		→ 10% by 2020
Greece	21.9%	→ 40% by 2020
Guatemala		→ **80% by 2030** [80% by 2027]
Guinea-Bissau		→ 2% by 2015
Guyana		→ 90% (no date)
Haiti		→ **47% by 2030** [50% by 2020]
Honduras		→ 60% by 2022 → 80% by 2038
Hungary	7.3%	→ 10.9% by 2020
India[3]		→ **40% by 2030**
Andaman and Nicobar		→ *3% (0.4% solar)*
Andhra Pradesh		→ *7% (0.2% solar)*
Arunchal Pradesh		→ *7% (0.2% solar)*
Assam		→ *7% (0.25% solar)*
Bihar		→ *5% (0.75% solar)* → *3% solar by 2022*
Chandigarh		→ *3% (0.4% solar)*
Chattisgarh		→ *6.75% (0.75% solar)* → *7.25% by 2016*
Dadra and Nagar Haveli		→ *3% (0.4% solar)*
Daman and Diu		→ *3% (0.4% solar)*
Delhi		→ *6.2% (0.25% solar)* → *9% by 2017*
Goa		→ *3.3% (0.6% solar)* → *6% by 2022*

Table R17. Share of Electricity Generation from Renewable Sources, Targets and 2014 Shares (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	SHARE[1]	TARGET
Gujarat		→ *9% (1.5% solar)* → *10% by 2017*
Haryana		→ *3.25% (0.25% solar)* → *5.5% by 2022*
Himachal Pradesh		→ *10.25% (0.25% solar)* → *19% by 2022*
Jammu and Kashmir		→ *6% (0.75% solar)* → *9% by 2017*
Jharkhand		→ *4% (1% solar)* → *4% by 2016*
Karnataka		→ *10.25% (0.25% solar)*
Kerala		→ *4.5% (0.25% solar)* → *6.6% by 2022*
Lakshadweep		→ *3% (0.4% solar)*
Madhya Pradesh		→ *7% (1% solar)*
Maharashtra		→ *9% (0.5% solar)*
Manipur		→ *5% (0.25% solar)*
Meghalaya		→ *1% (0.4% solar)*
Mizoram		→ *7% (0.25% solar)*
Nagaland		→ *8% (0.25% solar)*
Orissa		→ *6.5% (0.25% solar)*
Pondicherry		→ *3% (0.4% solar)*
Punjab		→ *4% (0.19% solar)*
Rajasthan		→ *9% (1.5% solar)*
Tamil Nadu		→ *11% (2% solar)*
Tripura		→ *2.5% (1.05% solar)*
Uttar Pradesh		→ *6% (1% solar)*
Uttarakhand		→ *7.075% (0.075% solar)*
West Bengal		→ *4.5% (0.15% solar)*
Indonesia		→ 26% by 2025
Iraq		→ 10% by 2030
Ireland	22.7%	→ 42.5% by 2020
Israel		→ **17% by 2030** → 10% by 2020
Italy	33.4%	→ 26% by 2020
Jamaica		→ 15% by 2015
Japan	12.2%	→ **22–24% by 2030** [13.5% by 2020; 20% by 2030]
Jordan	3%	→ **15% by 2015**
Kazakhstan		→ 3% by 2020 → 50% by 2030
Kiribati		→ 3% by 2020
Kuwait		→ 10% (no date)
Latvia	51.1%	→ 60% by 2020
Lebanon		→ 12% by 2020
Liberia		→ 30% by 2021
Libya		→ 7% by 2020 → 10% by 2025
Lithuania	13.7%	→ 21% by 2020
Luxembourg	5.9%	11.8% by 2020
Macedonia		→ 24.7% by 2020
Madagascar	63%	→ **79% (no date)** [75% by 2020]
Malaysia		→ 5% by 2015 → 9% by 2020 → 11% by 2030 → 15% by 2050
Maldives		→ 16% by 2017
Mali[4]		→ 10% by 2015 → 25% by 2033
Malta	3.3%	→ 3.8% by 2020
Marshall Islands		→ 20% by 2020
Mauritius		→ 35% by 2025
Mexico		→ 35% by 2024 → 50% by 2050
Moldova		→ 10% by 2020
Mongolia	4%	→ **20% by 2020** → **30% by 2030** [20–25% by 2020]
Morocco		→ **52% by 2039**
Myanmar	54%	→ 15–18% by 2020
Namibia		→ **70% by 2030**
Netherlands	10%	→ 37% by 2020
New Zealand		→ 90% by 2025
Cook Islands		→ 50% by 2015 → 100% by 2020
Niue		→ 100% by 2020
Tokelau		→ 100% (no date)
Nicaragua	56%	→ 90% by 2027
Nigeria[5]		→ 10% by 2020
Pakistan	0.43%	→ 10% by 2015
Palestine, State of		→ 10% by 2020
Papua New Guinea		→ **100% by 2030**
Paraguay		→ **60% increase 2014–2030**
Peru		→ 60% by 2025
Philippines	29%	→ 40% by 2020
Poland	12.4%	→ 19.3% by 2020
Portugal	52.1%	→ 45% by 2020
Qatar		→ 2% by 2020 → 20% by 2030
Romania	41.7%	→ 43% by 2020
Russian Federation[6]		→ 2.5% by 2015 → 4.5% by 2020

Table R17. Share of Electricity Generation from Renewable Sources, Targets and 2014 Shares (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	SHARE[1]	TARGET
Samoa		→ **100% by 2030**
São Tomé and Príncipe		→ **47% (no date)**
Senegal		→ 20% by 2017
Seychelles		→ 5% by 2020 → 15% by 2030
Sierra Leone		→ 18% by 2015 → 33% by 2020 → 36% by 2030
Singapore		→ **8% (no date)**
Slovakia	23%	→ 24% by 2020
Slovenia	33.9%	→ 39.3% by 2020
Solomon Islands	10.9%	→ 50% by 2015
South Africa		→ 9% by 2030
Spain	37.8%	→ 38.1% by 2020
Sri Lanka		→ 10% by 2016 → 20% by 2020
St. Kitts and Nevis		→ 20% by 2015
St. Lucia		→ 15% by 2015 → 35% by 2020
St. Vincent and the Grenadines		→ 30% by 2015 → 60% by 2020
Sudan		→ **20% by 2030** [11% by 2031]
Sweden	63.3%	→ 62.9% by 2020
Tanzania		→ 14% by 2015
Thailand[7]	13%	→ **20% by 2036** [10% by 2021]
Timor-Leste		→ 50% by 2020
Togo		→ 15% by 2020
Tonga		→ 50% by 2015
Tunisia		→ 11% by 2016 → 30% by 2030
Turkey		→ 30% by 2023
Tuvalu		→ 100% by 2020
Uganda		→ 61% by 2017
Ukraine	5.9%	→ 11% by 2020 → 20% by 2030
United Arab Emirates		No national target
Abu Dhabi		→ 7% by 2020
Dubai		→ 7% by 2020 → 15% by 2030
United Kingdom	17.8%	No national target
Scotland		→ 100% by 2020
United States[8]		No national target
Arizona		→ 15% by 2025
California		→ **50% by 2030** → 33% by 2020 → 25% by 2015
Colorado		→ 30% by 2020[9] → 10% or 20%[10]
Connecticut		→ 27% by 2020
Delaware		→ 25% of supply by 2025–2026
Hawaii		→ **100% by 2045** → 25% by 2020 → 40% by 2030
Illinois		→ 25% by 2015–2016
Maine		→ 40% by 2017
Maryland		→ 20% by 2020
Massachusetts		→ 15% by 2020 and additional 1% each year after
Michigan		→ 10% by 2015
Minnesota		→ 26.5% by 2025 (IOUs)[9] → 25% by 2025 (other utilities)
Missouri		→ 15% by 2021[9]
Montana		→ 15% by 2015
Nevada		→ 25% by 2025
New Hampshire		→ 24.8% by 2025
New Jersey		→ 24.5% by 2020
New Mexico		→ 20% by 2020 (IOUs)[9] → 10% by 2020 (co-ops)[10]
New York		→ **50% by 2030** [29% by 2015]
North Carolina		→ 12.5% by 2021[9] 10% by 2018[10]
Ohio		→ 25% by 2024
Oregon		→ 25% by 2025 (utilities with 3% or more of state's load) → 10% by 2025 (utilities with 1.5–3% of state's load) → 5% by 2025 (utilities with less than 1.5% of state's load)
Pennsylvania		→ 18% by 2020–2021
Rhode Island		→ 16% by 2019
Vermont		→ **55% by 2017** → **75% by 2032 [upgraded from voluntary goal]**
Washington		→ 9% by 2016 → 15% by 2020
Wisconsin		→ 10% by 2015

Table R17. Share of Electricity Generation from Renewable Sources, Targets and 2014 Shares (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	SHARE[1]	TARGET
District of Columbia		→ 20% by 2020
Northern Mariana Islands		→ 80% by 2015
Puerto Rico		→ 20% by 2035
US Virgin Islands		→ **30% of supply by 2030 [upgraded from voluntary goal]**
Uruguay	94.4%	→ **95% by 2017** [92% by 2015]
Vanuatu		→ **100% by 2030** [23% by 2014; 40% by 2015; 65% by 2020]
Vietnam		→ 5% by 2020
Yemen		→ 15% by 2025

[1] Brazil's target excludes all hydropower.

[2] In March 2012, Denmark set a target of 50% electricity consumption supplied by wind power by 2020.

[3] India does not classify hydropower installations larger than 25 MW as renewable energy sources, so hydro >25 MW is excluded from national shares and targets. De facto sub-national targets have been set through existing RPS policies.

[4] Mali's target excludes large-scale hydropower.

[5] Nigeria's target excludes hydropower plants >30 MW.

[6] The Russian Federation's targets exclude hydropower plants >25 MW.

[7] Thailand does not classify hydropower installations larger than 6 MW as renewable energy sources, so hydro >6 MW is excluded from national shares and targets.

[8] The United States does not have a renewable electricity target at the national level. De facto state-level targets have been set through existing RPS policies.

[9] RPS mandate for Investor-owned utilities (IOUs), which are utilities operating under private control rather than government or co-operative operation.

[10] RPS mandate for municipal utilities (munis) and co-operative utilities (co-ops). Munis are publicly owned and operated. Co-ops are owned and operated by members who also make up the utility's customer base.

Note: Unless otherwise noted, all targets and corresponding shares represent all renewables including hydropower. A number of state/provincial and local jurisdictions have additional targets not listed here. Historical targets have been added as they are identified by REN21. Only bolded targets are new/revised in 2015. A number of nations have already exceeded their renewable energy targets. In many of these cases, targets serve as a floor setting the minimum share of renewable electricity for the country. Some countries shown have other types of targets (see Reference Tables R12–R22). See Policy Landscape chapter for more information about subnational targets. Existing shares are indicative and may need adjusting if more accurate national statistics are published. Sources for reported data often do not specify the accounting method used; therefore, shares of electricity are likely to include a mixture of different accounting methods and thus are not directly comparable or consistent across countries. Where shares sourced from EUROSTAT differed from those provided to REN21 by country contributors, the former was given preference.

Source: See endnote 15 for this section.

Table R18. Renewable Energy Targets for Technology-Specific Share of Electricity Generation

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Benin	Electricity (off-grid and rural)	→ 50% by 2025
Colombia[1]	Electricity (grid-connected)	→ 3.5% by 2015; 6.5% by 2020
	Electricity (off-grid)	→ 20% by 2015; 30% by 2020
Denmark	Wind power	→ 50% by 2020
Djibouti	Solar PV (off-grid and rural)	→ 30% by 2017
Dominican Republic	Distributed power	→ 20% by 2016
Egypt	Wind power	→ 12% and 7.2 GW by 2020
Eritrea	Wind power	→ 50% (no date)
Guinea	Solar power	→ 6% of generation by 2025
	Wind power	→ 2% of generation by 2025
Haiti	**Biomass power**	→ **5.6% by 2030**
	Hydropower	→ **24.5% by 2030**
	Solar power	→ **7.55% by 2030**
	Wind power	→ **9.4% by 2030**
Japan	**Bio-power**	→ **3.7–4.6% by 2030** [3.3 GW by 2020; 6 GW by 2030]
	Geothermal power	→ **1–1.1% by 2030** [0.53 GW by 2020; 3.88 GW by 2030]
	Hydropower	→ **8.8–9.2% by 2030** [49 GW by 2020]
	Solar PV	→ **7% by 2030** [28 GW by 2020]
	Wind power	→ **1.7% by 2030 (5 GW total by 2020; 8.03 GW offshore by 2030)**
Latvia	Bio-power from solid biomass	→ 8% by 2016
Lesotho	Electricity	→ 35% of off-grid and rural electrification by 2020
Micronesia	Electricity	→ 10% in urban centres and 50% in rural areas by 2020
Myanmar	**Electricity**	→ **30% of rural electrification by 2030**
Trinidad and Tobago	Electricity	→ 5% of peak demand (or 60 MW) by 2020

[1] Colombia's target is to be met by "non-conventional sources of energy", which includes nuclear energy and renewables, small- and large-scale self-supply and distributed power generation, and non-diesel power generation in non-interconnected zones.

Note: Unless otherwise noted, all targets and corresponding shares represent all renewables including hydropower. A number of state/provincial and local jurisdictions have additional targets not listed here. Some countries shown have other types of targets (see Reference Tables R12–R22). See Policy Landscape chapter and Reference Table R23 for more information about subnational and municipal-level targets. Existing shares are indicative and may need adjusting if more accurate national statistical data are published.

Source: See endnote 16 for this section.

Table R19. Targets for Renewable Power installed Capacity and/or Generation

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Algeria	Electricity	22 GW by 2030
	Bio-power from waste-to-energy	1 GW by 2030
	Geothermal power	15 MW by 2030
	Solar PV	13.5 GW by 2030
	CSP	2 GW by 2030
	Wind power	5 GW by 2030
Antigua and Barbuda	**Electricity**	**5 MW by 2030**
Argentina	Electricity	3 GW by 2016
	Geothermal power	30 MW by 2016
Armenia	Hydropower (small-scale)	377 MW by 2020; 397 MW by 2025
	Geothermal power	50 MW by 2020; 100 MW by 2025
	Solar PV	40 MW by 2020; 80 MW by 2025
	Wind power	50 MW by 2020; 100 MW by 2025
Austria	Bio-power from solid biomass and biogas	200 MW added 2010–2020
	Hydropower	1 GW added 2010–2020
	Solar PV	1.2 GW added 2010–2020
	Wind power	2 GW added 2010–2020
Azerbaijan	Electricity	1 GW by 2020
Bangladesh	Bio-power from solid biomass	2 MW by 2014; 100,000 plants of 2.6 m^3 capacity capable of producing 40 MW of electricity
	Bio-power from biogas	4 MW by 2014; 7 MW by 2017
	Biogas digesters	150,000 plants by 2016
	Solar PV	500 MW by 2015
	Solar PV (off-grid and rural)	6 million solar home systems by 2016 (240 MW total); 50 mini-grids of 150 kW each; 1,550 solar irrigation pumps by 2017
	Wind power	**400 MW by 2030**
Belgium		No national target
Wallonia	*Electricity*	*8 TWh/year by 2020*
Bhutan	**Electricity**	**20 MW by 2025**
	Bio-power from solid biomass	**5 MW by 2025**
	Solar PV	**5 MW by 2025**
	Wind power	**5 MW by 2025**
Bolivia	Electricity	160 MW renewable energy capacity added 2015–2025
Bosnia and Herzegovina	**Hydropower**	**120 MW by 2030**
	Solar PV	**4 MW by 2030**
	Wind power	**175 MW by 2030**
Brazil	Bio-power	19.3 GW by 2021
	Hydropower (small-scale)	7.8 GW by 2021
	Wind power	15.6 GW by 2021
Bulgaria	Hydropower	Three 174 MW plants commissioned by 2017–2018
	Solar PV	80 MW solar PV park operational by 2014
Burundi	Bio-power from solid biomass	4 MW
	Hydropower	212 MW
	Solar PV	40 MW
	Wind power	10 MW

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Canada		No national target
Ontario	*Electricity*	*20 GW by 2025 supplied by a mix of renewable technologies, including:*
	Hydropower	*9.3 GW by 2025*
	Solar PV	*40 MW by 2025*
	Wind power	*5 GW by 2025*
Prince Edward Island	*Wind power*	*30 MW increase by 2030 (base year 2011)*
China	Solar power	150 GW by 2020 [100 GW by 2020]
	Solar PV	17.8 GW installed in 2015; 70 GW by 2017
	Wind power	250 GW by 2020 [200 GW by 2020]
	Wind power (onshore)	150 GW by 2017
Taipei	***Electricity***	***4.682 GW by 2015; 8.303 GW by 2020; 12.513 GW by 2025; 17.250 GW by 2030***
	Bio-power	***741 MW by 2015; 768 MW by 2020; 813 MW by 2025; 950 MW by 2030***
	Geothermal power	***10 MW by 2020; 150 MW by 2025; 200 MW by 2030*** [4 MW by 2015; 66 MW by 2020; 150 MW by 2025; 200 MW by 2030]
	Solar PV	***1.115 GW by 2015; 3.615 GW by 2020; 6.2 GW by 2025; 8.7 GW by 2030*** [420 MW by 2015; 1.02 GW by 2020; 2.5 GW by 2025; 3.1 GW by 2030]
	Wind power (onshore)	***737 MW by 2015; 1.2 GW by 2020; 1.2 GW by 2025; 1.2 GW by 2025***
	Wind power (offshore)	***520 MW by 2020; 2 GW by 2025; 4 GW by 2030***
Egypt	Hydropower	2.8 GW by 2020
	Solar PV	220 MW by 2020; 700 MW by 2027
	CSP	1.1 GW by 2020; 2.8 GW by 2017
	Wind power	7.2 GW by 2020
Ethiopia	Bio-power from bagasse	103.5 MW (no date)
	Geothermal power	75 MW by 2015; 450 MW by 2018; 1 GW by 2030
	Hydropower	10.6 GW (>90% large-scale) by 2015; 22 GW by 2030
	Wind power	770 MW by 2014
Finland	Bio-power	13.2 GW by 2020
	Hydropower	14.6 GW by 2020
	Wind power	884 MW by 2020
France	Ocean power	380 MW by 2020
	Wind power (onshore)	19 GW by 2020
	Wind power (offshore)	6 GW by 2020
	Solar	**8 GW by 2020** [5.4 GW by 2020]
Germany	Biomass	100 MW added per year
	Wind power (onshore)	2.5 GW added per year
	Wind power (offshore)	6.5 GW added by 2020
	Solar PV	2.5 GW added per year
Greece	Solar PV	2.2 GW by 2030
Grenada	**Geothermal power**	**15 MW (no date)**
	Solar power	**10 MW (no date)**
	Wind power	**2 MW (no date)**
India	Electricity	175 GW by 2022
	Bio-power	10 GW by 2022
	Hydropower (small-scale)[1]	5 GW by 2022
	Solar PV	20 million solar lighting systems added 2010–2022

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
India (contin.)	Solar PV and CSP	100 GW by 2022
	Wind power	60 GW by 2022
Andhra Pradesh	***Solar PV***	***Addition of 5,000 MW between 2015 and 2020***
Jharkhand	***Solar PV***	***2,650 MW installed by 2019–2020***
Indonesia	Geothermal power	12.6 GW by 2025
	Hydropower	2 GW by 2025, including 0.43 GW micro-hydropower
	Pumped storage[2]	3 GW by 2025
	Solar PV	156.8 MW by 2025
	Wind power	100 MW by 2025
Iran	Solar power and wind power	5 GW (no date)
Iraq	Solar PV	240 MW by 2016
	CSP	80 MW by 2016
	Wind power	80 MW by 2016
Italy	Bio-power	19,780 GWh/year generation from 2.8 GW capacity by 2020
	Geothermal power	6,759 GWh/year generation from 920 MW capacity by 2020
	Hydropower	42,000 GWh/year generation from 17.8 GW capacity by 2020
	Solar PV	23 GW by 2017
	Wind power (onshore)	18,000 GWh/year generation and 12 GW capacity by 2020
	Wind power (offshore)	2,000 GWh/year generation and 680 MW capacity by 2020
Japan	Ocean power (wave and tidal)	1.5 GW by 2030
Jordan	Electricity	1 GW by 2018
	Solar PV	300 MW by 2020
	CSP	300 MW by 2020
	Wind power	1.2 GW by 2020
Kazakhstan	Electricity	1.04 GW by 2020
Kenya	Geothermal power	1.9 GW by 2016; 5 GW by 2030
	Hydropower	794 MW by 2016
	Solar PV	423 MW by 2016
	Wind power	635 MW by 2016
Korea, Democratic People's Rep. of	Electricity	13,016 GWh/year (2.9% of total generation) by 2015; 21,977 GWh/year (4.7%) by 2020; 39,517 GWh/year (7.7%) by 2030 supplied by a mix of renewable technologies, including:
	Bio-power from solid biomass	2,628 GWh/year by 2030
	Bio-power from biogas	161 GWh/year by 2030
	Bio-power from landfill gas	1,340 GWh/year by 2030
	Geothermal power	2,046 GWh/year by 2030
	Hydropower (large-scale)	3,860 GWh/year by 2030
	Hydropower (small-scale)	1,926 GWh/year by 2030
	Ocean power	6,159 GWh/year by 2030
	Solar PV	2,046 GWh/year by 2030
	CSP	1,971 GWh/year by 2030
	Wind power	900 MW by 2016; 1.5 GW by 2019; 16,619 GWh/year by 2030
	Wind power (offshore)	2.5 GW by 2019
Kuwait	Solar PV	3.5 GW by 2030
	CSP	1.1 GW by 2030
	Wind power	3.1 GW by 2030

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Lebanon	Bio-power from biogas	15–25 MW by 2015
	Hydropower	40 MW by 2015
	Wind power	60–100 MW by 2015; 400–500 MW by 2020
Lesotho	Electricity	260 MW by 2030
Libya	Solar PV	129 MW by 2015; 344 MW by 2020; 844 MW by 2025
	CSP	125 MW by 2020; 375 MW by 2025
	Wind power	260 MW by 2015; 600 MW by 2020; 1 GW by 2025
Macedonia	Bio-power from solid biomass	50 GWh by 2020
	Bio-power from biogas	20 GWh by 2020
	Hydropower (small-scale)	216 GWh by 2020
	Solar PV	14 GWh by 2020
	Wind power	300 GWh by 2020
Malawi	Hydropower	346.5 MW by 2014
Malaysia	Electricity	2.1 GW (excluding large-scale hydropower), 11.2 TWh/year, or 10% of national supply (no date given) 6% of total capacity by 2015; 11% by 2020; 14% by 2030; 36% by 2050
Mexico	**Electricity**	**20 GW by 2030, of which:**
	Wind power	**10 GW by 2030**
Morocco	Hydropower	2 GW by 2020
	Solar PV and CSP	2 GW by 2020
	Wind power	2 GW by 2020
Mozambique	Bio-digesters for biogas	1,000 systems installed (no date)
	Hydropower, solar PV, wind power	2 GW each (no date)
	Solar PV	82,000 solar home systems installed (no date)
	Wind turbines for water pumping	3,000 stations installed (no date)
	Renewable energy- based productive systems	5,000 installed (no date)
Myanmar	**Hydropower**	**9.4 GW by 2030**
Nigeria	Bio-power	50 MW by 2015; 400 MW by 2025
	Hydropower (small-scale)[3]	600 MW by 2015; 2 GW by 2025
	Solar PV (large-scale, >1 MW)	75 MW by 2015; 500 MW by 2025
	Wind power	20 MW by 2015; 40 MW by 2025
	CSP	1 MW by 2015; 5 MW by 2025
Norway	Electricity	30 TWh/year generation by 2016
	Electricity	26.4 TWh common electricity certificate market with Sweden by 2020
Palestine, State of	Bio-power	21 MW by 2020
	Solar PV	45 MW by 2020
	CSP	20 MW by 2020
	Wind power	44 MW by 2020
Philippines	Electricity	Triple the 2010 capacity by 2030
	Bio-power	277 MW added 2010–2030
	Geothermal power	1.5 GW added 2010–2030
	Hydropower	5,398 MW added 2010–2030
	Ocean power	75 MW added 2010–2030
	Solar PV	284 MW added 2010–2030
	Wind power	2.3 GW added 2010–2030

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Poland	Wind power (offshore)	1 GW by 2020
Portugal	Electricity	15.8 GW by 2020
	Bio-power from solid biomass	769 MW by 2020
	Bio-power from biogas	59 MW by 2020
	Geothermal power	29 MW by 2020
	Hydropower (small-scale)	400 MW by 2020
	Ocean power (wave)	6 MW by 2020
	Solar PV	670 MW by 2020
	CSP	50 MW by 2020
	Wind power	5.3 GW onshore by 2020; 27 MW offshore by 2020
Qatar	Solar PV	1.8 GW by 2014
Russian Federat.	Hydropower (small-scale)[4], solar PV, wind power	6 GW combined by 2020
Rwanda	Biogas power	300 MW by 2017
	Geothermal power	310 MW by 2017
	Hydropower	340 MW by 2017
	Hydropower (small-scale)	42 MW by 2015
	Electricity (off-grid)	5 MW by 2017
Saudi Arabia	Electricity	54 GW by 2040
	Solar PV and CSP	41 GW by 2040 (25 GW CSP, 16 GW PV)
	Geothermal, waste-to-energy, wind power	13 GW combined by 2040
Serbia	Solar PV	150 MW by 2017
	Wind power	1.4 GW (no date)
Sierra Leone	Electricity	1 GW (no date)
Singapore	Solar PV	350 MW by 2020
Solomon Islands	**Geothermal power**	**20–40 MW (no date)**
	Hydropower	**3.77 MW (no date)**
	Solar power	3.2 MW (no date)
South Africa	Electricity	17.8 GW by 2030; 42% of new generation capacity installed 2010–2030
Spain	Bio-power from solid biomass	1.4 GW by 2020
	Bio-power from organic MSW[5]	200 MW by 2020
	Bio-power from biogas	400 MW by 2020
	Geothermal power	50 MW by 2020
	Hydropower	13.9 GW by 2020
	Pumped storage[2]	8.8 GW by 2020
	Ocean power	100 MW by 2020
	Solar PV	7.3 GW by 2020
	CSP	4.8 GW by 2020
	Wind power (onshore)	35 GW by 2020
	Wind power (offshore)	750 MW by 2020
Sudan	Bio-power from solid biomass	54 MW by 2031
	Bio-power from biogas	68 MW by 2031
	Hydropower	63 MW by 2031
	Solar PV	667 MW by 2031
	CSP	50 MW by 2031
	Wind power	680 MW by 2031

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Sweden	Electricity	25 TWh more renewable electricity annually by 2020 (base year 2002)
	Electricity	26.4 TWh common electricity certificate market with Norway by 2020
Switzerland	Electricity	12 TWh/year by 2035; 24.2 TWh/year by 2050
	Hydropower	43 TWh/year by 2035
Syria	Bio-power	140 MW by 2020; 260 MW by 2025; 400 MW by 2030
	Solar PV	45 MW by 2015; 380 MW by 2020; 1.1 GW by 2025; 1.8 GW by 2030
	CSP	50 MW by 2025
	Wind power	150 MW by 2015; 1 GW by 2020; 1.5 GW by 2025; 2 GW by 2030
Tajikistan	Hydropower (small-scale)	100 MW by 2020
Thailand	Bio-power from solid biomass	4.8 GW by 2021
	Bio-power from biogas	600 MW by 2021
	Bio-power from organic MSW[5]	400 MW by 2021
	Geothermal power	1 MW by 2021
	Hydropower	6.1 GW by 2021
	Ocean power (wave and tidal)	2 MW by 2021
	Solar PV	1 GW by 2014; 3 GW by 2021
	Wind power	1.8 GW by 2021
Trinidad and Tobago	Wind power	100 MW (no date given)
Tunisia	Electricity	1 GW (16% of capacity) by 2016; 4.6 GW (40% of capacity) by 2030
	Bio-power from solid biomass	40 MW by 2016; 300 MW by 2030
	Solar power	**10 GW by 2030** [Solar PV: 140 MW by 2016; 1.5 GW by 2030, CSP: 500 MW by 2030]
	Wind power	**16 GW by 2030** [430 MW by 2016; 1.7 GW by 2030]
Turkey	Bio-power from solid biomass	1 GW by 2023
	Geothermal	1 GW by 2023
	Hydropower	34 GW by 2023
	Solar PV	5 GW by 2023
	Wind power	20 GW by 2023
Uganda	Bio-power from organic MSW[5]	30 MW by 2017
	Geothermal power	45 MW by 2017
	Hydropower (large-scale)	1.2 GW by 2017
	Hydropower (mini- and micro-scale)	85 MW by 2017
	Solar PV (solar home systems)	700 kW by 2017
United Kingdom	Wind power (offshore)	39 GW by 2030
United States		No national target
Iowa	*Electricity*	*105 MW of generating capacity for IOUs*[6]
Texas	*Electricity*	*5,880 MW*
Uruguay	Bio-power	200 MW by 2015
	Wind power	1.3 GW by 2015
Venezuela	Electricity	613 MW new capacity installed 2013–2019, including:
	Wind	500 MW new capacity installed 2013–2019
Vietnam	Bio-power	200 MW by 2015
	Hydropower	19.2 GW by 2020
	Wind power	1 GW by 2020

Table R19. Targets for Renewable Power Installed Capacity and/or Generation (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	TECHNOLOGY	TARGET
Yemen	Bio-power	6 MW by 2025
	Geothermal power	200 MW by 2025
	Solar PV	4 MW by 2025
	CSP	100 MW by 2025
	Wind power	400 MW by 2025

[1] India does not classify hydropower installations larger than 25 MW as renewable energy sources. Therefore, national targets and data for India do not include hydropower facilities >25 MW. India 2014–2015 targets are for the national fiscal year, which runs from April 2014 through March 2015.

[2] Pumped hydro plants are not energy sources but a means of energy storage. As such, they involve conversion losses and are powered by renewable or non-renewable electricity. Pumped storage is included here because it can play an important role as balancing power, in particular for variable renewable resources.

[3] Nigeria's target excludes hydropower plants >30 MW.

[4] The Russian Federation's targets exclude hydropower plants >25 MW.

[5] It is not always possible to determine whether municipal solid waste (MSW) data include non-organic waste (plastics, metal, etc.) or only the organic biomass share. Uganda utilises predominantly organic waste.

[6] Investor-owned utilities (IOUs) are those operating under private control rather than government or co-operative operation.

Note: All capacity targets are for cumulative capacity unless otherwise noted. Targets are rounded to the nearest tenth decimal. Renewable energy targets are not standardised across countries; therefore, the table presents a variety of targets for the purpose of general comparison. Countries on this list may also have primary/final energy, electricity, heating/cooling or transport targets (see Reference Tables R12–R15, R16–R22).

Source: See endnote 17 for this section.

REN21 Renewable Energy Policy Network for the 21st Century

Table R20. Cumulative Number[1] of Countries/States/Provinces Enacting Feed-in Policies, and 2015 Revisions

Note: Text in **bold** indicates new/revised in 2015.

YEAR	CUMULATIVE #[1]	COUNTRIES/STATES/PROVINCES ADDED THAT YEAR
1978	1	United States[2]
1990	2	**Germany**
1991	3	Switzerland
1992	4	**Italy**
1993	6	Denmark; India
1994	9	Luxembourg; Spain; Greece
1997	10	Sri Lanka
1998	11	Sweden
1999	14	Portugal; Norway; Slovenia
2000	14	None identified
2001	17	Armenia; **France**; Latvia
2002	23	Algeria; Austria; Brazil; Czech Republic; Indonesia; Lithuania
2003	29	Cyprus; Estonia; Hungary; Republic of Korea; Slovak Republic; Maharashtra (India)
2004	34	Israel; Nicaragua; Prince Edward Island (Canada); Andhra Pradesh and Madhya Pradesh (India)
2005	41	China; **Ecuador**; Ireland; Turkey; Karnataka, Uttar Pradesh and Uttarakhand (India)
2006	46	Argentina; Pakistan; **Thailand**; Ontario (Canada); Kerala (India)
2007	55	Albania; Bulgaria; Croatia; Dominican Republic; Finland; Macedonia; Moldova; Mongolia; South Australia (Australia)
2008	70	Iran; Kenya; Liechtenstein; **Philippines**; San Marino; **Tanzania**; Queensland (Australia); Chhattisgarh, Gujarat, Haryana, Punjab, Rajasthan, Tamil Nadu and West Bengal (India); California (USA)
2009	81	**Japan**; Serbia; South Africa; Taipei (China); **Ukraine**; Australian Capital Territory, New South Wales and Victoria (Australia); Hawaii, Oregon and Vermont (USA)
2010	87	Belarus; Bosnia and Herzegovina; Malaysia; **Malta**; Mauritius; United Kingdom
2011	94	**Ghana**; Montenegro; Netherlands; Syria; Vietnam; Nova Scotia (Canada); Rhode Island (USA)
2012	99	Jordan; Nigeria; State of Palestine; Rwanda; Uganda
2013	101	Kazakhstan; Pakistan
2014	104	Egypt; Vanuatu; Virgin Islands (USA)
2015	104	None identified
Total[3]	**110**	

[1] "Cumulative number" refers to number of jurisdictions that had enacted feed-in policies as of the given year.

[2] The US PURPA policy (1978) is an early version of the FIT, which has since evolved.

[3] "Total existing" excludes nine countries that are known to have subsequently discontinued policies (Brazil, Czech Republic, Mauritius, Norway, Republic of Korea, South Africa, Spain, Sweden and the United States) and adds ten countries (Andorra, Honduras, Maldives, Panama, Peru, Poland, the Russian Federation, Senegal, Tajikistan and Uruguay) and five Indian states (Bihar, Himachal Pradesh, Jammu and Kashmir, Jharkhand and Orissa) that are believed to have FITs but with an unknown year of enactment.

Source: See endnote 18 for this section.

Table R20. Cumulative Number[1] of Countries/States/Provinces Enacting Feed-in Policies, and 2015 Revisions (continued)

Note: Text in **bold** indicates new/revised in 2015.

2015 FIT POLICY ADJUSTMENTS	
Ecuador	Rates removed for all technologies except biomass and small-scale hydropower
France	Solar PV: rates increased 10% for small-scale rooftop systems up to 100 kW Biogas: rates up 10–20% for co-generation facilities fuelled by biogas
Germany	Solar PV: replaced by tendering for projects between 500 kW and 10 MW
Ghana	Solar PV: temporary cap on project size (≤20 MW) and 150 MW overall
Italy	Suspended for projects not in compliance with electric grid code
Japan	Solar PV: rates reduced. Biomass: incentive created for small-scale biomass
Malta	Solar PV: new rates added for systems 1–40 kW and 40 kW–1 MW [previously uncovered]
Philippines	Wind and solar PV: rates reduced
Poland	Small-scale projects up to 10 kW qualify for FIT
Tanzania	Rate structure changed from one based on seasonally adjusted utility-avoided costs to a system of technology-differentiated tariffs adjusted based on the U.S. Consumer Price Index
Thailand	Expanded list of qualifying technologies for projects <10 MW
Ukraine	FIT introduced for geothermal power, small-scale wind and biomass (products and waste) Solar PV: FIT reduced

[1] "Cumulative number" refers to number of jurisdictions that had enacted feed-in policies as of the given year.

[2] The US PURPA policy (1978) is an early version of the FIT, which has since evolved.

[3] "Total" excludes nine countries that are known to have subsequently discontinued policies (Brazil, Czech Republic, Mauritius, Norway, Republic of Korea, South Africa, Spain, Sweden and the United States) and adds ten countries (Andorra, Honduras, Maldives, Panama, Peru, Poland, Russian Federation, Senegal, Tajikistan and Uruguay) and five Indian states (Bihar, Himachal Pradesh, Jammu and Kashmir, Jharkhand and Orissa) that are believed to have FITs but with an unknown year of enactment.

Source: See endnote 18 for this section.

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Table R21. Cumulative Number[1] of Countries/States/Provinces Enacting RPS/Quota Policies, and 2015 Revisions

Note: Text in **bold** indicates new/revised in 2015.

YEAR	CUMULATIVE #[1]	COUNTRIES/STATES/PROVINCES ADDED THAT YEAR
1983	1	Iowa (USA)
1994	2	Minnesota (USA)
1996	3	Arizona (USA)
1997	6	Maine, Massachusetts, Nevada (USA)
1998	9	Connecticut, Pennsylvania, Wisconsin (USA)
1999	12	Italy; New Jersey, Texas (USA)
2000	13	New Mexico (USA)
2001	15	Australia; Flanders (Belgium)
2002	18	United Kingdom; Wallonia (Belgium); **California** (USA)
2003	21	Japan; Sweden; Maharashtra (India)
2004	34	Poland; **Nova Scotia**, Ontario and Prince Edward Island (Canada); Andhra Pradesh, Karnataka, Madhya Pradesh, Orissa (India); Colorado, **Hawaii**, Maryland, **New York**, Rhode Island (USA)
2005	38	Gujarat (India); Delaware, District of Columbia, Montana (USA)
2006	39	Washington State (USA)
2007	45	China; Illinois, New Hampshire, North Carolina, Northern Mariana Islands, Oregon (USA)
2008	52	Chile; India; Philippines; Romania; Michigan, Missouri, Ohio2 (USA)
2009	53	**Kansas (USA)**
2010	56	Republic of Korea; British Columbia (Canada); Puerto Rico (USA)
2011	58	Albania; Israel
2012	59	Norway
2013	59	None identified
2014	59	None identified
2015	**61**	**Vermont, Virgin Islands (USA)**
Total[3]	**100**	

[1] "Cumulative number" refers to the number of jurisdictions that had enacted RPS/Quota policies as of the given year. Jurisdictions are listed under the year of first policy enactment. Many policies shown have been revised or renewed in subsequent years, and some policies shown may have been repealed or lapsed.

[2] Ohio's (USA) RPS policy was put on hold in 2014. It has not been officially revoked.

[3] "Total" adds 41 jurisdictions believed to have RPS/Quota policies but whose year of enactment is not known (Belarus, Ghana, Indonesia, Kyrgyzstan, Lithuania, Malaysia, Palau, Peru, Portugal, Senegal, South Africa, Sri Lanka, United Arab Emirates, the Indian states of Arunchal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh and West Bengal and the Indian Union Territories of Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Delhi, Lakshadweep and Puducherry) and excludes Italy, which phased out its RPS in 2012, and the US state of Kansas which downgraded its RPS to a voluntary goal in 2015. In the United States, there are nine additional states and territories with policy goals that are not legally binding RPS policies (Guam, Indiana, Kansas, North Dakota, Oklahoma, South Carolina, South Dakota, Utah and Virginia). West Virginia's non-binding goal was repealed in 2015. Three additional Canadian provinces also have non-binding policy goals (Alberta, Manitoba and Quebec).

Source: See endnote 19 for this section.

Table R22. Renewable Energy Auctions Held in 2015 by Country/State/Province

COUNTRY	TECHNOLOGY	DESCRIPTION
Brazil	Bioenergy	565.23 MW awarded
	Small-scale hydropower	262.43 MW awarded
	Solar PV	1,763.1 MW awarded
	Wind power	1,177 MW awarded
China	Solar PV	1 GW tender issued
France	Solar PV	240 MW of building-mounted PV offered; 800 MW of solar PV >250 kW offered
Germany	Solar PV	500 MW offered
Iraq	Electricity	4 pilot Independent Power Producer (IPP) projects offered
Jordan	Solar PV	200 MW awarded
	Wind power	117 MW awarded
Morocco	Wind power	850 MW awarded
Peru	Electricity	1,300 GWh of biomass, wind and solar PV power offered
Russian Federat.	Electricity	365 MW of solar PV, wind and hydropower awarded
South Africa	Renewable power	1,084 MW awarded in bid round 4.5
	Bio-power	25 MW awarded in bid round 4
	Small-scale hydropower	4.7 MW awarded in bid round 4
	Solar PV	415 MW awarded in bid round 4
	Wind power	676 MW awarded in bid round 4
Turkey	Wind power	3 GW offered (42 GW bid) in April

COUNTRY	TECHNOLOGY	DESCRIPTION
Australia		
Australian Capital Territory	Wind power	200 MW offered
India		
Jharkhand	Solar PV	1,200 MW offered
Telangana	Solar PV	400 MW offered
United Arab Emirates		
Dubai	Solar PV	200 MW awarded

Source: See endnote 20 for this section.

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Table R23. Heating and Cooling from Renewable Sources, Targets and 2014 Shares

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted.

COUNTRY	SHARE (2014)	TARGET
Austria	32.6%	32.6% by 2020
Belgium	7.8%	11.9% by 2020
Bhutan		Solar heating and cooling: 3 MW equivalent by 2025
Bulgaria	28.3%	24% renewables in total heating and cooling by 2020
China		Solar water heating: 280 GW_{th} (400 million m^2) by 2015
Croatia	36.2%	19.6% by 2020
Cyprus	21.8%	23.5% by 2020
Czech Rep.	16.7%	14.1% by 2020
Denmark	37.8%	39.8% by 2020
Estonia	45.2%	38% by 2020
Finland	51.9%	47% by 2020
France	17.8%	**38% by 2030** [33% by 2020]
Germany	12.2%	14% by 2020
Greece	26.9%	20% by 2020
Hungary	12.4%	18.9% by 2020
India		Solar water heating: 5.6 GW_{th} (8 million m^2) of new capacity to be added 2012–2017
Ireland	6.6%	15% by 2020
Italy	18.9%	17.1% by 2020 Bioenergy: 5,670 ktoe for heating and cooling by 2020 Geothermal: 300 ktoe for heating and cooling by 2020 Solar water and space heating: 1,586 ktoe by 2020
Jordan	1.76%	Solar water heating: systems for 30% of households by 2020
Kenya		Solar water heating: 60% of annual demand for buildings that use over 100 litres of hot water per day (no date)
Kosovo[1]		45.65% by 2020
Latvia	52.2%	53.4% by 2020
Lebanon		**15% renewables in gross final consumption in power and heating by 2030**
Libya		Solar water heating: 80 MW_{th} by 2015; 250 MWth by 2020
Lithuania	41.6%	39% by 2020
Luxembourg	7.4%	8.5% renewables in gross final consumption in heating and cooling by 2020
Malawi		**Produce 2,000 SWHs; increase total installed to 20,000 by 2030**
Malta	14.6%	6.2% by 2020
Mexico		Install 18.2 million m^2 of SWH collectors by 2027
Moldova		27% by 2020
Montenegro	36.3%	38.2% by 2020
Morocco		Solar water heating: 1.2 GW_{th} (1.7 million m^2) by 2020
Mozambique		Solar water and space heating: 100,000 systems installed in rural areas (no date)
Netherlands	5.2%	8.7% by 2020
Poland	13.9%	17% by 2020
Portugal	34%	30.6% by 2020
Romania	26.8%	22% by 2020
Serbia		30% by 2020
Sierra Leone		1% penetration of solar water heaters in hotels, guest houses and restaurants by 2015; 2% by 2020; 5% by 2030 1% penetration of solar water heaters in the residential sector by 2030
Slovakia	8.7%	14.6% by 2020
Slovenia	33.3%	30.8% by 2020
Spain	15.8%	18.9% by 2020 Bioenergy: 4,653 ktoe by 2020 Geothermal: 9.5 ktoe by 2020 Heat pumps: 50.8 ktoe by 2020 Solar water and space heating: 644 ktoe by 2020
Sweden	68.1%	62.1% by 2020
Thailand		Bioenergy: 8,200 ktoe by 2022 Biogas: 1,000 ktoe by 2022 Organic MSW[2]: 35 ktoe by 2022 Solar water heating: 300,000 systems in operation and 100 ktoe by 2022
Uganda		Solar water heating: 21 MW_{th} (30,000 m^2) by 2017
Ukraine		12.4% by 2020
United Kingdom	4.5%	12% by 2020

[1] Kosovo is not a member of the United Nations.

[2] It is not always possible to determine whether municipal solid waste (MSW) data include non-organic waste (plastics, metal, etc.) or only the organic biomass share.

Note: Targets refer to share of renewable heating and cooling in total energy supply unless otherwise noted. Historical targets have been added as they are identified by REN21. Only bolded targets are new/revised in 2015. A number of nations have already exceeded their renewable energy targets. In many of these cases, targets serve as a floor setting the minimum share of renewable heat for the country. Table includes targets established under EU National Renewable Energy Action Plans. Because heating and cooling targets are not standardised across countries, the table presents a variety of targets for the purpose of general comparison.

Source: See endnote 21 for this section.

BACK

Table R24. Transportation Energy from Renewable Sources, Targets and 2014 Shares

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	SHARE	TARGET
EU-28	5.9%	10% of EU-wide transport final energy demand by 2020
Albania		→ 10% by 2020
Austria	8.9%	→ 11.4% by 2020
Belgium	4.9%	→ 10% by 2020
Wallonia		→ *10.14% by 2020*
Bulgaria	5.3%	→ 11% by 2020
Croatia	2.1%	→ 10% by 2020
Cyprus	2.7%	→ 4.9% by 2020
Czech Republic	6.1%	→ 10.8% by 2020
Denmark	5.8%	→ 10% by 2020
Estonia	0.2%	→ 10% by 2020
Finland	21.6%	→ 20% by 2020
France	**7.8%**	→ **15% by 2020** [10.5% by 2020]
Germany	6.6%	→ 20% by 2020
Greece	1.4%	→ 10.1% by 2020
Hungary	6.9%	→ 10% by 2020
Iceland	0.6%	→ 10% by 2020
Indonesia		→ 10.2% biofuel share of primary energy by 2025
Ireland	5.2%	→ 10% by 2020
Italy	4.5%	→ 10.1% (2,899 ktoe) by 2020
Latvia	3.2%	→ 10% by 2020
Liberia		→ 5% palm oil blends in transport fuel by 2030
Lithuania	4.2%	→ 10% by 2020
Luxembourg	5.2%	→ 10% by 2020
Malta	4.7%	→ 10.7% by 2020
Moldova		→ 20% by 2020
Netherlands	5.7%	→ 10% by 2020
Norway	4.8%	→ 10% by 2020
Panama		→ **30% of new vehicle purchases for public fleets to be flex-fuel (no date)**
Poland	5.7%	→ 20% by 2020
Portugal	3.4%	→ 10% by 2020
Qatar		→ 10% by 2020
Romania	3.8%	→ 10% by 2020
Slovakia	6.9%	→ 10% by 2020
Slovenia	2.6%	→ 10.5% by 2020
Spain	0.5%	→ 11.3% from biodiesel by 2020 2,313 ktoe ethanol/bio-ETBE[1] by 2020 4.7 GWh/year electricity in transport by 2020 (501 ktoe from renewable sources by 2020)
Sri Lanka		→ 20% from biofuels by 2020
Sweden	19.2%	Vehicle fleet independent from fossil fuels by 2030
Thailand		9 million litres/day ethanol consumption by 2022 6 million litres/day biodiesel consumption by 2022 25 million litres/day advanced biofuels production by 2022
Uganda		2,200 million litres/year biofuels consumption by 2017
Ukraine		→ 10% by 2020
United Kingdom	4.9%	→ 5% by 2014; 10.3% by 2020
Vietnam		→ 1% of transport petroleum energy demand by 2015; 5% by 2025
Zimbabwe		→ 10% by 2015

[1] ETBE is a form of biofuel produced from ethanol and isobutylene.

Note: Targets refer to share of renewable transport in total energy supply unless otherwise noted. Historical targets have been added as they are identified by REN21. Only bolded targets are new/revised in 2015. A number of nations have already exceeded their renewable energy targets. In many of these cases, targets serve as a floor setting the minimum share of renewable energy for the country

Source: See endnote 22 for this section.

Table R25. National and State/Provincial Biofuel Blend Mandates

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted, and text in *italics* indicates policies adopted at the state/provincial level.

COUNTRY	MANDATE
Angola	E10
Argentina	E5 and B10
Australia	*State: E6 and B2 in New South Wales;* ***E3 by July 2017, E4 by July 2018*** *and B0.5 in Queensland*
Belgium	E4 and B4
Brazil	E27.5 and **B10** [B7]
Canada	*National:* E5 and B2 *Provincial:* E5 and B2 in Alberta; E5 and B4 in British Columbia; E8.5 and B2 in Manitoba; E5, B2 and B3 by 2016 and B4 by 2017 in Ontario; E7.5 and B2 in Saskatchewan
China[1]	E10 in nine provinces, B1 in Taipei
Colombia	E8 and B10
Costa Rica	E7 and B20
Ecuador	B5 and E10, **E5 in 2016**
Ethiopia	E10
Guatemala	E5
India	**E10**
Indonesia	E3, B5 and **15% gasoil**
Italy	0.6% advanced biofuels blend by 2018; 1% by 2022
Jamaica	E10
Korea, Republic of	**B2.5**; B3 by 2018 [B2]
Malawi	E10
Malaysia	**E10 and B10** [B5]
Mozambique	E10 in 2012–15; E15 in 2016–20; E20 from 2021
Norway	B3.5
Panama	**E7**; E10 by April 2016 (E5)
Paraguay	E25 and B1
Peru	E7.8 and B2
Philippines	E10 and B2; B5 in 2015
South Africa	**E2 and B5 (targets came into force in 2015)**
Sudan	E5
Thailand	E5 and **B7** [B5]
Turkey	E2
Ukraine	E5; E7 by 2017
United States	***National:*** RFS 2015 standards: 465 million litres cellulosic biofuel, 6.54 billion litres biodiesel, 10.9 billion litres advanced biofuel, 64.09 billion litres total renewable fuels 2016 standards: 870 million litres cellulosic biofuel, 7.19 billion gallons biodiesel, 13.67 billion litres advanced biofuel, 68.55 billion litres total renewable fuels. A standard of 7.57 billion litres biodiesel was set for 2017. State: E10 in Hawaii; E2 and B2 in Louisiana; B5 in Massachusetts; E20 and B10 in Minnesota; E10 in Missouri and Montana; B5 in New Mexico; E10 and B5 in Oregon; B2 one year after 200 million gallons, and B20 one year after 400 million gallons in Pennsylvania; E2 and B2, increasing to B5 180 days after in-state feedstock, and oil-seed crushing capacity can meet 3% requirement in Washington.
Uruguay	E5 and B5
Vietnam	E5
Zimbabwe	E5, to be raised to E10 and E15 (no date given)

[1] Chinese provincial mandates include Anhui, Heilongjian, Henan, Jilin and Liaoning.

Note: 'E' refers to ethanol and 'B' refers to biodiesel. Chile has targets of E5 and B5 but has no current blending mandate. The Dominican Republic has targets of B2 and E15 for 2015 but has no current blending mandate. Fiji approved voluntary B5 and E10 blending in 2011 with a mandate expected. The Kenyan city of Kisumu has an E10 mandate. Mexico has a pilot E2 mandate in the city of Guadalajara. Nigeria has a target of E10 but no current blending mandate. Reference Table R25 lists only biofuel blend mandates; transport and biofuel targets can be found in Reference Table R21.

Source: See endnote 23 for this section.

Table R26. City and Local Renewable Energy Targets: Selected Examples

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted.

TARGETS FOR 100% OF TOTAL ENERGY OR ELECTRICITY FROM RENEWABLES

	TARGET DATE FOR 100% TOTAL ENERGY	TARGET DATE FOR 100% ELECTRICITY
Aspen, Colorado, USA		2015
Burlington, Vermont, USA		Achieved in 2014
Byron Shire County, Australia	**2025**	
Coffs Harbour, Australia		**2030**
Copenhagen, Denmark	2050	
Frankfurt, Germany	2050	
Fukushima Prefecture, Japan	2040	
Greensburg, Kansas, USA		Achieved in 2015
Hamburg, Germany	2050	
Jeju Self Governing Province, Republic of Korea		2030
Lancaster, California, USA		2020
Malmö, Sweden		2030
Munich, Germany		2025
Osnabrück, Germany		2030
Oxford County, Australia	**2050**	
Palo Alto, California, USA		(no date given)
Rochester, Minnesota, USA		**2031**
San Diego, California, USA		**2035**
San Francisco, California, USA		2020
San Jose, California, USA		2022
Seattle, Washington, USA		(no date given)
Skellefteå, Sweden		2020
Sønderborg, Denmark	2029	
Sydney, Australia	2030	
Ulm, Germany		2025
Uralla, Australia	**(no date given)**	
Vancouver, Canada	**2050**	
Växjö, Sweden	2030	

TARGETS FOR RENEWABLE SHARE OF TOTAL ENERGY, ALL CONSUMERS

Austin, Texas, USA	→ 65% by 2025
Boulder, Colorado, USA	→ 30% by 2020
Calgary, Alberta, Canada	→ 30% by 2036
Cape Town, South Africa	→ 10% by 2020
Howrah, India	→ 10% by 2018
Nagano Prefecture, Japan	→ 70% by 2050
Oaxaca, Mexico	→ 5% by 2017
Paris, France	→ 25% by 2020
Skellefteå, Sweden	Net exporter of biomass, hydro or wind energy by 2020

TARGETS FOR RENEWABLE SHARE OF ELECTRICITY, ALL CONSUMERS

Amsterdam, Netherlands	→ 25% by 2025; 50% by 2040
Austin, Texas, USA	→ 35% by 2020
Canberra, Australian Capital Territory, Australia	→ 90% by 2020
Cape Town, South Africa	→ 15% by 2020
Nagano Prefecture, Japan	→ 10% by 2020; 20% by 2030; 30% by 2050
Taipei City, Taipei, China	→ 12% by 2020
Tokyo, Japan	→ **24% by 2024** [20% by 2024]
Wellington, New Zealand	→ 78–90% by 2020

Table R26. City and Local Renewable Energy Targets: Selected Examples (continued)

Note: Text in **bold** indicates new/revised in 2015, brackets '[ ]' indicate previous targets where new targets were enacted.

TARGET FOR RENEWABLE ELECTRIC CAPACITY OR GENERATION	
Adelaide, Australia	2 MW of solar PV on residential and commercial buildings by 2020
Esklistuna, Sweden	48 GWh from wind power, 9.5 GWh from solar PV by 2020
Gothenburg, Sweden	500 GWh by 2030
Los Angeles, California, USA	1.3 GW of solar PV by 2020
New York, New York, USA	350 MW of solar PV by 2024
San Francisco, California, USA	→ 100% of peak demand (950 MW) by 2020

TARGETS FOR GOVERNMENT SELF-GENERATION / OWN-USE PURCHASES OF RENEWABLE ENERGY	
Belo Horizonte, Brazil	→ **30% of electricity from solar PV by 2030**
Cockburn, Australia	→ 20% of final energy in city buildings by 2020
Ghent, Belgium	→ 50% of final energy by 2020
Hepburn Shire, Australia	→ 100% of final energy in public buildings; 8% of electricity for public lighting
Kristianstad, Sweden	→ 100% of final energy by 2020
Malmö, Sweden	→ 100% of final energy by 2020
Portland, Oregon, USA	→ 100% of final energy by 2030
Sydney, Australia	→ 100% of electricity in buildings; 20% for street lamps

HEAT-RELATED MANDATES AND TARGETS	
Amsterdam, Netherlands	District heating for at least 200,000 houses by 2040 (using biogas, woody biomass and waste heat)
Chandigarh, India	Mandatory use of solar water heating in industries, hotels, hospitals, prisons, canteens, housing complexes, and government and residential buildings (as of 2013)
Helsingborg, Sweden	100% renewable energy district heating (community-scale) by 2035
Loures, Portugal	Solar thermal systems mandated as of 2013 in all sports facilities and schools that have good sun exposure
Munich, Germany	80% reduction of heat demand by 2058 (base year 2009) through passive solar design (includes heat, process heat and water heating)
Nantes, France	Extend the district heating system to source heat from biomass boilers for half of city inhabitants by 2017
Osnabrück, Germany	100% renewable heat by 2050
Täby, Sweden	100% renewable heat in local government operations by 2020
Vienna, Austria	50% of total heat demand with solar thermal energy by 2050

Note: Table provides a sample of local renewable energy commitments worldwide. It does not aim to present a comprehensive picture of all municipal renewable energy goals.
Source: See endnote 24 for this section.

GLOBAL OVERVIEW

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bp-statistical-review-of-world-energy-2015-full-report.pdf. Traditional biomass use in 2014 of 760 Mtoe assumes an increase of 1 Mtoe from 2013 based on 2013 value of 759 Mtoe from IEA, op. cit. note 2, pp. 348–49; 2012 value of 758 Mtoe from IEA, *World Energy Outlook 2014* (Paris: 2014), p. 242; 2013 value "estimated at around 32 EJ" from IEA, *Medium-Term Renewable Energy Market Report 2015* (Paris: 2015), p. 244, https://www.iea.org/bookshop/708-Medium-Term_Renewable_Energy_Market_Report_2015. Modern bio-heat energy values for 2013 (industrial, residential, and other uses, including heat from heat plants) of 321.7 Mtoe (13.468 EJ) based on combined value of 14.8 EJ estimated for all renewable heat, of which around 91% is biomass, from IEA, idem, p. 243. Bio-power generation of 36.9 Mtoe (429.3 TWh), based on data from IEA, idem, p. 139, except for the following countries: United States data from US Energy Information Administration (EIA), *Electric Power Monthly*, February 2016, Table 1.1.A, http://www.eia.gov/electricity/monthly/current_year/february2016.pdf, and corrected for difference between net and gross electricity generation; Germany preliminary statistics from Bundesministerium für Wirtschaft und Energie (BMWi), *Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015* (Berlin: February 2016), https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/entwicklung_der_erneuerbaren_energien_in_deutschland_im_jahr_2015.pdf?__blob=publicationFile&v=12 ; United Kingdom from UK Department of Energy & Climate Change (DECC), "Energy Trends Section 6 – Renewables" (London: March 2016), Table 6.1, https://www.gov.uk/government/statistics/energy-trends-section-6-renewables; Government of India, Ministry of New and Renewable Energy (MNRE), "Physical progress (achievements) – up to the month of December 2015," http://www.mnre.gov.in/mission-and-vision-2/achievements/, viewed 1 February 2016; MNRE, "Physical progress (achievements) – up to the month of December 2014," http://www.mnre.gov.in/mission-and-vision-2/achievements/, viewed 21 January 2015. Wind power generation of 60.4 Mtoe (702 TWh) from IEA, idem, pp. 164, 170. Solar PV generation of 18.3 Mtoe (212 TWh), from IEA Photovoltaic Power System Programme (IEA PVPS), *Trends 2015 in Photovoltaic Applications*, *Survey Report of Selected IEA Countries Between 1992 and 2014* (Paris: 2015), Table 11, p. 57, http://www.iea-pvps.org/fileadmin/dam/public/report/national/IEA-PVPS_-_Trends_2015_-_MedRes.pdf. CSP estimated at 0.7 Mtoe (8.2 TWh), based on the reported output of Spain and the United States (7,393 GWh) and their share of global CSP capacity in 2014 (91%), from Red Eléctrica de España (REE), *El Sistema Eléctrico Español, Avance 2015* (Madrid: 2015), http://www.ree.es/sites/default/files/downloadable/avance_informe_sistema_electrico_2015_v2.pdf, and from US EIA, op. cit. this note, Tables 1.1A and 6.2B. Ocean power was 0.1 Mtoe (1.1 TWh), from IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit. this note, p. 158. Geothermal electricity generation of 6.3 Mtoe (73.5 TWh), from Ruggero Bertani, "Geothermal power generation in the world 2010-2014 update report," *Proceedings of the World Geothermal Congress 2015* (Melbourne, Australia: 19–25 April 2015). Hydropower of 334 Mtoe (3,885 TWh) from BP, op. cit. this note. Solar thermal heating/cooling estimated at 28.8 Mtoe (1.21 EJ), from Franz Mauthner, AEE-Institute for Sustainable Technologies (AEE INTEC), Gleisdorf, Austria, personal communications with REN21, April 2016, and from Franz Mauthner, Werner Weiss, and Monika Spörk-Dür, *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2014* (Gleisdorf, Austria: IEA Solar Heating and Cooling Programme (SHC), 2016). Note that the estimate does not consider air collectors. Geothermal heat (excluding heat pumps) estimated at 6.3 Mtoe (0.26 EJ), based on 2014 value from John W. Lund and Tonya L. Boyd, "Direct utilization of geothermal energy: 2015 worldwide review," in *Proceedings of the World Geothermal Congress 2015*, op. cit. this note. For liquid biofuels, ethanol use was estimated at 47.8 Mtoe (2.05 EJ) and biodiesel use at 23.3 Mtoe (0.98 EJ), based on 94.5 billion litres and 30.4 billion litres, respectively, from IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit. this note, pp. 260–61, and from F.O. Licht, 2016; conversion factors from US Department of Energy (DOE), *Alternative Fuels Data Center*, http://www.afdc.energy.gov/fuels. Nuclear power generation was assumed to contribute 218 Mtoe (2,537 TWh) of final energy, from BP, op. cit. this note.

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35 IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit. note 31.

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38 IEA, op. cit. note 2, p. 344.

39 Kopetz, op. cit. note 33; Teske, op. cit. note 14.

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45 Ibid. Fred Pearce, "Peak coal: why the industry's dominance may soon be over," Yale e360 Digest, 19 June 2014, http://e360.yale.edu/feature/peak_coal_why_the_industrys_dominance_may_soon_be_over/2777/. See also IEA, op. cit. note 2, Executive Summary.

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48 Second largest after China based on preliminary 2014 data from IEA, *Key Coal Trends Excerpt from Coal Information* (Paris: 2015), p. 13, http://www.iea.org/publications/freepublications/publication/KeyCoalTrends.pdf; Katherine Tweed, "America's coal production falls to its lowest level since 1986," Greentech Media, 11 January 2016, http://www.greentechmedia.com/articles/read/Americas-Coal-Production-Falls-to-Its-Lowest-Level-Since-1986; coal's share of US electricity generation fell from 53% to 35% in five years, from Pearce, op. cit. note 3; coal has been overtaken by natural gas and renewables, and gas surpassed coal as the dominant source of electricity generation for the first time ever in April 2015, from Tweed, op. cit. this note; market value of the stock of the top five US coal producers fell from more than USD 45 billion around 2010 to under USD 2 billion by early 2016, from David Crane, "King Coal and the irony of the endgame," Greenbiz, 16 February 2016, http://www.greenbiz.com/article/king-coal-and-irony-endgame.

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50 Integration from Paul Simons, IEA, presentation at 17e Colloque du Syndicat des Energies Renouvelables, UNESCO, Paris, 4 February 2016; lack of policy security/predictability and political instability in many countries, particularly in the developing world, from Galán, op. cit. note 33; fiscal constraints from idem and from Sargsyan, op. cit. note 1. **Sidebar 1** based on the following sources: All information from REN21, *UNECE Renewable Energy Status Report* (Paris: December 2015), www.ren21.net/regional, except where otherwise noted; onshore wind potential based on country profiles published in IRENA, *Renewable Energy Country Profiles for the European Union* (Abu Dhabi: June 2013), http://www.irena.org/DocumentDownloads/Publications/_EU27Complete.pdf, and in IRENA, *Renewable Energy Country Profiles: Eurasia, Non-EU Europe and North America* (Abu Dhabi: December 2013); CSP potential from IEA, *Solar Energy Perspectives* (Paris: OECD/IEA, 2011), p. 58, http://www.iea.org/publications/freepublications/publication/Solar_Energy_Perspectives2011.pdf; solar water heating based on information compiled from local co-ordinating contributors and from Franz Mauthner, Werner Weiss, and Monika Spörk-Dür, *Solar Heat Worldwide: Market and Contribution to the Energy Supply 2013* (Gleisdorf, Austria: IEA Solar Heating & Cooling Programme, June 2015), p. 30, http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2015.pdf; strategies and targets from IEA, *Eastern Europe, Caucasus and Central Asia* (Paris: OECD/IEA, 2015), https://www.iea.org/publications/freepublications/publication/INOGATE_Summary_FINAL.pdf. The countries without feed-in tariffs are Moldova, the Russian Federation, Tajikistan, Turkmenistan and Uzbekistan. As of 2015, tendering was used in Albania, Bosnia and Herzegovina, Montenegro and the Russian Federation. Net metering has been adopted in Armenia, Belarus, Montenegro and Ukraine. Countries without national energy efficiency targets include Armenia, Azerbaijan, Georgia, Kyrgyzstan and Turkmenistan. Countries without national energy efficiency awareness campaigns are Albania, Armenia, Turkmenistan and Ukraine. For investment data, see Figure 13 in REN21, *UNECE Renewable Energy Status Report*, op. cit. this note; entrenched interests as a barrier from Samantha Ölz, independent consultant, Moscow, personal communication with REN21, 24 January 2016.

51 Hinrichs-Rahlwes, op. cit. note 14.

52 FS–UNEP Centre and BNEF, op. cit. note 41, p. 19.

53 Galán, op. cit. note 33; Alex Morales, "Renewable energy freeing island nations from fossil fuel prices," Renewable Energy World, 11 December 2015, http://www.renewableenergyworld.com/articles/2015/12/renewable-energy-freeing-island-nations-from-fossil-fuel-prices; "Case study: Pakistan's wind energy market," *WWEA Quarterly Bulletin*, March 2015, p. 12. See also Carlo Schick, WWEA, "Avenues for community wind in developing countries: trends and innovative business models from South Africa and Mexico," presentation, Husum, Germany, 15 September 2015, www.wwindea.org.

54 IEA, op. cit. note 2, p. 344; Sargsyan, op. cit. note 1. Based on internal changes at the World Bank as well as experience with various countries. See also Market and Industry Trends chapter.

55 See Market and Industry Trends chapter.

56 Brazil, India and Mexico from Hinrichs-Rahlwes, op. cit. note 14; Chile, Mexico, Morocco and South Africa from BNEF, "Clean energy defies fossil fuel price crash to attract record $329bn global investment in 2015," press release (London and New York: 14 January 2016), http://about.bnef.com/press-releases/clean-energy-defies-fossil-fuel-price-crash-to-attract-record-329bn-global-investment-in-2015/; Chris Mooney, "This will give you hope: developing countries are racing to install wind and solar," *Washington Post*, 19 May 2015, http://www.washingtonpost.com/news/energy-environment/wp/2015/05/19/this-will-give-you-hope-developing-countries-are-racing-to-install-wind-and-solar/. See also Market and Industry Trends chapter.

57 IRENA, *Renewable Energy and Jobs – Annual Review 2016* (Abu Dhabi: 2016). **Sidebar 2** from idem.

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66 Ferroukhi, op. cit. note 1; Katherine Tweed, "Bigger risk, bigger returns in renewable energy's emerging markets," Greentech Media, 20 April 2016, http://www.greentechmedia.com/articles/read/Bigger-Risk-Bigger-Returns-in-Renewable-Energys-Emerging-Markets.

67 FS–UNEP Centre and BNEF, op. cit. note 41.

68 Ibid., p. 23.

69 Based on investment data for 2015 from Ibid.; GDP at purchaser's prices for 2014 from World Bank, "Gross domestic product 2014," World Development Indicators, http://data.worldbank.org/indicator/NY.GDP.MKTP.CD, viewed 25 April 2016.

70 Population data for 2014 from World Bank, "Population, total," World Development Indicators, http://data.worldbank.org/indicator/SP.POP.TOTL, viewed 10 March 2016. See Investment Flows chapter for more on BNEF investment data. Note that data on small distributed capacity (solar PV <1 MW) are available only for countries investing USD 0.2 billion or more during the year. In addition, data are not available by country for investment in ocean energy, so this technology is not included in the rankings. Global investment in ocean energy during 2015 was USD 215 million, per FS–UNEP Centre and BNEF, op. cit. note 41, p. 15.

71 Galán, op. cit. note 33.

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74 FS–UNEP Centre and BNEF, op. cit. note 41, p. 38. See also, for example: Tina Casey, "Flow battery vs. Tesla battery smackdown looming," CleanTechnica, 21 June 2015, http://cleantechnica.com/2015/06/21/flow-battery-vs-tesla-battery-smackdown-looming/; Eric Wesoff, "Flow battery builder UET ends year with $25M investment from Japan's Orix," Greentech Media, 29 December 2015, https://www.greentechmedia.com/articles/read/Flow-Battery-Builder-UET-Ends-Year-With-25M-Investment-From-Japans-ORIX; Graphenano, "Graphenano announces the launch of a manufacturing plant for graphene-based batteries," 16 November 2015, http://www.graphene-info.com/graphenano-announces-launch-manufacturing-plant-graphene-based-batteries; Lewis Krauskopf, "General Electric aims big in energy storage after battery step back," *Reuters*, 26 July 2015, http://www.reuters.com/article/us-general-electric-energy-storage-idUSKCN0Q00FS20150726; James Ayre, "Bosch + GS Yuasa "on target" to offer lithium-ion batteries with twice the energy density at half the cost by 2020," CleanTechnica, 15 July 2015, http://cleantechnica.com/2015/07/15/bosch-gs-yuasa-target-offer-lithium-ion-batteries-twice-energy-density-half-cost-2020/.

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76 See Market and Industry Trends chapter, Reference Table R1 and related endnotes for details.

77 Ibid.

78 Ibid.

79 Tom Randall, "Fossil fuels just lost the race against renewables," *Bloomberg*, 14 April 2015, http://www.bloomberg.com/news/articles/2015-04-14/fossil-fuels-just-lost-the-race-against-renewables.

80 Share of net additions from an estimate of 62.5%, based on a total of approximately 147.5 GW of renewable capacity added (net), as noted in this report, and on assumed combined net additions of 88.5 GW nuclear and fossil fuel capacity, for a total of 235.7 GW global net additions, of which renewables account for nearly 62.5%. Nuclear and fossil fuel estimate based on the following: net capacity additions of 42 GW coal and 40 GW natural gas, from FS–UNEP Centre and BNEF, op. cit. note 41, p. 31. Note that there also were (unspecified) net reductions in oil-fired generating capacity that are not included in these calculations. Net nuclear capacity increase of 6.52 GW based on year-end 2014 and year-end 2015 cumulative capacity, from International Atomic Energy Agency, "Nuclear power capacity trends," PRIS Database, http://www.iaea.org/pris/, updated 27 April 2016. For more detail on renewable power generating capacity, see Reference Table R1, technology sections in Market and Industry Trends chapter and related endnotes. Note that some hydropower capacity added may have been for refurbishment of existing plants; however, even if half of hydropower capacity additions were assumed to be net (replacement), and not included, the renewable energy share of total (net) additions is 60%.

81 Renewable share of total global electric generating capacity is based on an estimated renewable total of nearly 1,849 GW at end-2015 (see Reference Table R1 and related endnote for details and sources) and on total global electric capacity in the range of 6,399 GW. Estimated total global capacity for end-2015 is based on 2014 total of 6,163 GW, from IEA, op. cit. note 2, p. 311; on about 235.7 GW of net power capacity additions in 2015, as outlined in Endnote 80. Share of generation based on the following: Total global electricity generation in 2015 is estimated at 23,741 TWh, based on 23,536.5 TWh in 2014 from BP, op. cit. note 31, and on an estimated 0.87% growth in global electricity generation for 2015. The growth rate is based on the weighted average actual change in total generation for the following countries (which together account for nearly two-thirds of global generation in 2014): United States (-0.15% net generation), EU-28 (+2.46% gross generation for the first 11 months of each year), Russian Federation (+0.2%), India (+3.76%), China (+0.5%) and Brazil (-0.13%). Sources for 2014 and 2015 total electricity generation by country are: US EIA, op. cit. note 31, Table 1.1; European Commission, Eurostat database, http://ec.europa.eu/eurostat; System Operator of the Unified Power System of Russian Federation, www.so-ups.ru; Government of India, Ministry of Power, Central Electricity Authority, "Monthly Generation Report," www.cea.nic.in/monthlyarchive.html; CNEA, "National Electric Power Statistics," http://www.nea.gov.cn/2016-01/15/c_135013789.htm; National Operator of the Electrical System of Brazil (ONS), "Geração de Energia," http://www.ons.org.br/historico/geracao_energia.aspx. Hydropower generation in 2015 is estimated at 3,940 TWh, based on 2014 hydropower output of 3,885 TWh from BP, op. cit. note 31, as well as observed average year-on-year change in output (+1.4%) for many top producing countries (China, Brazil, Canada, the United States, the EU-28, Russian Federation, India, Norway, Turkey, Japan and Mexico), which together accounted for over three-fourths of global hydropower output in 2014. Hydropower generation from country sources as follows: US EIA, op. cit. this note; Statistics Canada, http://www5.statcan.gc.ca; European Commission, op. cit. this note; Statistics Norway, www.ssb.no; ONS, op. cit. this note; System Operator of the Unified Power System of Russia, op. cit. this note; Government of India, op. cit. this note; CNEA, op. cit. this note; Turkish Electricity Transmission Company, http://www.teias.gov.tr ; Emi Ichiyanagi, Japan Renewable Energy Foundation (JREF), based on data from Japan's Agency for Natural Resources and Energy, personal communication with REN21, March 2016; Mexico's Secretary of Energy (Secretaría de Energía), "Prospectiva de Energías Renovables 2015-2029," http://www.gob.mx/cms/uploads/attachment/file/44324/Prospectiva_Energ_as_Renovables_2015_-_2029_VF_22.12.15.pdf. Sources for non-hydro renewable generation of 1,693 TWh in 2015 are detailed by technology in the Market and Industry Trends chapter. **Figure 3** based on idem.

82 IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit note 31, p. 131.

83 Adnan Z. Amin, "The falling costs of renewable energy: no more excuses," *Huffington Post*, 30 November 2015, http://www.huffingtonpost.com/adnan-z-amin/post_10557_b_8600240.html; Jessika Trancik et al., *Technology Improvement and Emissions Reductions as Mutually Reinforcing Efforts: Observations from the Global Development of Solar and Wind Energy* (Cambridge, MA: Massachusetts Institute of Technology, November 2015), p. 6, http://trancik.scripts.mit.edu/home/wp-content/uploads/2015/11/Trancik_INDCReport.pdf.

84 Brazil, Mexico, New Zealand, Turkey, and parts of Australia, China and the United States from Steve Sawyer, GWEC, personal communication with REN21, 29 October 2015; Canadian Wind Energy Association (CanWEA), "Wind energy continues rapid growth in Canada in 2015," press release (Ottawa: 12 January 2016), http://canwea.ca/wind-energy-continues-rapid-growth-in-canada-in-2015/; South Africa from GWEC, "Wind energy has saved South Africa R1.8 billion more than it cost for first half of 2015 – and it's cash positive for Eskom," undated, http://www.gwec.net/wind-energy-has-saved-south-africa-r1-8-billion-more-than-it-cost-for-first-half-of-2015-and-its-cash-positive-for-eskom/, and from Joanne Calitz, Crescent Mushwana, and Tobias Bischhof-Niemz, "Financial benefits of renewables in Africa in 2015," CSIR Energy Centre, 14 August 2015, http://www.csir.co.za/media_releases/docs/Financial%20benefits%20of%20Wind%20and%20PV%202015.pdf; United States also from "Wind power now cheaper than natural gas for Xcel, CEO says," Renewable Energy World, 27 October 2015, http://www.renewableenergyworld.com/articles/2015/10/wind-power-now-cheaper-than-natural-gas-for-xcel-ceo-says, and from Ryan Wiser et al., *2014 Wind Technologies Market Report*, prepared for US DOE, Office of Energy Efficiency and Renewable Energy (EERE) (Berkeley, CA: Lawrence Berkeley National Laboratory, August 2015), p. viii, http://energy.gov/sites/prod/files/2015/08/f25/2014-Wind-Technologies-Market-Report-8.7.pdf. See also IEA, op. cit. note 36, p. 81.

85 Wind in Egypt, Mexico, Morocco and Peru from Steve Sawyer, GWEC, personal communication with REN21, 20 April 2016, and from Steve Sawyer, "Global wind energy insight: wind leading the charge in transformation of power system," Renewable Energy World, 19 April 2016, http://www.renewableenergyworld.com/articles/2016/04/global-wind-energy-insight-wind-leading-the-charge-in-transformation-of-power-system.html. Morocco's Vice-Minister for Energy and Environment, Abderrahim El Hafidi, made an announcement about the winner of the country's recent 850 MW wind tender, in which the winning price was about USD 0.03/kWh (about EUR 0.028), making it cheaper to build wind than an (unmitigated) coal plant, even if coal were free, from Steve Sawyer, GWEC, personal communication with REN21, 26 January 2016. The bidders will take advantage of Morocco's coastal exposure to the North Atlantic trade winds, from idem. In India, the winning bid during a solar auction prompted the country's energy minister to declare solar energy cheaper than coal-fired generation, from Piyush Goyal on 19 January 2016, cited in Kunal Anand, "For the first time In modern India's history, solar energy is cheaper than coal," *India Times*, 27 January 2016, http://www.indiatimes.com/news/india/for-the-first-time-in-modern-india-s-history-solar-energy-is-cheaper-than-coal-249907.html, and from Giles Parkinson, "India energy minister says solar power now cheaper than coal," RenewEconomy, 21 January 2016, http://reneweconomy.com.au/2016/india-energy-minister-says-solar-power-now-cheaper-coal-29756. A recent government auction in India's sunny state of Rajasthan put the winning solar bid at roughly the same price as recent coal projects, from Huizhong Wu, "India's big move into solar is already paying off," *CNN*, 7 March 2016, http://money.cnn.com/2016/03/07/technology/india-solar-energy-coal/. In Mexico, solar bids in March 2016 averaged USD 40.5/MWh, from Vanessa Dezem and Adam Williams, "Mexico first power auction awards 1,720 MW of wind, solar," Renewable Energy World, 30 March 2016, http://www.renewableenergyworld.com/articles/2016/03/mexico-first-power-auction-awards-1-720-mw-of-wind-solar.html. In Peru, the fourth auction for renewable generation led to 13 awarded projects, with 99% of the annual energy required covered, from a total of 111 participants. The average price obtained was 22% below current conventional energy price in Peru, from Lucas Furlano, Fundación Bariloche, Argentina, personal communication with REN21, 5

April 2016. Dubai, UAE's tender was with the Dubai Electricity and Water Authority for what was then the lowest-cost unsubsidised electricity to date, just under USD 60/MWh, from "Modules, large-scale PV see big price drop in 2010-2014," PV Insider, 9 November 2015, http://analysis.pv-insider.com/pv-module-prices-drop-80-below-2009-levels-czech-rep-reignites-home-user-market. Note, however, that the race for the lowest-ever prices has some downsides that are seldom discussed. For example, very low bids – such as the early 2016 Spanish auction with wind onshore at zero Euros – cannot be explained solely by cost reductions, but there is an element of strategic outcompeting of new players through extremely low bids and then, at a later date, increasing prices or not constructing projects at all (if penalties are not high enough). Whereas incumbents can usually afford to lose an auction or two, new and independent producers cannot. Rainer Hinrichs-Rahlwes, EREF, personal communication with REN21, 11 March 2016.

86 IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit. note 31, p. 16.

87 Rankings were determined by gathering data for the world's top countries for hydropower, wind, solar PV, CSP, biomass and geothermal power capacity. See Market and Industry Trends chapter and related endnotes for more detailed information. Data from the following sources: **China:** Hydropower from CNEA, *National Electric Power Industry Statistics*, in National Energy Board, 15 January 2016, http://www.nea.gov.cn/2016-01/15/c_135013789.htm; wind power from GWEC, op. cit. note 28, p. 11; solar PV from CNEA, cited in China Electricity Council, "2015 PV-Related Statistics," 6 February 2016, http://www.cec.org.cn/yaowenkuaidi/2016-02-05/148942.html (using Google Translate), and from IEA PVPS, *Snapshot of Global PV Markets 2015* (Paris: 2016), http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/IEA-PVPS_-__A_Snapshot_of_Global_PV_-_1992-2015_-_Final.pdf; bio-power from China National Renewable Energy Centre, provided by Amanda Zhang, Chinese Renewable Energy Industries Association (CREIA), personal communication with REN21, 26 April 2016, and from IRENA, op. cit. note 40; geothermal power from GEA unpublished database, provided by Benjamin Matek, GEA, personal communication with REN21, March–May 2016; CSP from NREL, "Concentrating solar power projects in China," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=CN, updated 17 February 2014, from CSP Today, op. cit. note 40, updated and viewed continuously on numerous occasions leading up to 22 April 2016; ocean power from Ocean Energy Systems (OES), *Annual Report 2015* (Lisbon: April, 2016), http://www.ocean-energy-systems.org. **United States:** Hydropower from US EIA, op. cit. note 31, Table 6.2B; wind power from American Wind Energy Association (AWEA), "US Wind Industry Fourth Quarter 2015 Market Report" (Washington, DC: 27 January 2015), p. 1, http://awea.files.cms-plus.com/FileDownloads/pdfs/4Q2015%20AWEA%20Market%20Report%20Public%20Version.pdf; solar PV from GTM Research and US Solar Energy Industry Association (SEIA), "Solar Market Insight 2015 Q4: Executive Summary" (Washington, DC: 9 March 2016), http://www.seia.org/research-resources/solar-market-insight-2015-q4; bio-power from US Federal Energy Regulatory Commission (FERC), "Office of Energy Projects Energy Infrastructure Update for December 2015," http://www.ferc.gov/legal/staff-reports/2015/dec-infrastructure.pdf. Note that bio-power data are lower according to data from US EIA, *Electric Power Monthly with Data for December 2015* (Washington, DC: February 2016), p. 129, Table 6.1., www.eia.gov/electricity/monthly/pdf/epm.pdf; geothermal from GEA database, op. cit. this note; CSP from NREL, "Concentrating solar power projects in the United States," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=US, updated 17 February 2014, from CSP Today, op. cit. note 40, updated and viewed continuously on numerous occasions leading up to 22 April 2016, and from Parthiv Kurup and Craig Turchi, "NREL CSP Data – US plants V2," presentation (Golden, CO: NREL, 19 February 2016), p. 2; ocean power from OES, op. cit. this note. **Brazil:** Hydropower based on data from Agência Nacional de Energia Elétrica (ANEEL), "Resumo geral dos novos empreendimentos de geração," updated February 2016, http://www.aneel.gov.br/arquivos/zip/Resumo_Geral_das_Usinas_março_2015.zip wind power from GWEC, op. cit. note 28, p. 11, and from WWEA, *World Wind Energy Report 2015* (Bonn: May 2016); solar PV and bio-power from ANEEL, "Banco de informações de geração," http://www.aneel.gov.br/aplicacoes/capacidadebrasil/Combustivel.cfm, viewed 16 February 2016, provided by Maria Beatriz Monteiro and Suani Teixeira Coelho, February 2016, and from Becquerel Institute, April 2016. **Germany:** Hydropower from Bundesministerium für Wirtschaft und Energie (BMWi) and Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), *Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat / Working Group on Renewable Energy-Statistics)*, February 2016, p. 8, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf?__blob=publicationFile&v=6; wind power from BMWi, *Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015* (Berlin: February 2016), http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/erneuerbare-energien-in-zahlen-2015.pdf, and from BMWi, *Development of Renewable Energy Sources in Germany 2015, Statistical data from the Working Group on Renewable Energy-Statistics (AGEE-Stat), as at February 2016*, p. 17, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/development-of-renewable-energy-sources-in-germany-2015.pdf?__blob=publicationFile&v=8; solar PV from BMWi, *Erneuerbare Energien in Deutschland...*, op. cit. this note; bio-power from BMWi, *Development of Renewable Energy Sources in Germany 2015*, op. cit. this note; CSP from NREL, "Concentrating solar power projects in Germany," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=DE, updated 17 February 2014; CSP Today, op. cit. note 40, continuously updated and viewed on numerous occasions leading up to 22 April 2016; geothermal power from GEA database, op. cit. this note. **Canada:** Hydropower from Statistics Canada, Table 127-0009, "Installed generating capacity, by class of electricity producer," http://www5.statcan.gc.ca, from IHA, "2016 Key Trends in Hydropower" (London: March 2016), http://www.hydropower.org, and from IHA, personal communication with REN21, February–April 2016; wind power from CanWEA, op. cit. note 84; solar PV from IEA PVPS, op. cit. this note; bio-power from Michael Paunescu, Senior Policy Advisor, Renewable Energy, Electricity Resources Branch, Natural Resources Canada, Government of Canada, personal communication with REN21, 25 April 2016; CSP (pilot only) from NREL, "City of Medicine Hat ISCC Project," http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=278, updated 3 August 2015; CSP Today, op. cit. note 40, updated and viewed continuously on numerous occasions leading up to 22 April 2016; ocean power from OES, op. cit. this note.

88 China share based on data and references provided elsewhere in this section.

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India," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=IN, updated 17 February 2014, from CSP Today, op. cit. note 40, updated and viewed continuously on numerous occasions leading up to 22 April 2016, and from Heba Hashem, "India's PV-led solar growth casts eyes on performance of CSP projects," CSP Today, 9 November 2015, http://social.csptoday.com/markets/india%E2%80%99s-pv-led-solar-growth-casts-eyes-performance-csp-projects. **Italy:** Hydropower from Gestore dei Servizi Energetici (GSE), "Energia da fonti rinnovabili in Italia, Dati preliminari 2015," 29 February 2016, http://www.gse.it/it/Statistiche/RapportiStatistici/Pagine/default.aspx; wind power from European Wind Energy Agency (EWEA), *Wind in Power: 2015 European Statistics* (Brussels: February 2016), p. 4; solar PV from IEA PVPS, op. cit. note 87, and from GSE, op. cit. this note; bio-power from idem; geothermal power from idem and from GEA database, op. cit. note 87; CSP (all pilots) from NREL, "Concentrating solar power projects in Italy," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=IT, updated 17 February 2014, and from CSP Today, op. cit. note 40, updated and viewed continuously on numerous occasions leading up to 22 April 2016; ocean power from OES, op. cit. note 87. **Spain:** Hydropower from REE, "Potencia Instalada nacional (MW)," 8 April 2016, www.ree.es; wind power from EWEA, op. cit. this note; solar PV from IEA PVPS, op. cit. note 87; bio-power from REE, op. cit. note 31, p. 5; Crespo, op. cit. note 40; also from REE, op. cit. note 31, p. 5; ocean power from OES, op. cit. note 87. **Figure 4** based on sources in this note and in Endnote 88, and on data for EU, BRICS and world available throughout this report, including Reference Tables R1 and R2 and associated endnotes.

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91 Leadership in bioenergy from GlobalData, cited in 25x'25, "China pushed global renewable installed capacity past 900 GWs in 2015," Weekly REsource, 15 January 2016, http://www.25x25.org/index.php?option=com_content&task=view&id=1327&Itemid=246; China added 830 MW in 2015, per Zhang, op. cit. note 87. See Market and Industry Trends chapter for more details and sources about added capacities and rankings. Curtailment from, for example, Max Dupuy and Wang Xuan, "China's string of new policies addressing renewable energy curtailment: an update," Regulatory Assistance Project, 8 April 2016, http://www.raponline.org/featured-work/chinas-string-of-new-policies-addressing-renewable-energy-curtailment-an, and from Feifei Shen, "China's grid operator blames bad planning for idled renewable energy," Renewable Energy World, 1 April 2016, http://www.renewableenergyworld.com/articles/2016/04/china-s-grid-operator-blames-bad-planning-for-idled-renewable-energy.html.

92 For details on hydropower, solar PV and wind power capacity in India and Japan, see relevant sections in Market and Industry Trends chapter.

93 See Market and Industry Trends chapter.

94 Malaysia for hydropower and solar PV; Pakistan for solar PV and wind power; Philippines for geothermal, wind power and solar PV; Republic of Korea for tidal, wind and solar PV; Thailand for wind and solar PV; Vietnam for hydropower and solar PV. See relevant sections in Market and Industry Trends chapter; IEA PVPS, op. cit. note 87; and GWEC, op. cit. note 28, p. 11.

95 EWEA, op. cit. note 89, pp. 3, 6, 7.

96 Ibid., p. 8. Renewable energy accounted for 28.7% of Europe's power generation in 2015, followed by nuclear (26.8%) and coal (hard coal 15.6% and lignite 10.4%), with gas, oil and other conventional sources accounting for the remaining 18.3%, from Agora Energiewende, *Energy Transition in the Power Sector in Europe: State of Affairs in 2015* (Berlin: April 2016), pp. 1, 31, https://www.agora-energiewende.de/fileadmin/Projekte/2016/EU-Review_2015/Agora_State_of_Affairs_EU_2015_WEB.pdf.

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99 Justin Scheck, "After years of growth, renewable-energy investors pull back from Europe," *Wall Street Journal*, 4 February 2016, http://www.wsj.com/articles/after-years-of-growth-green-energy-investors-pull-back-from-europe-1454591209; FS–UNEP Centre and BNEF, op. cit. note 41; Hinrichs-Rahlwes, op. cit. note 14; Adam Brown, Energy Insights, Paris, personal communication with REN21, 6 May 2016.

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101 Includes estimated generation from distributed solar PV generation and based on data from US EIA, *Electric Power Monthly with Data for December 2015*, op. cit. note 87, Table ES1.B.

102 See Market and Industry Trends chapter.

103 Costa Rican Electricity Institute, cited in "Costa Rica boasts 99% renewable energy in 2015," *Agence France Presse*, 18 December 2015, http://news.yahoo.com/costa-rica-boasts-99-renewable-energy-2015-210416028.html. Costa Rica generated almost all (99%) of its electricity with renewable energy, including hydro (about 75%), geothermal, wind, biomass and solar, from idem. For Costa Rica, see also Umair Irfan, "German model hard to follow, even for Germans," E&E News, 12 May 2016, http://www.eenews.net/climatewire/2016/05/12/stories/1060037088. Uruguay share of 92.8% in 2015, from Uruguay Secretary of Energy, Ministerio de Industria, Energía y Minería, personal communication with REN21, 29 April 2016. Chile has rapidly surpassed targets, starting with one calling for 10% renewables by 2024, which it replaced in 2013 with a target of 20% by 2024 (target surpassed in 2015), from Lucas Furlano, Fundacion Bariloche, Argentina,

personal communication with REN21, 4 April 2016; see also Comité Consultivo de Energía 2050, *Hoja de Ruta 2050: Hacia una Energía Sustentable e Inclusiva Para Chile* (Santiago: September 2015), http://www.energia2050.cl/uploads/libros/hojaderuta.pdf.

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105 See Market and Industry Trends chapter.

106 Ibid.

107 Ibid.

108 Ibid.

109 Australia added 935 MW for a total of 5,065 MW, from IEA PVPS, op. cit. note 87, p. 18; "Australian solar industry celebrates the new year by ticking over 1.5m PV systems and one solar panel per person," SunWiz, undated, http://www.sunwiz.com.au/index.php/2012-06-26-00-47-40/73-newsletter/384-australian-solar-industry-celebrates-the-new-year-by-ticking-over-1-5m-pv-systems.html.

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112 Middle East Solar Industry Association, *Middle East Solar Outlook for 2016* (Dubai: 2016), p. 3, http://www.mesia.com/wp-content/uploads/MESIA-Outlook-2016-web.pdf.

113 See Market and Industry Trends chapter.

114 Mackay Miller et al., *Status Report on Power System Transformation: A 21st Century Power Partnership Report* (Golden, CO: NREL, May 2015), pp. iv–ix, http://www.nrel.gov/docs/fy15osti/63366.pdf. See also Sidebar 7 in GSR 2014. With regard to markets, the merit dispatch order is challenged by near-zero marginal cost renewables eating into wholesale prices, one of the reasons that EU utilities lose money, from Nico Tyabji, BNEF, personal communication with REN21, 9 April 2016. By one estimate, the aggregated profits of 15 of the largest European power companies (including EDF, Enel, ENGIE, E.ON, RWE, Iberdrola, Vattenfall, EDP, Statkraft and Fortum) were close to zero or negative in 2015, compared with billions of euros in 2010. These companies reduced their fossil fuel power portfolio by something in the range of 20–25 GW and increased their non-hydro renewables portfolio by about 5 GW (mainly wind power, but increasingly solar PV as well), from Romain Zissler, Japan Renewable Energy Foundation, personal communication with REN21, 7 April 2016. See, for example, Bernd Radowitz, "RE shine, but fossils force RWE to write-downs and lower guidance," Recharge News, 17 February 2016, http://www.rechargenews.com/wind/1424156/re-shine-but-fossils-force-rwe-to-write-downs-and-lower-guidance.

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118 Miller et al., op. cit. note 114, pp. iv–ix.

119 Ibid.; Martinot, op. cit. note 117.

120 Martinot, op. cit. note 114.

121 Eric Martinot, *Grid Integration of Renewables in China: Learning from the Cases of California, Germany, and Denmark*, A White Paper for the China Variable-Generation Integration Group (Beijing: May 2015), www.martinot.info/Martinot_CVIG_2015_DE-DK-CA.pdf; Martinot, op. cit. note 114. Overall, grids are operating better than expected with rising renewable energy shares, even in developing countries, per Sargsyan, op. cit. note 1. Grid operators in Denmark, "who 15 years ago would have considered it impossible to run the grid stably with three-fifths renewable supply, now achieve this routinely. They have become among the world's most adept at integrating diverse, distributed, often variable, renewable resources. As a result, Danish electricity supply is the most reliable in Europe," from Laurie Guevara-Stone, "A small country goes big with renewables: Denmark's goal to be fossil fuel free," RMI Outlet, 2 March 2016, http://blog.rmi.org/blog_2016_03_02_a_small_country_goes_big_with_renewables.

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10 **Figure 6** based on the following sources: total 2014 final energy consumption (estimated at 8,561 Mtoe) based on 8,480 Mtoe for 2013 from IEA, *World Energy Statistics and Balances, 2015 Edition* (Paris: 2015), https://www.iea.org/statistics/relateddatabases/worldenergystatisticsandbalances/ and escalated by the 0.95% increase in global primary energy demand from 2013 to 2014, derived from BP, *Statistical Review of World Energy 2015* (London: 2015), http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf. Traditional biomass use in 2014 of 760 Mtoe assumes an increase of 1 Mtoe from 2013 based on 2013 value of 759 Mtoe from IEA, op. cit. note 2, pp. 348–49; 2012 value of 758 Mtoe from IEA, *World Energy Outlook 2014* (Paris: 2014), p. 242; 2013 value "estimated at around 32 EJ" from IEA, op. cit. note 4, p. 244. Modern bio-heat energy values for 2013 (industrial, residential, and other uses, including heat from heat plants) of 321.7 Mtoe (13.468 EJ) based on combined value of 14.8 EJ estimated for all renewable heat, of which around 91% is biomass, from idem, p. 243. Bio-power generation of 36.9 Mtoe (429.3 TWh), based on data from idem, p. 139, except for the following country sources: United States from US Energy Information Administration (EIA), *Electric Power Monthly*, Table 1.1.A, http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01_a, viewed 20 March 2016, and corrected for difference between net and gross electricity generation; Germany preliminary statistics from Bundesministerium für Wirtschaft und Energie (BMWi), *Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015* (Berlin: February 2016), https://www.bmwi.de/BMWi/Redaktion/PDF/E/erneuerbare-energien-in-zahlen-2015,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf; United Kingdom from UK Department of Energy & Climate Change (DECC), "Energy Trends Section 6 – Renewables" (London: March 2016), Table 6.1, https://www.gov.uk/government/statistics/energy-trends-section-6-renewables; India from Government of India, Ministry of New and Renewable Energy (MNRE), "Physical progress (achievements) – up to the month of December 2015," http://www.mnre.gov.in/mission-and-vision-2/achievements/, viewed 1 February 2016, and from MNRE, "Physical progress (achievements) – up to the month of December 2014," http://www.mnre.gov.in/mission-and-vision-2/achievements/, viewed 21 January 2015; total electricity generation adjusted to electricity in final energy consumption to account for in-plant losses and transmission losses, etc., using the ratio of total electricity generation to total electricity in final energy consumption (83%); total final energy consumption based on 2013 data from IEA, op. cit. note 7.

11 **Figure 7** data for 2015 calculated using a linear extrapolation based on IEA, "Statistics: World: Renewables and Waste 2008–2013," http://www.iea.org/statistics/statisticssearch/report/?country=WORLD&product=RenewablesandWaste&-year=2013. Municipal solid waste (MSW) values were assumed to be only 50% renewable, consistent with IEA assumptions. Calculations exclude industrial waste.

12 Traditional use of biomass refers to the use of fuelwood, animal dung and agricultural residues in simple stoves with very low combustion efficiency. There are no precise universally accepted definitions for what comprises traditional use of biomass. The definition adopted by the IEA (op. cit. note 7) is "the use of solid biomass in the residential sector of non-OECD member countries, excluding countries in non-OECD Europe and Eurasia". This, however, does not take into account the efficient use of biomass in developing countries nor the inefficient use within residential heating in some OECD countries. A discussion on this and other methodological issues associated with biomass can be found in Sustainable Energy for All, *Progress Toward Sustainable Energy: Global Tracking Framework Summary Report* (Washington, DC: June 2015), http://trackingenergy4all.worldbank.org/~/media/GIAWB/GTF/Documents/GTF-2015-Summary-Report.pdf.

13 Projections for 2014 and 2015 from a linear extrapolation based on data (2005–13) from IEA, op. cit. note 7. Estimates of traditional biomass use vary widely, given the difficulties of measuring or even estimating a resource that often is traded informally. For example, one source (Helena Chum et al., "Bioenergy," in Ottmar Edenhofer et al., eds., *IPPC Special Report on Renewable Energy Sources and Climate Change Mitigation* (Cambridge, UK and New York, NY: Cambridge University Press, 2011), http://www.ipcc.ch/pdf/special-reports/srren/Chapter%202%20Bioenergy.pdf) suggests that the national databases on which the IEA statistics rely systematically underestimate fuelwood consumption, and applied a supplement of 20–40% on these estimates based on country-specific analyses in over 20 countries.

14 United Nations Food and Agriculture Organization (FAO), "Forest Products Statistics," http://www.fao.org/forestry/statistics/80938/en/, viewed 18 March 2016.

15 Based on a linear extrapolation to 2015 of charcoal production data (2010–14) in FAO, FAOSAT database, http://faostat3.fao.org/download/F/FO/E, viewed 18 March 2016.

16 Total modern biomass use in 2015 based on IEA, estimate of total modern renewable heat in 2013 of 14.8 EJ, 91% of which was bioenergy (13.5 EJ) and assuming continuing growth at 3.5%/year, from IEA, op. cit. note 4, p. 242. Considerable uncertainties surround bioenergy use in industry, as some countries that are known to have significant uses of residues, for example in the paper industry, do not report this in statistical returns. Industrial

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heat estimate is based on an extrapolation assuming a continuing rate of growth at historical levels (2000–11) of 1.3%/year, up from 8 EJ/year in 2011, from Anselm Eisentraut and Adam Brown, *Heating Without Global Warming: Market Developments and Policy Considerations for Renewable Heat* (Paris: IEA, 2014), p. 30, http://www.iea.org/publications/freepublications/publication/heating-without-global-warming.html. The estimate of modern bioenergy use in buildings is calculated as the difference between the industrial and the total modern bioenergy demand.

17 Estimate based on the following: 297 GW_{th} of bioenergy heat plant capacity installed as of 2008, from Chum et al., op. cit. note 13. Projections based on this number have been made for past GSRs. The combination of the Chum et al. data, plus past GSR projections, was used to estimate 2014 values of 305 GW_{th} using a linear regression. The 2015 value presented here assumes a 3.5% growth rate from that 305 GW_{th} value, based on the same percent increase for modern heat generation as presented in IEA, op. cit. note 4, p. 242. Note that accurate heat data, including from bioenergy, are very difficult to obtain as most capacity installations and output are not metered. Even if plant capacities are known, there often is no knowledge of whether a 1 MW_{th} plant, for example, is used for 80 hours or 8,000 hours per year.

18 Eisentraut and Brown, op. cit. note 16.

19 Ibid.

20 Ibid.

21 Ibid.

22 Based on data in IEA, op. cit. note 4 and in EurObserv'ER, *Solid Biomass Barometer* (Paris: 2015), http://www.eurobserv-er.org/category/all-solid-biomass-barometers/.

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27 Bruce Dorminey, "Low heating oil prices depress domestic wood pellet market," Renewable Energy World, 29 February 2016, http://www.renewableenergyworld.com/articles/2016/02/low-heating-oil-prices-depress-domestic-wood-pellet-market.html.

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29 European Commission Intelligent Energy Europe Projects Database, "Development of sustainable heat markets for biogas plants in Europe (BIOGASHEAT)," https://ec.europa.eu/energy/intelligent/projects/en/projects/biogasheat, viewed 13 May 2016.

30 Xia Zuzhang, *China's Domestic Biogas Sector Must Adjust to Changing Conditions* (London: International Institute for Environment and Development, January 2014), http://pubs.iied.org/pdfs/17185IIED.pdf; MNRE, "Physical progress (achievements)," http://www.mnre.gov.in/mission-and-vision-2/achievements, viewed 1 February 2016.

31 Bio-electricity capacity data based on the 2015 forecast data in IEA, op. cit. note 4, except for the following: US capacity data based on US Federal Energy Regulatory Commission (FERC), "Office of Energy Projects Energy Infrastructure Update for December 2015," http://www.ferc.gov/legal/staff-reports/2015/dec-infrastructure.pdf; Brazilian Electricity Regulatory Agency (ANEEL), "Banco de informacoes de geração," http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm, viewed 9 May 2016; China National Renewable Energy Centre, provided by Amanda Zhang, Chinese Renewable Energy Industries Association (CREIA), personal communication with REN21, 26 April 2016; Germany preliminary statistics from BMWi, op. cit. note 10; United Kingdom from UK DECC, op. cit. note 10; India from MNRE, op. cit. note 10; Japan from Hironao Matsubara, Institute for Sustainable Energy Policies (ISEP), Tokyo, Japan, personal communication with REN21, 10 April 2016. Bio-electricity generation statistics based on 2015 forecast data from IEA, op. cit. note 4, except for the following: US data from US EIA, op. cit. note 10, corrected for difference between net and gross electricity generation; Germany preliminary statistics from BMWi, op. cit. note 10; United Kingdom from UK DECC, op. cit. note 10; India from MNRE, op. cit. note 10.

32 **Figure 8** based on IEA data for 2005–13, from IEA, op. cit. note 6, and on REN21 analysis of generation for 2013 and 2014 (→ *see Endnote 31).*

33 Capacity data based on FERC, op. cit. note 31; US generation based on data in US EIA, op. cit. note 10.

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41 China National Renewable Energy Centre, op. cit. note 31.

42 Estimated based on capacity figure of 10.3 GW.

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45 MNRE, op. cit. note 10.

46 New projects with a capacity of 389 MW were awarded PPAs in April 2015 and are expected to be constructed and brought into operation between 2018 and 2019. See IEA and International Renewable Energy Agency (IRENA) Policies & Measures

Database, "Brazil Renewable Energy Auctions," http://www.iea.org/policiesandmeasures/pams/brazil/name-146121-en.php. Contracts for a further 1,993 MW were awarded in December 2015 to 22 existing biomass plants, 20 of which use sugarcane bagasse as fuel, and two which use wood residues, from Lucas Morais, "Brazil awards 1.9 GW of biomass contracts in Dec 11 auction," SeeNews Renewables, 11 December 2015, http://renewables.seenews.com/news/brazil-awards-1-9-gw-of-biomass-contracts-in-dec-11-auction-505298.

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57 Ibid.

58 Ibid.; IEA, op. cit. note 4.

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61 Brazil Ministry of Mines and Energy, op. cit. note 47.

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23 Japan added 11 GW for a total of 34.41 GW, from IEA PVPS, op. cit. note 1. Japan added 10 GW in 2015, up from 9.7 GW in 2014, from SolarPower Europe, op. cit. note 2, p. 20. Note that Japan officially reports data in AC; these sources have converted those data to DC for consistency across countries. Japan added 9,940 MW for a total of 30,300 MW, from Ministry of Economy, Trade and Industry (METI), "Announcement regarding the present status of introduction of facilities generating renewable energy as of October 30, 2015" (Tokyo: February 2016). Capacity at end of 2015 is estimated from monthly installation capacity, provided by Hironao Matsubara, Institute for Sustainable Energy Policies (ISEP), Tokyo, personal communication with REN21, February 2016.

24 Residential capacity (systems <10 kW) amounting to 0.9 GW was connected to the grid in 2015 for a year-end total of 8 GW. An estimated 5 GW of commercial plants (under 1 MW) was added in 2015 for a total of 14 GW, and 4 GW of utility-scale (over 1 MW) plants was connected to the grid, for a total of almost 8 GW, from Hironao Matsubara, ISEP, Tokyo, personal communication with REN21, 10 April 2016.

25 Kenji Kaneko, "PV systems for abandoned farm land increasing in Japan," Nikkei BP CleanTech Institute, 13 January 2016, http://techon.nikkeibp.co.jp/atclen/news_en/15mk/011300302/; golf courses from Steve Mollman, "A matter of course: Japan is building solar energy plants on abandoned golf courses – and the idea is spreading," qz.com, 6 July 2015, http://qz.com/445330/japan-is-building-solar-energy-plants-on-abandoned-golf-courses-and-the-idea-is-spreading/, from Andrew Burger, "Utility solar still attractive in Japan despite FIT cut," Renewable Energy World, 7 August 2015, http://www.renewableenergyworld.com/articles/2015/08/utility-solar-still-attractive-in-japan-despite-fit-cut.html, and from Christopher Hooton, "Japan is turning its abandoned golf courses into solar power plants," *The Independent* (UK), 20 July 2015, http://www.independent.co.uk/sport/golf/japan-is-turning-its-abandoned-golf-courses-into-solar-power-plants-10402042.html.

26 Figure of 10% from Daisuke Hirabayashi, "Solar power proved its worth this summer," *Asahi Shimbun Asia & Japan Watch*, 3 September 2015, http://ajw.asahi.com/article/behind_news/social_affairs/AJ201509030045; figure of 3% for annual generation estimated from data of Japan's FIT scheme from Agency for Natural Resources and Energy, METI, provided by Matsubara, op. cit. note 24.

27 Junko Movellan, "Japan passes FIT peak: now what for 87 GW renewable queue, 2030 energy mix?" Renewable Energy World, 25 November 2015, http://www.renewableenergyworld.com/articles/2015/11/japan-passes-fit-peak-now-what-for-87-gw-re-queue-2030-energy-mix; Joe Jackson, "Despite nuclear fears, Japan solar energy sector slow to catch on," *Al Jazeera*, 23 January 2016, http://america.aljazeera.com/articles/2016/1/23/japan-solar-energy-nuclear-fears.html. Rules introduced in 2015 allowed Japan's power companies to stop accepting power from solar PV plants, including some uncompensated curtailments; these rules were cited as a barrier to investment in solar PV during 2015 due to concerns about uncertainty and the potential for lost income, from Andy Colthorpe, "Japan's FIT degression back to previous levels as utility curtails solar output," PV-Tech, 23 February 2016, http://www.pv-tech.org/news/japans-fit-degression-back-to-previous-levels-as-utility-curtails-solar-out.

28 "Energy markets liberalization: Japan Inc. makes big renewables push," *Nikkei Asian Review*, 17 March 2015, http://asia.nikkei.com/Business/Trends/Japan-Inc.-makes-big-renewables-push. In April 2016, Japan went from having 10 regional utilities to an open retail market; as of early April, Japan had nearly 280 licensed electricity retailers, although most electricity was still purchased by existing large utilities, from Matsubara, op. cit. note 24. Note that as of December 2015, more than 750 applicants had signed up to provide electricity, from Bloomberg, cited in Becky Beetz, "Japan: Solar tax breaks will be removed, PV accounts for 3.3% in Q3," *PV Magazine*, 3 December 2015, http://www.pv-magazine.com/news/details/beitrag/japan--solar-tax-breaks-will-be-removed--pv-accounts-for-33-in-q3_100022270.

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30 India's total year-end capacity was 5,200 MW, from Indian Ministry of New and Renewable Energy (MNRE), "Physical progress (achievements)," undated, http://mnre.gov.in/mission-and-vision-2/achievements/, and from Bridge to India, both provided by Bajaj, op. cit. this note; total capacity was 5,046 MW, from IEA PVPS, op. cit. note 1, p. 18; state-level capacity data from Becky Beetz, "India: Solar capacity passes 5 GW, 750 MW project receives IFC support," *PV Magazine*, 18 January 2016, http://www.pv-magazine.com/news/details/beitrag/india--solar-capacity-passes-5-gw--750-mw-project-receives-ifc-support_100022828/.

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32 Mostly ground-mounted from Ioannis-Thomas Theologitis, SolarPower Europe, personal communication with REN21, 7 April 2016; as of November, India had added about 525 MW of rooftop solar PV capacity in 2015, from Clover, op. cit. note 31.

33 "What will it take for India to achieve its massive renewable energy goals?" *Renewable Energy World Magazine*, March/April 2016, p. 14.

34 Republic of Korea estimate of 1,011 MW for cumulative year-end capacity of 3,427 MW, from IEA PVPS, op. cit. note 1, p. 18.

35 Data for Pakistan are highly uncertain. Figure of 500 MW for capacity added is unofficial and subject to change, from Masson, op. cit. note 2. An estimated 600 MW added for total of 1 GW, from IEA PVPS, op. cit. note 1, p. 18. About 800 MW was reported for the fiscal year (July 2014–June 2015) through customs statistics, and at least one 100 MW plant was completed, from Pakistan Solar Association, provided by Frank Haugwitz, Asia Europe Clean Energy (Solar) Advisory Co. Ltd. (AECEA), personal communication with REN21, 17 April 2016. Data for actual installations and calendar-year additions and cumulative capacity were not available from this source at time of publication. Chronic power shortages from Saleem Shaikh, "Pakistan turns desert into a sea of solar panels," Climate News Network, 19 May 2015, http://www.climatenewsnetwork.net/pakistan-turns-desert-into-a-sea-of-solar-panels/. Other incentives included removal of import and sales taxes on solar panels and a new mortgage finance scheme for rooftop installations, from idem.

36 Heba Hashem, "Pakistan's new tariffs spur influx of developers from East and West," PV Insider, 10 August 2015, http://analysis.pv-insider.com/pakistans-new-tariffs-spur-influx-developers-east-and-west. As of August 2015, 24 independent solar projects were at various stages of development, with cumulative capacity of almost 800 MW, from idem.

37 The Philippines added 122 MW for a total of 155 MW, and Thailand added 121 MW for a total of 1.42 GW, from IEA PVPS, op. cit. note 1, p. 18. The Democratic People's Republic of Korea has seen a significant increase in solar PV use as costs have plummeted, reflecting a rising demand for electricity to charge mobile phones, provide lighting and other services, from James Pearson, "In North Korea, solar panel boom the gives power to the people," *Reuters*, 22 April 2015, http://planetark.org/wen/73102.

38 Based on data from IEA PVPS, op. cit. note 1, and from Becquerel Institute, April 2016.

39 Based on data for the United States and for Canada. See other endnotes in this section for full references.

40 Canadian Solar Industries Association, provided by Masson, op. cit. note 2; IEA PVPS, op. cit. note 1, p. 18. Note that Canada officially reports data in AC; these sources converted data to DC for consistency across countries.

41 The United States added 7,260 MW of solar PV for a total of 25.6 GW, from GTM Research and US Solar Energy Industries Association (SEIA), *US Solar Market Insight: 2015 Year-in-Review*, Executive Summary (Washington, DC: March 2016), p. 4; added 5,942 MW of natural gas in 2015, from US Federal Energy Regulatory Commission (FERC), "Office of Energy Projects Energy Infrastructure Update for December 2015," www.ferc.gov/legal/staff-reports/2015/dec-infrastructure.pdf; and added 6,573.2 GW of natural gas, from US Energy Information Administration (EIA), *Electric Power Monthly with Data for December 2015* (Washington, DC: February 2016), Table 6.1, www.eia.gov/electricity/monthly/pdf/epm.pdf. Note that both FERC and EIA report lower capacity additions for solar PV and wind power because they omit plants with capacity below 1 MW. See also GTM Research and SEIA, op. cit. this note.

42 GTM Research and SEIA, op. cit. note 41, p. 4.

43 PV Market Alliance website, op. cit. note 5; ITC also from IHS, cited in Katie Fehrenbacher, "There is a flood of solar farms in the US that are racing to beat a government deadline," *Fortune*, 8 June 2015, https://fortune.com/2015/06/08/theres-a-flood-of-solar-farms-in-the-u-s-that-are-racing-to-beat-a-government-deadline/. The federal ITC will remain at 30% through 2019 and then step down to 26% in 2020, 22% in 2021 and 10% in 2022 for all projects but direct-owned residential, for which it will expire; projects that commence construction can qualify, from GTM Research and SEIA, op. cit. note 41, p. 7.

44 GTM Research and SEIA, op. cit. note 41, p. 10. The US residential market was up 66% over 2014, and 2015 was the fourth consecutive year with annual growth of over 50%, from idem, pp. 6, 10. Direct ownership and new loan products from Nicole Litvak, "US residential solar financing 2015–2020," Greentech Media, 29 July 2015, http://www.greentechmedia.com/research/report/us-residential-solar-financing-2015-2020. It also is driven by innovative business models, such as third-party ownership, from SolarPower Europe, op. cit. note 2, p. 20.

45 An estimated 4,150 MW of utility solar was added in 2015 for a total exceeding 19.8 GW, from GTM Research and SEIA, op. cit. note 41, p. 6.

46 California and North Carolina from Ibid., p. 9. Hawaii from the following sources: Herman K. Trabish, "17% of Hawaiian electric customers now have rooftop solar," Utility Dive, 1 February 2016, http://www.utilitydive.com/news/17-of-hawaiian-electric-customers-now-have-rooftop-solar/413014/; Duane Shimogawa, "Hawaiian Electric has 77,000 installed solar PV systems across Hawaii," Bizjournals, 28 January 2016, http://www.bizjournals.com/pacific/news/2016/01/28/hawaiian-electric-has-77-000-installed-solar-pv.html; an estimated 12% of all homes in Hawaii had solar, from Brian Korgaonkar, "How Hawaii has empowered energy storage and forever changed the US solar industry," Renewable Energy World, 21 December 2015, http://www.renewableenergyworld.com/articles/2015/12/how-hawaii-has-empowered-energy-storage-and-forever-changed-the-u-s-solar-industry.html. Most capacity added (87%) was in the top 10 states, from GTM Research and SEIA, op. cit. note 41, p. 7; however, growth is becoming widespread due to improving economics, from Miriam Makyhoun, Ryan Edge, and Nick Esch, *Utility Solar Market Snapshot: Sustained Growth in 2014* (Washington, DC: Solar Electric Power Association, May 2015), https://www.solarelectricpower.org/media/322918/solar-market-snapshot-2014.pdf.

47 This is true especially in Texas and the US Southeast, where some utilities are replacing retired coal plants with utility-scale solar PV and combined-cycle natural gas, from GTM Research and SEIA, op. cit. note 41, p. 11. Some utilities have begun to report that they approached solar PV as a least cost resource, from Makyhoun, Edge, and Esch, op. cit. note 46, p. 10. See also Becky Beetz, "Solar becoming 'least-cost option' for US utilities," *PV Magazine*, 5 May 2015, http://www.pv-magazine.com/news/details/beitrag/solar-becoming-least-cost-option-for-us-utilities_100019329#axzz3dMAG1BMk.

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53 Based on data from Becquerel Institute, 2016, and from IEA PVPS, op. cit. note 1. The EU added 7,572 MW; all of Europe added 8.1 GW for a total of 96.9 GW, from SolarPower Europe, op. cit. note 2.

54 UK figure of 3.7 GW from SolarPower Europe, op. cit. note 2, and from Masson, op. cit. note 2. The UK added 3,537 MW according to preliminary data from UK Department of Energy & Climate Change (DECC), "Energy Trends Section 6 – Renewables" (London: March 2016), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511939/Renewables.pdf. Germany added 1,355 MW for a total of 39,698 MW, from Bundesministerium für Wirtschaft und Energie (BMWi),

Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015 (Berlin: February 2015), p. 4, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/erneuerbare-energien-in-zahlen-2015.pdf, and added 1,453 MW for a year-end total of 39,702.9 MW, from IEA PVPS, op. cit. note 1, and from Masson, op. cit. note 2. France added an estimated 879 MW for a total of 6.58 GW, from idem, p. 18. Share of total EU installations based on data from Becquerel Institute, April 2016, and IEA PVPS, op. cit. note 1. One-third of France's capacity additions were in one 300 MW plant, from SolarPower Europe, op. cit. note 2, p. 11.

55 The Netherlands added an estimated 450 MW for a total of 1.57 GW, and Italy added 300 MW for a total of 18.92 GW, from IEA PVPS, op. cit. note 1, p. 9; Italian market down dramatically (most developers have left Italy for markets overseas) from Masson, op. cit. note 2; the Netherlands added about 400 MW in 2015, and additions there as well as in Denmark (about 180 MW) were driven mainly by net metering, from SolarPower Europe, op. cit. note 2, p. 12.

56 In 2008, Spain added 2.6 GW of capacity, which represented half of global installations that year, from REN21, *Renewables Global Status Report 2009 Update* (Paris: 2009); added about 56 MW in 2015 for a total of 5.44 GW, from IEA PVPS, op. cit. note 1; and added 49 MW in 2015, up from 22 MW in 2014, from SolarPower Europe, op. cit. note 2, p. 11; situation in 2015 from SolarPower Europe, op. cit. note 1; SolarPower Europe, op. cit. note 2, p. 19; Ilias Tsagas, "Spain approves 'sun tax,' discriminates against solar PV," Renewable Energy World, 23 October 2015, http://www.renewableenergyworld.com/articles/2015/10/spain-approves-sun-tax-discriminates-against-solar-pv; Blanca Diaz Lopez, "Spain's supreme tribunal rules against PV system owners," *PV Magazine*, 22 January 2016, http://www.pv-magazine.com/news/details/beitrag/spains-supreme-tribunal-rules-agains-pv-system-owners_100022919/. Spain added 56 MW for a total of 5.44 GW, from IEA PVPS, op. cit. note 1, p. 18; Spain had 4,667 MW of capacity at end-2015, based on preliminary data from RED Eléctrica de España (REE), *El Sistema Eléctrico Español: Avance 2015* (Madrid: 2016), p. 4, http://www.ree.es/sites/default/files/downloadable/avance_informe_sistema_electrico_2015_v2.pdf.

57 Subsidy expiration and FIT cuts from Jonathan Gifford, "UK: Solar outshines hydro, drives down coal in 2015," *PV Magazine*, 7 January 2016, http://www.pv-magazine.com/news/details/beitrag/uk--solar-outshines-hydro--drives-down-coal-in-2015_100022703/, and from Chris Roselund, "2015: The year in solar," *PV Magazine*, 5 January 2016, http://www.pv-magazine.com/news/details/beitrag/2015--the-year-in-solar_100022618/. The UK had about 9.1 GW at year-end, per Masson, op. cit. note 2, and the country had 8,915 MW, according to preliminary estimates from UK DECC, op. cit. note 54.

58 Gifford, op. cit. note 57.

59 Reduction relative to 2014 based on 1.9 GW added in 2014, from BMWi, *Marktanalyse Photovoltaik-Dachlagen* (Berlin: 2015), http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/bmwi_de/marktanalysen-photovoltaik-photovoltaik.pdf. Germany added 1.89 GW in 2014 (compared with 3.14 GW in 2014 and 7.27 GW in 2012) for a total of 38.23 GW, from German Federal Network Agency, cited in "Germany added only 1.89 GW of PV capacity in 2014," Photon, 3 February 2015, http://www.photon.info/en/news/germany-added-only-189-gw-pv-capacity-2014; Germany added 1.9 GW for a total of 38.2 GW at the end of 2014, from Bundesverband Solar Wirtschaft e.V. (BSW-Solar), "Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)," March 2015, https://www.solarwirtschaft.de/fileadmin/media/pdf/2015_4_BSW_Solar_Faktenblatt_Photovoltaik.pdf. Official target (EEG corridor) of 2.4–2.6 GW, from BMWi, op. cit. note 54, p. 4.

60 Germany's year-end capacity totalled 39,698 MW (1,355 MW added in 2015), preliminary data from BMWi, op. cit. note 54; Germany's cumulative capacity was 39,703.9 MW, from IEA PVPS, op. cit. note 1.

61 SolarPower Europe, "2015: A positive year for solar," op. cit. note 1. Self-consumption is becoming the primary driver for distributed PV, from Schmela, op. cit. note 52. However, self-consumption policies are very complicated, particularly in France, Germany and Spain, and thus not supporting solar PV deployment, from Masson, op. cit. note 2. The list of countries constraining self-consumption in some way is long (e.g., Austria, Belgium, France, Germany, Spain), from SolarPower Europe, op. cit. note 2, pp. 17–18.

62 Alexandre Roesch, SolarPower Europe, personal communication with REN21, 17 March 2016.

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66 Based on Melbourne Energy Institute and Royal Melbourne Institute of Technology, *Five Years of Declining Annual Consumption of Grid-Supplied Electricity in Eastern Australia: Causes and Consequences*, cited in Giles Parkinson, "Graph of the day: how solar PV slashed electricity demand," REnew Economy, 4 September 2015, http://reneweconomy.com.au/2015/graph-of-the-day-how-solar-pv-slashed-electricity-demand. See also Giles Parkinson, "Solar makes its mark on unsuspecting global energy markets," REnew Economy, 31 March 2015, http://reneweconomy.com.au/2015/solar-makes-its-mark-on-unsuspecting-global-energy-markets, and Ian Clover, "Half of all Australian households could adopt solar by 2018, finds the Climate Council," *PV Magazine*, 22 October 2015, http://www.pv-magazine.com/news/details/beitrag/half-of-all-australian-households-could-adopt-solar-by-2018--finds-the-climate-council_100021644/.

67 Chandler, op. cit. note 65.

68 IEA PVPS, op. cit. note 3, pp. 11, 30.

69 Estimate of 1.1–1.2 GW added for a year-end total of 1.9–2 GW across the region, from Masson, op. cit. note 2.

70 Chile added 446 MW (DC) for a total of 848 MW, from IEA PVPS, op. cit. note 1; Chile added 316 MW (AC) in 2015 for a total of 536 MW (AC) in operation at year's end, but including projects in the test phase, total capacity was 848 MW at end-2015, up from 402 MW (AC) at the beginning of the year, with 2,195 MW (AC) under construction by end-2015, from Chile National Center for Innovation and Promotion of Sustainable Energy (CIFES), Ministry of Energy, http://cifes.gob.cl/documentos/home-destacado/reporte-cifes-enero-2016/, cited in Blanca Diaz Lopez and Christian Roselund, "Chile: 316 MW–AC of solar PV came online in 2015," *PV Magazine*, 20 January 2016, http://www.pv-magazine.com/news/details/beitrag/chile--316-mw-ac-of-solar-pv-came-online-in-2015_100022880/; 316 MW of commercial capacity added in 2015 for a year-end total of 848 MW, from CIFES, *Reporte CIFES—Energías Renovables en el Mercado Eléctrico Chileno* (Santiago: January 2016), p. 2, http://cifes.gob.cl/wp-content/uploads/2016/01/Reporte_CIFES_Enero_v3.pdf. Rapid growth was due mainly to very large-scale projects, driven by Chile's renewable energy law and very high spot market prices thanks to the country's mining industry, from Movellan, op. cit. note 13.

71 Deutsche Bank, cited in Becky Beetz, "Chile: Solar cheaper than fossil fuels," *PV Magazine*, 5 November 2015, http://www.pv-magazine.com/news/details/beitrag/chile--solar-cheaper-than-fossil-fuels_100021869/.

72 The country added nearly 0.4 GW to make solar its fastest growing power source, from Honduras National Electric Energy Company, cited in Blanca Diaz Lopez, "389 MW of solar comes online in Honduras in 2015 to date," *PV Magazine*, 19 November 2015, http://www.pv-magazine.com/news/details/beitrag/389-mw-of-solar-comes-online-in-honduras-in-2015-to-date_100022041/; year-end capacity of 389 MW also from Becquerel Institute, April 2016; generous FIT (for the first 300 MW) and regulatory certainty that set it apart from its neighbours, from Christian Roselund, "Honduras: 232 MW of PV projects receive three cent bonus," *PV Magazine*, 27 August 2015, http://www.pv-magazine.com/news/details/beitrag/honduras--232-mw-of-pv-projects-receive-three-cent-bonus_100020762; Adam Critchley, "Honduras emerges as Central America's solar success story," Greentech Media, 7 September 2015, http://www.greentechmedia.com/articles/read/honduras-emerges-as-central-americas-solar-success-story. **Figure 17** based on country-specific data and on sources provided throughout this section. Data for Taipei, China from PVPS, op. cit. note 1.

73 The decline in oil prices hurt the solar market in Mexico, from Adam James, "Mexico: Where oil prices really do impact solar," Greentech Media, 28 April 2015, http://www.greentechmedia.com/articles/read/mexico-where-oil-prices-really-do-impact-solar; deployment in Mexico was on hold awaiting the Energy Transition Law, and Brazil's market was affected by the country's economic woes, from GTM Research, cited in Kenning, op. cit. note 2; Brazil's challenges also from Vanessa Dezem, "Brazil state shelves auction for 200 MW of solar power," Renewable Energy World, 29 February 2016, http://www.renewableenergyworld.com/articles/2016/02/brazil-state-shelves-auction-for-200-mw-of-solar-power.html. Both Brazil and Mexico had substantial capacity in the pipeline: Mexico had over 5 GW of permitted projects, and Brazil had over 2 GW contracted, from GTM Research, cited in Kenning, op. cit. note 2. Mexico added 103 MW for a total of 282 MW, from IEA PVPS, op. cit. note 1, p. 18. Mexico was the region's leading market for distributed solar PV with more than 50 MW added through the national net metering programme, from Blanca Díaz López, "Mexico remains the leading distributed solar market in Latin America," *PV Magazine*, 3 March 2016, http://www.pv-magazine.com/news/details/beitrag/mexico-remains-the-leading-distributed-solar-market-in-latin-america_100023534/, and had a cumulative 114 MW at end-2014, from Comisión Federal de Electricidad (CRE), "Estadísticas: Contratos de interconexión en pequeña y mediana escala – año 2015," p. 5, http://www.cre.gob.mx/documento/2109.pdf. In Brazil, 833 MW of new capacity was awarded out of a total 11.2 GW of total qualified bids, from Eric Wesoff, "Brazil announces the winners of its 833 MW solar auction," Greentech Media, 7 September 2015, http://www.greentechmedia.com/articles/read/Brazil-Announces-the-Winners-of-Its-833-MW-Solar-Auction. Construction began late in the year on a 254 MW plant in Bahia state, with power contracted at USD 0.08/kWh, from Ian Clover, "Enel Green Power begins construction of 254 MW Brazil solar plant," *PV Magazine*, 29 December 2015, http://www.pv-magazine.com/news/details/beitrag/enel-green-power-begins-construction-of-254-mw-brazil-solar-plant_100022581. In Peru, 144 MW was bid by Enel Green Power at USD 47.98/MWh, and another 40 MW was bid by Enersur at USD 48.50/MWh, from Henry Lindon, "Tremendously low 4.8¢/kWh solar price in Peru, unsubsidized," CleanTechnica, 25 February 2016, http://cleantechnica.com/2016/02/25/tremendously-low-4-8%C2%A2kwh-solar-price-in-peru-unsubsidized/, and from Masson, op. cit. note 2.

74 See, for example, Robert Muhn, Yingli Chile, cited in Movellan, op. cit. note 13.

75 Masson, op. cit. note 2 and March 2015. Deployment of solar PV is driven largely by decisions of large banks to support specific projects that they consider to pose relatively low risk, from idem.

76 Some of the fastest markets and drivers from Apricum PV Market Model Q3 2015, cited in Kurz, op. cit. note 7; IHS, MENASOL 2015, cited in Heba Hashem, "PV hit grid parity and Jordan, UAE as MENA capacity surges," PV Insider, 29 May 2015, http://analysis.pv-insider.com/pv-hits-grid-parity-jordan-uae-mena-capacity-surges.

77 Masson, op. cit. note 2.

78 See, for example: "Solar developments in Jordan," *Renewable Energy World Magazine*, September/October 2015, p. 10; "Cleaner, cheaper energy sources," *Jordan Times*, 29 December 2015, http://www.jordantimes.com/opinion/editorial/cleaner-cheaper-energy-sources; Ilias Tsagas, "Jordan's second PV tender leads to record low tariffs," *PV Magazine*, 18 May 2015, http://www.pv-magazine.com/news/details/beitrag/jordans-second-pv-tender-leads-to-record-low-tariffs-_100019481/; IHS, MENASOL 2015, cited in Hashem, op. cit. note 76. Jordan also has been busy installing solar panels on rooftops of homes, mosques and universities, from Ilias Tsagas, "Jordan's rooftop PV sector thriving," *PV Magazine*, 11 February 2015, http://www.pv-magazine.com/news/details/beitrag/jordans-rooftop-pv-sector-thriving_100018111/, from Edgar Meza, "Jordan launches plan to install solar on 6,000 mosques," *PV Magazine*, 16 March 2015, http://www.pv-magazine.com/news/details/beitrag/jordan-launches-plan-to-install-solar-on-6-000-mosques_100018618/, and from Ilias Tsagas, "Jordan's universities install solar," *PV Magazine*, 2 March 2015, http://www.pv-magazine.com/news/details/beitrag/jordans-universities-install-solar_100018383/.

79 Israel added 200 MW for a total of 880.7 MW, from IEA PVPS, op. cit. note 1. See also Anna Hirtenstein, "Israel's 340-MW solar goal on hold as industry waits for government policies," Renewable Energy World, 10 August 2015, http://www.renewableenergyworld.com/articles/2015/08/israel-s-340-mw-solar-goal-on-hold-as-industry-waits-for-government-policies.html. Progress was slow in Israel due to a large discovery of natural gas offshore in recent years and to uncertainty about government regulations, per idem. Kuwait, the State of Palestine and Saudi Arabia all had some capacity in operation at end-2015, from Becquerel Institute, April 2016. Andrew Burger, "Egypt's renewable energy drive gains steam," Renewable Energy World, 9 June 2015, http://www.renewableenergyworld.com/articles/2015/06/egypt-s-renewable-energy-drive-gains-steam.html; Damian Carrington, "Saudi Arabia is hedging its bets with solar power," Business Insider, 23 May 2015, http://www.businessinsider.com/saudi-arabia-solar-power-2015-5; "Gaza to get 30 megawatts of solar energy," World Bulletin, 16 April 2015, http://www.worldbulletin.net/news/157990/gaza-to-get-30-megawatts-of-solar-energy.

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scatec-solar-launches-egyptian-activities-towards-building-250-mw-of-solar_100021715/; Burger, op. cit. note 79.

83 Beetz, op. cit. note 80. See also: Ian Clover, "SkyPower announces $440m, 200 MW Djibouti solar plans," *PV Magazine*, 2 October 2015, http://www.pv-magazine.com/news/details/beitrag/skypower-announces-440m--200-mw-djibouti-solar-plans_100021344/; "Akuo Energy: Signature of the largest solar project in West Africa, with the Malian government," Tecsol, 24 October 2015, http://tecsol.blogs.com/mon_weblog/2015/10/akuo-energy-signature-du-grand-projet-solaire-dafrique-de-louest-avec-le-gouvernement-malien.html (using Google Translate); Ian Clover, "Nigeria signs $100m development deal for 50 MW solar farm," *PV Magazine*, 11 November 2015, http://www.pv-magazine.com/news/details/beitrag/nigeria-signs-100m-development-deal-for-50-mw-solar-farm_100021935/; Katherine Tweed, "Ignite Power will bring solar to 250,000 homes in Rwanda by 2018," Greentech Media, 1 February 2016, http://www.greentechmedia.com/articles/read/ignite-power-will-bring-solar-to-250000-homes-in-rwanda-by-2018; Solar Solutions West Africa, "Top 20 – largest solar PV projects West Africa," http://www.solarsolutionswestafrica.com/top20-solar-pv-projects-west-africa/, viewed 6 April 2016; REN21, *SADC Renewable Energy and Energy Efficiency Status Report 2015* (Paris: 2015), http://www.ren21.net/wp-content/uploads/2015/10/REN21_SADC_Report_web.pdf.

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88 Lenardic, "Large-scale PV power plants – Top 50," op. cit. note 88; Lenardic, "Large-scale PV power plants – Ranking 51–100," op. cit. note 88; Lenardic, "Large-scale PV power plants – Ranking 101–150," op. cit. note 88.

89 Denis Lenardic, pvresources, personal communication with REN21, 6 March 2016.

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91 Fraunhofer Institute for Solar Energy Systems (ISE) and US National Renewable Energy Laboratory (NREL), *Current Status of Concentrator Photovoltaic (CPV) Technology* (Freiburg, Germany and Golden, CO: February 2016), pp. 6, 7, https://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/current-status-of-concentrator-photovoltaic-cpv-technology.pdf. CPV entered the marketplace only in the mid-2000s, with the first plant exceeding 1 MW installed in Spain during 2006. The technology is still young and a small player, and there remains a lack of reliable data on all fronts, from idem, pp. 7, 10.

92 Simon P. Philipps et al., *Current Status of Concentrator Photovoltaic (CPV) Technology* (Freiburg, Germany and Golden, CO: Fraunhofer ISE and NREL, January 2015), p. 6, http://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/current-status-of-concentrator-photovoltaic-cpv-technology.pdf; Alexandre Roesch, SolarPower Europe, personal communication with REN21, 7 April 2016.

93 Projects came online in China, Japan, Mexico, South Africa, the United States and some countries in Europe, based on data provided at CPV Consortium, "Listing projects," http://cpvconsortium.org/projects, viewed 19 March 2016, and from Fraunhofer ISE and NREL, op. cit. note 91, p. 11; cancelled from Masson, op. cit. note 2. In 2015 around 17 MW was newly installed, from Fraunhofer ISE and NREL, op. cit. note 91. For additional information, see also IHS, *Top Solar Power Industry Trends for 2015* (Englewood, CO: 2015), https://www.ihs.com/pdf/Top-Solar-Power-Industry-Trends-for-2015_213963110915583632.pdf.

94 Fraunhofer ISE and NREL, op. cit. note 91, p. 5. More than 90% of capacity was high-concentration PV (HCPV) with two-axis tracking, from idem, p. 6.

95 In Italy, solar PV generated 24,676 GWh of electricity in 2015, up by 13% over 2014, according to preliminary statistics from Terna, cited in Ilias Tsagas, "Solar PV provides 7.8 percent of Italy's electricity in 2015," Renewable Energy World, 11 February 2016, http://www.renewableenergyworld.com/articles/2016/02/solar-pv-provides-7-8-percent-of-italy-s-electricity-in-2015; Greece based on 3,658 GWh of solar PV generation and total electricity consumption of 56.4 TWh in 2015, for a solar PV share of 6.48%, from ΛΕΙΤΟΥΡΓΟΣ ΑΓΟΡΑΣ ΗΛΕΚΤΡΙΚΗΣ ΕΝΕΡΓΕΙΑΣ Α.Ε., Μηνιαίο Δελτίο Ειδικού Λογαριασμού ΑΠΕ & ΣΗΘΥΑ (Pireas: December 2015), provided by Ioannis Tsipouridis, R.E.D. Pro Consultants S.A., Athens, personal communication with REN21, 25 April 2016; Germany data is preliminary and for gross electricity consumption, from BMWi, op. cit. note 54; solar PV generation of 5.9% (share of gross electricity generation), from AG Energiebilanzen, "Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern," 28 January 2016, provided by AGEE-Stat, personal communication with REN21, 4 April 2016.

96 Figures of 3.5% and 7% from IEA PVPS, op. cit. note 1, p. 6; estimated nearly 4% of total from SolarPower Europe, op. cit. note 2, p. 4; data for 2008 from Gaëtan Masson, "Editorial: 2013, a qualified record-year for photovoltaics," EPIA, March 2014, http://www.epia.org/news/news/?page=1#news-278.

97 Figure of 22 countries from IEA PVPS, op. cit. note 1, pp. 6, 16. An estimated 17 out of 28 EU member states had enough to generate at least 1% of electricity with solar PV at end-2015, from Schmela, op. cit. note 52.

98 Frank Haugwitz, AECEA, personal communication with REN21, 11 April 2016.

99 IEA PVPS, op. cit. note 1, pp. 17, 18. Estimate for electricity generation is theoretical calculation based on average yield and installed solar PV capacity as of 31 December 2015.

100 Back on their feet from Haugwitz, op. cit. note 98; consolidate from Masson, op. cit. note 2.

101 Consolidation into downstream (including O&M and EPC) from Theologitis, op. cit. note 32; focusing on markets elsewhere from Alexandra S. Mebane, "An in-depth interview with JinkoSolar's

CSO & Head of Emerging Markets: Arturo Herrero," Solar Plaza, 20 February 2015, http://www.solarplaza.com/article/an-in-depth-interview-with-jinkosolars-cso-head-of; many Italian companies, for example, have turned to overseas markets, from Becquerel Institute and IEA PVPS, personal communication with REN21, 18 March 2016; shipments to all markets outside of Europe were on the rise by early 2014, from Shyam Mehta, "5 crucial solar manufacturing stats for 2014," Greentech Media, 17 March 2014, http://www.greentechmedia.com/articles/read/Five-Crucial-Solar-Manufacturing-Stats-for-2014-GTM-Research.

102 See, for example, Fraunhofer ISE and NREL, op. cit. note 91; Oscar de la Rubia, Institute for Concentration Photovoltaics Systems, Spain, cited in "CPV's golden opportunity in the MENA region," Solar GCC Alliance, 11 February 2015, http://www.solargcc.com/cpvs-golden-opportunity-in-the-mena-region/; Paula Mints, "Fifteen things to watch out for in 2016," Renewable Energy World, 8 January 2016, http://www.renewableenergyworld.com/articles/2016/01/fifteen-things-to-watch-out-for-in-2016.html. For CSP, see CSP section in this GSR.

103 See, for example: Justin Doom, "Canada imposes tariff on imported Chinese solar equipment," Renewable Energy World, 9 March 2015, http://www.renewableenergyworld.com/rea/news/article/2015/03/canada-imposes-tariff-on-imported-chinese-solar-equipment; Tom Miles and David Lawder, "US wins WTO dispute against India's solar rules," *Reuters*, 25 February 2016, http://planetark.org/wen/74192; BNEF and Business Council for Sustainable Energy (BCSE), *2016 Sustainable Energy in America Factbook* (London and Washington, DC: 2016), http://www.bcse.org/wp-content/uploads/BCSE-2016-Sustainable-Energy-in-America-Factbook.pdf; Ilana Solomon and Ben Beachy, "The WTO just ruled against India's booming solar program," *Huffington Post*, 24 February 2016, http://www.huffingtonpost.com/ben-beachy/the-wto-just-ruled-agains_b_9307884.html.

104 Jason Deign, "Europe's module import verdict to test price convergence with China," PV Insider, 16 October 2015," http://analysis.pv-insider.com/europes-module-import-verdict-test-price-convergence-china. Module prices tend to be more global than soft costs; however, US module prices are largely driven by trade policy, including anti-dumping and countervailing duties on Chinese module suppliers, from SEIA and GTM Research, "US Solar Market Insight 2015 Q4" (Washington, DC: 9 March 2016), http://www.seia.org/research-resources/solar-market-insight-2015-q4.

105 GTM Research, *PV Pulse*, April 2016. The cheapest offers were below USD 0.5/Wp, and probably as low as USD 0.44/Wp, per PV Insights, provided by Masson, op. cit. note 2.

106 Vince Font, "How innovations in BOS will keep solar affordable in a post-ITC world," *Renewable Energy World Magazine*, November/December 2015, pp. 26–31, http://www.renewableenergyworld.com/articles/print/volume-18/issue-110/features/solar/how-innovations-in-bos-will-keep-solar-affordable-in-a-post-itc-world.html.

107 Galen Barbose and Naïm Darghouth, Lawrence Berkeley National Laboratory (LBNL), "Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States," Report Summary (Berkeley, CA: August 2015), https://emp.lbl.gov/sites/all/files/lbnl-188238%20presentation_0.pdf. Soft costs also include marketing and customer acquisition, system design, installation labor, and permitting and inspections, from idem.

108 Galen Barbose and Naïm Darghouth, *Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States* (Berkeley, CA: LBNL, August 2015), pp. 23–24, https://emp.lbl.gov/sites/all/files/lbnl-188238_2.pdf. Soft costs in Germany are well below those in Japan and the United States, from Masson, op. cit. note 2. Costs continue to be higher in Japan than many other countries, however; see, for example, Andy Colthorpe, "Japan's government confirms plans for solar tender," PV-Tech, 4 March 2016, http://www.pv-tech.org/news/japans-government-speaks-about-utility-scale-pv-tenders-explains-thinking-b.

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49 According to the online Solar Heat for Industrial Processes database (www.ship-plants.info), Chile, China and the United States lead in volume of installed solar process heat collector area. Chile boasts the world's largest solar process heat installation – the 27.5 MW_{th} plant at the Gaby copper mine. Austria and Germany lead in the number of projects, with 23 and 21 projects, respectively. German systems are by far the smallest of all key market installations, per Bärbel Epp, op. cit. note 43.

50 To tackle the obstacle of having few planning guidelines, the research group of the IEA Task 49 (Solar Heat in Industrial Processes) developed and published the so-called Integration Guideline (http://task49.iea-shc.org/data/sites/1/publications/150218_IEA%20Task%2049_D_B2_Integration_Guideline-final.pdf), a step-by-step guide on how to integrate solar heat in industrial processes, per Wolfgang Glatzl, AEE INTEC, Gleisdorf, Austria, personal communication with REN21, April 2016; Bärbel Epp, "Very few countries have policies explicitly supporting renewable deployment in the industry sector," interview with Ruud Kempener, Technology Roadmap Analyst at the International Renewable Energy Agency (IRENA) Innovation and Technology Centre in Bonn, Germany, Solar Thermal World, 2 March 2015, http://www.solarthermalworld.org/content/very-few-countries-have-policies-explicitly-supporting-renewable-deployment-industry-sector; IRENA, *Renewable Energy Options for the Industry Sector: Global and Regional Potential until 2030* (Abu Dhabi: 2015), http://www.irena.org/remap/IRENA_RE_Potential_for_Industry_BP_2015.pdf.

51 Gabi Sartori, Australian Renewable Energy Agency, Canberra, Australia, personal communication with solrico, March 2016.

52 Epp, op. cit. note 43.

53 Virach Maneekhao, Department of Alternative Energy Development and Efficiency (DEDE), Bangkok, Thailand, personal communication with solrico, November 2015.

54 Daniel Mugnier, Tecsol, Perpignan, France, personal communication with REN21, March 2016.

55 Ibid.

56 Estimating the number of newly installed solar cooling systems in 2015 is difficult because of the growing number of sorption chiller manufacturers and of PV cooling systems, and the diversification of markets in the Middle East, Asia and Australia; thus, it is no longer possible to assess a global market overview at end-2015, per Uli Jakob, Green Chiller Association for Sorption Cooling, Berlin, Germany, personal communication with REN21, March 2016.

57 Annual newly installed solar cooling systems from Solem

Consulting / Tecsol within TASK 48 of IEA SHC, per Jakob, op. cit. note 56.

58 The German Chiller manufacturer Invensor commissioned the largest solar cooling installation in its company history in March 2015 at the German weighing technology manufacturer Wipotec. The installation has 100 kW of cooling capacity and 480 m^2 of collector field (the collector field and cooling load are separate units) for air conditioning of the production and office buildings, per Hayo Angerer-Wachenfeld, Invensor, Berlin, Germany, personal communication with REN21, April 2016. As of early 2016, a 3,000 m^2 solar process heating and cooling system was under construction in Graz at the industry company AVL, per Christian Holter, S.O.L.I.D., Graz, Austria, personal communication with REN21, April 2016. The Sheikh Zayed Desert Learning Center in Abu Dhabi is partly cooled by a 1,134 m^2 collector field, which drives a 352 kW capacity lithium absorption chiller, per Bärbel Epp, "UAE: Museum in Al Ain Garden City receives 5-Pearl Estidama rating," Solar Thermal World, 4 May 2015, http://www.solarthermalworld.org/content/uae-museum-al-ain-garden-city-receives-5-pearl-estidama-rating.

59 For the first time, a solar cooling week was organised in March 2015 by IEA SHC TASK 48, in co-operation with Professor Yajun Dai from Shanghai Jiao Tong University, per Eva Augsten, "Solar Cooling Week in China: sector still growing in Asia and Europe," Solar Thermal World, 30 April 2015, http://www.solarthermalworld.org/content/solar-cooling-week-china-sector-still-growing-asia-and-europe. Favorable countries for 100 kW solar cooling systems are Egypt, Jordan, Morocco, the State of Palestine, Tunisia and Yemen, per United Nations Environmental Programme, *Assessment on the Commercial Viability of Solar Cooling Technologies and Applications in the Arab Region* (Nairobi: 2014), http://www.solarthermalworld.org/sites/gstec/files/story/2016-04-05/solar_cooling_in_arab_region_0.pdf.

60 Daniel Mugnier, Tecsol, Perpignan, France, personal communication with REN21, April 2016.

61 Desiccant cooling (DEC) systems lack commercial offers and seriously aggressive actors in comparison with absorption and adsorption chiller technologies. The complexity of DEC systems often lead to the selection of absorption technology for solar cooling projects in 2015, per Mugnier, op. cit. note 54.

62 Bärbel Epp and Stephanie Banse, "Success and crisis close together," *Sun & Wind Energy 6/2015*, November 2015, pp. 22–35, http://www.sunwindenergy.com/sites/default/emagftp/SWE_S_06__2015/index.html#/22 .

63 Jaideep Malaviya, "India: First mirror manufacturer for concentrating collector application," Solar Thermal World, 26 January 2016, http://www.solarthermalworld.org/content/india-first-mirror-manufacturer-concentrating-collector-application. The United Nations Development Programme is subsidising the installation of 90 demonstration and replication projects totalling 45,000 m^2 of collector area between 2012 and 2017, from Jaideep Malaviya, "India: UNDP supports 53 new concentrating solar thermal projects," Solar Thermal World, 23 February 2015, http://www.solarthermalworld.org/content/india-undp-supports-53-new-concentrating-solar-thermal-projects.

64 Alejandro Diego Rosell, "Mexico: First local vacuum tube manufacturer to start production in 2018," Solar Thermal World, 16 October 2015, http://www.solarthermalworld.org/content/mexico-first-local-vacuum-tube-manufacturer-start-production-2018; Alejandro Diego Rosell, "Mexico: Pilot polymer water heater factory by 2016," Solar Thermal World, 26 June 2015, http://www.solarthermalworld.org/content/mexico-pilot-polymer-water-heater-factory-2016.

65 The three vacuum tube collector manufacturers reached a production capacity of at least 10 million tubes in 2014, enough to cover the demand of newly installed vacuum tube collector systems with 1,024,665 m^2 in 2015, per Bärbel Epp, "Turkey: Market development 2015 and forecast 2016," Solar Thermal World, 26 November 2015, http://www.solarthermalworld.org/content/turkey-market-development-2015-and-forecast-2016. Market figures for Turkey for 2015 from Ülke, op. cit. note 14.

66 Costas Travasaros, EBHE, Piraeus, Greece, personal communication with REN21, February 2016; Klaus Mischensky, Austria Solar, Vienna, Austria, personal communication with REN21, March 2016.

67 Over the last two years, maybe 90% of the companies active in solar thermal have gone out of business, per Javier Ferrada, Britec, Santiago, Chile, personal communication with REN21, February 2016. See Alejandro Diego Rosell, "Chile: New tax credits – better late than never," Solar Thermal World, 2 March 2015, http://www.solarthermalworld.org/content/chile-new-tax-credits-better-late-never.

68 Linuo New Materials did not make money in the last few years because of the decreasing prices of raw glass tubing and because its manufacturing technology was outdated, per Epp and Banse, op. cit. note 62. The world´s largest manufacturer of vacuum tubes and systems, the Sunrise East Group with its two brands Sunrain and Micoe, purchased a 30% stake in Pengpusang, known internationally as Prosunpro, per idem.

69 Bärbel Epp, "Europe: Market decline claims four victims in collector industry," Solar Thermal World, 17 November 2015, http://www.solarthermalworld.org/content/europe-market-decline-claims-four-victims-collector-industry.

70 Ensol and Hewalex announced strong growth rates in 2014, according to the world map survey, per Epp and Banse, op. cit. note 62.

71 Novasol and Sumersol have begun to offer innovative financing schemes to decrease the dependency of stop-and-go support schemes. Navasol's clients can pay back the investment in monthly instalments equivalent to the monthly energy bills they used to pay, plus a certain discount. Sumersol offers energy service contracts, selling solar heat instead of solar systems to customers, per Alejandro Diego Rosell, "Spain: Market growth despite incentive scheme stop and go," Solar Thermal World, 2 February 2016, http://www.solarthermalworld.org/content/spain-market-growth-despite-incentive-scheme-stop-and-go.

72 According to Skyline Innovations, the company had completed 104 ESCO projects by February 2014; 96 were in design/build phase at that time and another 41 were signed to be built, per Justin Schafer, Product Manager, Skyline, in an interview, "We try to take the complication out of the energy business, not only for our customers, but also for our industry partners," Solar Thermal World, 28 February 2014, http://www.solarthermalworld.org/content/we-try-take-complication-out-energy-business-not-only-our-customers-also-our-industry. S.O.L.I.D. in Austria had 13 plants under ESCO contracts with a total collector area of 26,427 m^2 in May 2015, per Harald Blazek, S.O.L.I.D., Graz, Austria, personal communication with REN21, April–May 2015.

73 Sumersol from Spain has been experiencing continuous growth in offering heat delivery contracts as an ESCO. Founding Partner Juan José Rojo confirms: "Five years ago, we set up maybe two to three systems per year. Now, we are installing more than ten and intend to reach 50 over the medium term," as quoted in Rosell, op. cit. note 71. Sunti, a French start-up founded in November 2014, offers solar process heat to firms as an ESCO, per Bärbel Epp, "France: New ESCO focuses on process heat," Solar Thermal World, 2 May 2015, http://www.solarthermalworld.org/content/france-new-esco-focuses-process-heat. The German company Enertracting, founded in 2011, focuses on the ESCO business; at the end of 2015, it had under contract six systems with a total collector area of more than 1,000 m^2, per Roland Heinzen, Enertracting, Kassel, Germany, personal communication with solrico, April 2015. The solar process heat company Sunvapor offers the sale of heat as opposed to equipment, per Steven Meyers, Visiting Scientist, Sunvapor, personal communication with REN21, March 2016.

74 Austrian installation company Mysolar specialises in replacing 18 year old on average solar water heaters that have been losing efficiency because of ageing collectors. At a fixed price, the company replaces old collectors with new ones – a growing business field, as the increasing number of partners in different federal states shows, per Eva Augsten, "Austria: Mysolar offers to replace old solar thermal collectors," Solar Thermal World, 9 November 2015, http://www.solarthermalworld.org/content/austria-mysolar-offers-replace-old-solar-thermal-collectors.

75 An average 88% of the annually installed collector units in Israel were replacing existing systems, and only 12% were new ones between 2010 and 2014, per Eddie Bet-Hazavdi, Department of Energy Conservation within the Ministry of National Infrastructures, Energy and Water Resources, Tel Aviv, Israel, personal communication with solrico, June 2015.

76 Epp and Banse, op. cit. note 62.

77 Ibid.

78 The largest brands of vacuum tube collectors in China in 2015

were Micoe, Sunrain, Himin and Linuo-Paradigma, per Cheng Hongzhi, SunVision Management Consulting, Dezhou, China, personal communication with REN21, April 2016. Micoe and Sunrain are the two brands of the manufacturer Sunrise East Group.

79 The TASK on Price Reduction of Solar Thermal Systems was launched in October, per Eva Augsten, "IEA SHC: Industry invited to join research community for lower solar heat costs," Solar Thermal World, October 2015, http://www.solarthermalworld.org/content/iea-shc-industry-invited-join-research-community-lower-solar-heat-costs.

80 Bärbel Epp, "Germany/Belgium: Container solutions to standardise commercial solar thermal systems," Solar Thermal World, 2 February 2016, http://www.solarthermalworld.org/content/germanybelgium-container-solutions-standardise-commercial-solar-thermal-systems-0.

81 Domestic hot water supply stations *have been used mainly in German-speaking countries to date but have become increasingly popular in* southern and eastern Europe*, especially for large buildings that are equipped with buffer tanks,* per Eva Augsten, "Tap water stations: top marks for hygiene," Sun & Wind Energy, November 2015, http://www.sunwindenergy.com/content/tap-water-stations-top-marks-hygiene.

82 Viessmann from Bärbel Epp, "Germany: ISH 2015 and its prominent novelties," Solar Thermal World, 30 March 2015, http://www.solarthermalworld.org/content/germany-ish-2015-and-its-prominent-novelties; Sunlumo from Bärbel Epp, "Germany: Two national awards for solar thermal specialists," Solar Thermal World, 27 January 2016, http://www.solarthermalworld.org/content/germany-two-national-awards-solar-thermal-specialists. The Sunlumo collector received the German Federal Ecodesign Award in the Product category, from idem.

83 The Global Solar Certification Network (GSCN) was developed within TASK 43, called Solar Rating and Certification – Global Collector Certification, per Bärbel Epp, "IEA SHC: Mutual recognition of test and inspection reports saves industry costs," Solar Thermal World, 4 August 2015, http://www.solarthermalworld.org/content/iea-shc-mutual-recognition-test-and-inspection-reports-saves-industry-costs.

84 Epp, op. cit. note 83; An example of the cost-saving possibilities: a manufacturer that certifies eight different collector types on three regional market would pay around EUR 288,000. Under the new scheme of mutual recognition the fees go down to only EUR 96,000, per Jan Erik Nielsen, Solarkey Int., Hvalsø, Denmark, head of GSCN (http://www.gscn.solar/), personal communication with solrico, November 2015.

85 Bärbel Epp, "ISH 2015: Letter A with or without + dominates International Heating Fair," Solar Thermal World, 13 March 2015, http://www.solarthermalworld.org/content/ish-2015-letter-or-without-dominates-international-heating-fair.

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87 The relevant solar thermal institutions in Europe – ESTIF, Solar Keymark Network and BSW Solar – have difficulties implementing Solergy because the initiative lacks broad industry support and is not anchored in the EU regulations, per Bärbel Epp, "Germany: Debate about voluntary collector output label Solergy," Solar Thermal World, 4 November 2015, http://www.solarthermalworld.org/content/germany-debate-about-voluntary-collector-output-label-solergy; Bärbel Epp, "Solergy collector label: EU commission confirms clear distinction from energy labelling," Solar Thermal World, 28 December 2015, http://www.solarthermalworld.org/content/solergy-collector-label-eu-commission-confirms-clear-distinction-energy-labelling. By end-January 2016, around 200 collector types were labelled partly by the German certification body Din Certco, per Marisol Oropeza, "News from Solergy," Solar Heat Initiative newsletter, 15 February 2016, http://solar-heating-initiative.com/.

88 Vanessa Kriele, "Quality infrastructure crucial to emerging markets," Solar Thermal World, 11 January 2016, http://www.solarthermalworld.org/content/quality-infrastructure-crucial-emerging-markets; IRENA, *Quality Infrastructure for Renewable Energy Technologies: Solar Water Heaters* (Abu Dhabi: December 2015), http://www.irena.org/DocumentDownloads/Publications/IRENA_QI_3_SWH_2015.pdf.

89 Alejandro Diego Rosell, "MENA: First online training program on solar water heaters certification," Solar Thermal World, 21 June 2015, http://www.solarthermalworld.org/content/mena-first-online-training-program-solar-water-heaters-certification. The Initiative of the Pan American Standards Commission (Copant) aims to develop regional standards for solar water heaters with the aim of harmonising them with ISO standards, per Vanessa Kriele, "Latin America on its way to solar thermal quality standards," Solar Thermal World, 31 August 2015, http://www.solarthermalworld.org/content/latin-america-its-way-solar-thermal-quality-standards.

90 A total of 39 suppliers with 76 collectors was analysed in a survey, with 76% of the supplied collectors based on parabolic trough technology, followed by 16% with lineal Fresnel technology, per Ana Huidobro, "Medium temperature solar collectors database, TASK 11.1 – small scale and low cost installations for power and industrial process heat applications," Tecnalia, July 2015, http://www.stage-ste.eu/keydocuments/docs/STAGE-STE_D110.pdf.

91 Database STAGE-STE, cited in Tecnalia, "Medium temperature solar collectors manufacturers and models database" (Donostia-San Sebastian, Spain: November 2015), http://www.stage-ste.eu/keydocuments/solarthermalcollectors.php.

92 Artic Solar manufactures the XCPC collectors, which provide enough heat for commercial buildings as well as high-temperature applications, per the company's website, http://www.articsolar.com/about.html. Skyven Technologies is developing a solar thermal panel which concentrates radiation to a closed, controllable piping network, per the company's website, http://www.skyven.co/technology/. Oorja Solar develops concentrating solar thermal collectors for new industrial applications, per the company's website, http://www.oorja.in/intersolar-india-2015-oorja-presents-on-novel-solar-thermal-applications/.

93 Database STAGE-STE, op. cit. note 91.

94 Among the more than 9,600 buildings of the US General Services Administration, appropriate candidates for PV-T are those which have a larger domestic hot water load that is provided by electricity not gas, per Jesse Dean et al., *Photovoltaic-Thermal New Technology Demonstration* (Golden, CO: US National Renewable Energy Laboratory, January 2015).

95 Ibid., op. cit. note 94.

96 The annual electrical co-efficient of performance (COP_{el}) of 12 monitored solar cooling systems between 10 and 1,750 kW_{cool} was between 6 and 25, with an average value of 12.9, which is three times higher than the state of the art compression chiller systems, per Uli Jakob, "Best Practice Brochure from IEA SHC TASK 48 Quality Assurance & Support Measures for Solar Cooling Systems" (Germany: Green Chiller Association for Sorption Cooling, June 2015), http://task48.iea-shc.org/data/sites/1/publications/Task%2048%20-%20Activity%20D2%20Final%20Report%20-%20November%202015.pdf. A COP_{el} of 12.9 means that the system produces the equivalent of 12.9 kWh of cooling energy from each kWh of electricity. Riccardo Battisti, „Solar cooling 2.0: new generation growing up," Solar Thermal World, 1 October 2015, http://www.solarthermalworld.org/content/solar-cooling-20-new-generation-growing.

97 Bärbel Epp, "Denmark/Italy: Green cooling kit from Purix addresses growing split chiller market," Solar Thermal World, 23 December 2015, http://www.solarthermalworld.org/content/denmarkitaly-green-cooling-kit-purix-addresses-growing-split-chiller-market; Solarinvent and Solabcool from Riccardo Battisti, "Solar cooling: from research to market competitiveness," Solar Thermal World, 6 October 2015, http://www.solarthermalworld.org/content/solar-cooling-research-market-competitiveness. Meibes developed a 5 kW sorption chiller and will offer complete system kits including space heating and cooling energy distribution, per Andre Breuer, Meibes, Gerichshain, Germany, personal communication with REN21, April 2016.

98 Compact Thermal Energy Storage has a huge potential for latent heat and sorption materials in the long run – in seasonal solar heat storage for small and medium applications, as well as in the building sector, per Wim van Helden and Matthias Rommel,

Compact Thermal Energy Storage. IEA SHC Position Paper (Cedar, MI: August 2015), http://www.solarthermalworld.org/sites/gstec/files/news/file/2015-09-25/iea-shc_compact-thermal-storage-position-paper_aug2015.pdf.

99 Ibid.

100 The experts calculated that based on the costs of substituted energy, the maximum acceptable storage capacity costs of a compact storage were in the range of EUR 2–4 per kWh of installed storage capacity for seasonal storage systems with a 25-year lifetime and a 1% interest loan, per Ibid.

WIND POWER

1 Figure of 22% and capacity data based on the following: global additions in 2015 were 63,792 MW for a year-end total of 433,119 MW, from FTI Consulting, *Global Wind Market Update—Demand & Supply 2015* (London: 2016), Demand-Side Analysis, p. iv; additions were 63,467 MW for a total of 432,883 MW, from Global Wind Energy Council (GWEC), *Global Wind Report: Annual Market Update 2015* (Brussels: April 2016), p. 11, http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_19_04.pdf; additions were 62,732.3 MW for a global total of 432,560.4 MW, from EurObserv'ER, *Wind Energy Barometer* (Paris: February 2016), p. 3, www.eurobserv-er.org/wind-energy-barometer-2016/; additions were 64,164.2 MW for a total of 435,465.1 MW, from World Wind Energy Association (WWEA), *World Wind Energy Report 2015* (Bonn: May 2016); and net additions were 62,937 MW for a total of 431,948 MW, from International Renewable Energy Agency (IRENA), *Renewable Capacity Statistics 2016* (Abu Dhabi: April 2016), http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Capacity_Statistics_2016.pdf. **Figure 23** based on historical data from GWEC, op. cit. this note, and from WWEA, op. cit. this note; data for 2015 from sources in this note.

2 Based on data from GWEC, "Global Wind Statistics 2015" (Brussels: February 2016), http://www.gwec.net/wp-content/uploads/vip/GWEC-PRstats-2015_LR.pdf.

3 GWEC, op. cit. note 1. Countries with more than 1 GW included 17 countries in Europe, 4 in Asia-Pacific, 4 in the Americas (Brazil, Canada, United States, Mexico) and 1 in Africa (South Africa), from idem, p. 9. Note that 112 countries/regions had wind installations as of end-2015, per Jean-Daniel Pitteloud, WWEA, personal communication with REN21, 8 April 2016.

4 Leading source of new capacity from FTI Consulting, op. cit. note 1, Wind Farm Owner-Operators, p. 1; generation from Fatih Birol, Executive Director, International Energy Agency (IEA), Foreword in GWEC, op. cit. note 1, p. 6. The increase in wind generation during 2015 was equal to almost half of global electricity growth, from Birol, op. cit. this note.

5 GWEC, op. cit. note 1, p. 11; WWEA, op. cit. note 1.

6 GWEC, op. cit. note 1, p. 11. **Figure 24** based on country-specific data and sources provided throughout this section.

7 GWEC, op. cit. note 1; WWEA, op. cit. note 1; Steve Sawyer, GWEC, personal communication with REN21, 14 January 2016; Stefan Gsänger, WWEA, personal communication with REN21, 3 December 2015; WWEA, "Special: World Wind Energy Report 2014," Quarterly Bulletin, Special Issue 2015, http://www.wwindea.org/wwea-bulletin-special-issue-2015/.

8 GWEC, op. cit. note 1; Djordje Daskalovic, "Energy min says Serbia's first wind park to go on stream by end-2015," SeeNews Renewables, 14 October 2015, http://renewables.seenews.com/news/energy-min-says-serbias-first-wind-park-to-go-on-stream-by-end-2015-497292; Serbia added 9.9 MW for a total of the same, from European Wind Energy Agency (EWEA), *Wind in Power: 2015 European Statistics* (Brussels: February 2016), p. 4; Samoa installed 0.6 MW in 2015, from GWEC, op. cit. note 1, p. 16, http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_19_04.pdf; Mauritius joined the list in early 2016, from "Mauritius wind farm soon to be operational," ESI Africa, 17 December 2015, http://www.esi-africa.com/news/mauritius-wind-farm-soon-to-be-operational/.

9 The top five in 2015 were estimated to be Denmark (898.1 W per person), Sweden (621.4 W), Germany (558.1 W), Ireland (539.3 W) and Spain (494.6 W); Portugal was not far behind with 488.3 W per person, and the island of Bonaire (with 10.8 MW of capacity) had 620.4 W per person, all per WWEA, op. cit. note 1. The top five in 2014 were Denmark (876.8 W per person), Sweden (557.9 W), Germany (499.6 W), Spain (481.5 W) and Ireland (470.1 W), followed by Portugal (454.4 W), Canada (278.3 W), Austria (254.8 W), Estonia (240.6 W) and the United States (206.2 W), from WWEA, *World Wind Energy Report 2014* (Bonn: 2015).

10 Policy uncertainty from EWEA, op. cit. note 8, p. 10, and from GWEC, op. cit. note 1. Other drivers from GWEC, op. cit. note 1, p. 4, and from WWEA, "Worldwide wind market booming like never before: wind capacity over 392 gigawatt," press release (Bonn: 9 September 2015), http://www.wwindea.org/hyr2015/.

11 Sawyer, op. cit. note 7; GWEC, op. cit. note 1.

12 Eighth consecutive year based on GWEC, *Global Wind Report 2014: Annual Market Update* (Brussels: April 2015), p. 8, http://www.gwec.net/wp-content/uploads/2015/03/GWEC_Global_Wind_2014_Report_LR.pdf, and on GWEC, op. cit. note 1; shares based on idem., both sources, and on FTI Consulting, op. cit. note 1. North America includes the United States and Canada. By contrast, the EU accounted for 23% of the global market in 2014 and 32% in 2013, and North America accounted for 13% in 2014 and less than 8% in 2013, from GWEC, both sources.

13 FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 1.

14 Addition of 30,753 MW for a total of 145,362 MW, from Chinese Wind Energy Association (CWEA), cited in GWEC, op. cit. note 1, and in FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 25. China added 32,970 MW for total of 148,000 MW, from WWEA, op. cit. note 1.

15 Based on additions of 32,970 MW for total of 129,340 MW, from China National Energy Board, cited in China National Energy Administration (CNEA), "Energy Board: 2015 national wind power industry to continue to maintain strong growth momentum," 4 February 2016, www.nea.gov.cn/2016-02/04/c_135073627.htm (using Google Translate); additions of 33,900 MW for total of 129,710 MW, from China Electricity Council, provided by Shi Pengfei, CWEA, personal communication with REN21, 15 March 2016. Differences in statistics result, at least in part, from differences in what is counted and when. Note that most of the capacity added in 2015 was feeding the grid by year's end. The difference in statistics among Chinese organisations and agencies is explained by the fact that they count different things: installed capacity refers to capacity that is constructed and usually has wires carrying electricity from the turbines to a substation; capacity qualifies as grid-connected, i.e., included in China Electricity Council statistics, once certification is granted and operators begin receiving the FIT premium payment, which can take weeks or even months. It is no longer the case that thousands of turbines stand idle awaiting connection in China because projects must be permitted in order to start construction; however, there is still often a several month lag from when turbines are wire-connected to the substation until the process of certification and payment of FIT premium is complete. Steve Sawyer, GWEC, personal communication with REN21, 30 March 2016.

16 Steve Sawyer, GWEC, personal communication with REN21, 14 January and 10 February 2016.

17 GWEC, "China wind power blows past EU," press release (Washington, DC/Beijing/Tokyo/Delhi/Cape Town/Mexico City: 10 February 2016), http://www.gwec.net/china-wind-power-blows-past-eu-global-wind-statistics-release/. Energy security was a driver, but not as important as climate change, per Steve Sawyer, GWEC, personal communication with REN21, 21 October 2015.

18 Top provinces and shares based on data from China National Energy Board, cited by CNEA, "2015 Wind Power Industry Development," 2 February 2016, www.nea.gov.cn/2016-02/02/c_135066586.htm (using Google Translate).

19 GWEC, op. cit. note 8.

20 As of early February, estimated average curtailment over the year 2015 was 15%, from China National Energy Board, op. cit. note 18, and from GWEC, op. cit. note 1, pp. 9, 36; curtailment averaged 20% during 2015, from Frank Haugwitz, Asia Europe Clean Energy (Solar) Advisory Co. Ltd. (AECEA), personal communication with REN21, 11 April 2016, from David Stanway, "China wasted 20 percent of wind power generation in 2015," *Reuters*, 17 March 2016, http://www.reuters.com/article/us-china-power-renewables-idUSKCN0WJ124, and from "Lots of wind power wasted: energy administration," *Xinhua*, 17 March 2016, http://news.xinhuanet.com/english/2016-03/17/c_135198759.htm. Note that curtailment rates were 8% in 2014 and 17% in 2012, from China National Energy Board, cited by CNEA, "Wind Power Industry Monitoring," 12 February 2015, http://www.nea.gov.cn/2015-02/12/c_133989991.htm (using Google Translate). It should be taken into account that 2014 was a low wind speed year compared to average, from Shi Pengfei, CWEA, personal communication with REN21, 1 April 2015.

21 Sue-Lin Wong and Charlie Zhu, "Chinese wind earnings under pressure with fifth of farms idle," *Reuters*, 17 May 2015, http://af.reuters.com/article/commoditiesNews/idAFL3N0Y24DM20150517.

22 Wind generation and share of output from China National

Energy Board, op. cit. note 18. This is up from 156.3 GWh in 2014, from China Electricity Council, available in Chinese at http://www.cec.org.cn/guihuayutongji/gongxufenxi/dianliyunxingjiankuang/2015-02-02/133565.html, provided by Liming Qiao, GWEC, personal communication with REN21, 16 April 2015; 2.8% of output in 2014 from China Renewable Energy Engineering Institute (CREEI), *Wind Power Statistical Evaluation Report of China* (in Chinese), 14 April 2015, provided by Shi, op. cit. note 15. China's wind-generated electricity in 2012 was just over 100 TWh, from GWEC, op. cit. note 1, p. 9.

23 Based on 22,465.03 MW at the end of 2014, from Indian Ministry of New and Renewable Resources (MNRE), "Physical progress (achievements) up to the month of December 2015," www.mnre.gov.in/mission-and-vision-2/achievements, viewed 21 January 2015, and on 25,088.19 MW at end-2015, from MNRE, idem, viewed 1 February 2016. Additions of 2,623 MW for a year-end total of 25,088 MW, from GWEC, op. cit. note 1, p. 11, and 2015 added capacity was 2,621 MW for a total of 25,088 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, pp. 7, 25. Note that 2,294 MW was added for a total of 24,759 MW, from WWEA, op. cit. note 1.

24 "India adding 2800 MW of wind capacity in 2015," *GWEC Newsletter*, January 2016, http://www.gwec.net/india-adding-2800-mw-of-wind-capacity-in-2015/; Steve Sawyer, GWEC, personal communication with REN21, 10 February 2016.

25 Japan added 245 MW for a total of 3,038 MW, the Republic of Korea added 225 MW for a total of 835 MW, and all of Asia added 33,859 MW for a total of 175,831 MW, all from GWEC, op. cit. note 1, p. 11. Japan added 244.6 MW for a total of 3,038.2 MW, and the Republic of Korea added 225 MW for a total of 834 MW, both from WWEA, op. cit. note 1. All of Asia added 33,606 MW in 2015 for a total of 175,573 MW, from EurObserv'ER, op. cit. note 1. Asia added a net of 33,882 MW (including additions also in Taipei (China), Kazakhstan, the Philippines and Vietnam, from IRENA, *Renewable Capacity Statistics 2016* (Abu Dhabi: April 2016), http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Capacity_Statistics_2016.pdf. Note that Vietnam is not included here, but by some reports the country added capacity in 2015. See endnotes for offshore wind developments. Capacity also was added in the Philippines, Taipei (China) and Thailand, per FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 3.

26 Projects from Bloomberg New Energy Finance (BNEF), "China approves 34 GW of new wind projects," Week in Review, 19 May 2015, http://about.bnef.com/landing-pages/china-approves-34gw-new-wind-projects/. No new capacity came online in 2015, per GWEC, op. cit. 1, p. 11, and IRENA, op. cit. note 1. Note, however, that an estimated 80 MW was installed in Pakistan during 2015, per FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 3.

27 The United States added 8,598 MW for a total of 73,992 MW, from American Wind Energy Association (AWEA), "US Wind Industry 2015 Annual Market Update: US Wind Power Capacity and Generation Growth in 2015" (Washington, DC: April 2016), http://awea.files.cms-plus.com/Annual%20Report%20Capacity%20and%20Generation%202015.pdf. Rankings based on data in this section. The United States added a net of 8,346.4 MW in 2015 for a total of 72,577.9 MW, from US Energy Information Administration (EIA), *Electric Power Monthly with Data for December 2015* (Washington, DC: US Department of Energy (DOE), February 2016), Table 6.1., p. 129, http://www.eia.gov/electricity/monthly/pdf/epm.pdf; wind power generated 190.927 TWh of electricity in 2015, from EIA, idem, Table 1.1.A., p. 15, http://www.eia.gov/electricity/monthly/pdf/epm.pdf. Note that EIA data do not include facilities smaller than 1 MW and do not include off-grid capacity.

28 Based on figure of 41% from AWEA, op. cit. note 27.

29 Fourth quarter from AWEA, "American wind power posts second strongest quarter ever, readies to help states meet Clean Power Plan affordably," press release (Washington, DC: 27 January 2016), http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=8325; increase of 77% from AWEA, "US Wind Industry Fourth Quarter 2015 Market Report" (Washington, DC: 27 January 2015), p. 1, http://awea.files.cms-plus.com/FileDownloads/pdfs/4Q2015%20AWEA%20Market%20Report%20Public%20Version.pdf; drivers from BNEF and Business Council for Sustainable Energy (BCSE), *2016 Sustainable Energy in America Factbook* (London and Washington, DC: 2016), p. 60, http://www.bcse.org/wp-content/uploads/BCSE-2016-Sustainable-Energy-in-America-Factbook.pdf.

30 AWEA, "US wind industry leaders praise multi-year extension of tax credits," press release (Washington, DC: 18 December 2015), http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=8254.

31 Texas added 1,307 MW, followed by Oklahoma (853 MW), Kansas (599 MW) and Iowa (502 MW), from AWEA, "US Wind Industry Fourth Quarter 2015 Market Report," op. cit. note 29.

32 AWEA, "American wind power posts second strongest quarter ever…," op. cit. note 29. Going beyond state mandates (Renewable Portfolio Standards) includes utilities in, for example, Colorado and Alabama, from David Labrador, "US wind power demand: corporations take the lead," RMI Outlet, 22 February 2016, http://blog.rmi.org/blog_2016_02_22_us_wind_power_demand_corporations_take_the_lead. At the same time, a growing number of utilities have met state RPS mandates and are slowing their new contracts, from Brian Eckhouse, "Google's clean-power deal shows wind farms finding new customers," *Bloomberg*, 5 December 2015, http://www.bloomberg.com/news/articles/2015-12-04/google-clean-power-deal-shows-wind-farms-finding-new-customers.

33 Labrador, op. cit. note 32. Corporate procurement in the United States continues to accelerate, from AWEA, "American wind power posts second strongest quarter ever…," op. cit. note 29. An estimated 52% of the megawatts contracted through PPAs in 2015 (2,074 MW wind power) were signed by non-utility purchasers (including corporations, universities, cities) to reduce emissions and secure low-cost, fixed price electricity, from AWEA, "US Wind Industry 2015 Annual Market Update: Non-utility buyers increase wind demand in 2015" (Washington, DC: April 2015), http://awea.files.cms-plus.com/Annual%20Report%20Non-Utility%20Purchasers%202015.pdf. Cost-competitiveness from Eckhouse, op. cit. note 32.

34 AWEA, "American wind power posts second strongest quarter ever…," op. cit. note 29.

35 Canada added 1,506 MW for a total of 11,205 MW, from Canadian Wind Energy Association (CanWEA), "Wind energy continues rapid growth in Canada in 2015," press release (Ottawa: 12 January 2016), http://canwea.ca/wind-energy-continues-rapid-growth-in-canada-in-2015/.

36 Ibid. Growth slowed based on GSR 2015 and FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. iv.

37 Ontario added 871 MW (for a total of 4,361 MW), followed by Québec (added 397 MW) and Nova Scotia (added 186 MW), from CanWEA, op. cit. note 35.

38 CanWEA, op. cit. note 35. As of early 2016, Prince Edward Island got an estimated 40% of its electricity supply from wind energy, and Nova Scotia about 10%, from idem.

39 EWEA, op. cit. note 8, pp. 4, 6; GWEC, op. cit. note 1. The EU added 12,518.8 MW for a total of 141,718.2 MW, from EurObserv'ER, op. cit. note 1.

40 EWEA, op. cit. note 8, pp. 4, 5.

41 Ibid., pp. 4, 6. The EU added an estimated 6,581 MW of new fossil capacity in 2015 (including 4,714 MW of coal and 1,867 MW of natural gas; plus 100 MW of nuclear), but the region decommissioned about 15,587 MW of fossil capacity (including 8,051 MW of coal, 4,254 MW of natural gas and 3,282 MW of fuel oil, plus 1,825 MW of nuclear), from EWEA, op. cit. note 8, p. 6.

42 EWEA, op. cit. note 8, p. 8.

43 GWEC, op. cit. note 1, pp. 13, 15.

44 Preliminary statistics from Bundesministerium für Wirtschaft und Energie (BMWi), *Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015* (Berlin: February 2016), http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/erneuerbare-energien-in-zahlen-2015.pdf, and from BMWi, "Development of Renewable Energy Sources in Germany 2015," statistical data from the Working Group on Renewable Energy-Statistics (AGEE-Stat), as at February 2016, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/development-of-renewable-energy-sources-in-germany-2015.pdf?__blob=publicationFile&v=8. Considering decommissioned onshore capacity of 195 MW, Germany's capacity increased by a net of 5.8 GW for a year-end total of 44.9 GW, from Deutsche WindGuard, *Status of Land-Based Wind Energy Development in*

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Germany, January 2016, p. 1, https://www.wind-energie.de/sites/default/files/attachments/page/statistics/20160127-factsheet-status-land-based-wind-energy-development-germany-2015.pdf. Added (gross) 6,013 MW for a year-end total of 44,947 MW, from GWEC, op. cit. note 1, p. 11; added a national record of 5,926 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 1; added 4,919 MW for a total of 45,192 MW, from WWEA, op. cit. note 1.

45 EWEA, op. cit. note 8, p. 10; Deutsche WindGuard, op. cit. note 44.

46 Wind power generated 87,975 GWh in 2015, up from 57,357 GWh in 2014, for an increase of over 53%, based on data from Working Group on Renewable Energy-Statistics (AGEE-Stat) and BMWi, *Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland* (Berlin: February 2016), p. 7, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf. Reasons for increase from BMWi, *Erneuerbare Energien in Deutschland*, op. cit. note 44.

47 EWEA, op. cit. note 8, p. 4. Poland added 1,266 MW for a total of 5,100 MW, France added 1,073 MW for a total of 10,369 MW and the UK added 1,201 MW for a total of 13,453 MW, all from FTI Consulting, op. cit. note 1, Demand-Side Analysis, pp. 2, 7. Poland added 1,266 MW for a total of 5,100 MW, France added 997 MW for a total of 10,293 MW and the UK added 1,174 MW for a total of 13,614 MW, from WWEA, op. cit. note 1. Poland added 1,264 MW for a total of 5,100 MW, France added 999 MW for a total of 10,312 MW and UK added 867.5 MW for a total of 13,855 MW, all from EurObserv'ER, op. cit. note 1, p. 6, www.eurobserv-er.org/wind-energy-barometer-2016/. The UK had a year-end 2014 total of 12,987 MW, with an estimated 1,204 MW added based on a preliminary year-end total of 14,191 MW, from UK Department of Energy and Climate Change (DECC), "Energy Trends: Renewables, Energy Trends Section 6: Renewables" (London: updated 31 March 2016), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511939/Renewables.pdf. France added 999 MW in 2015 for a total of 10,312 in 2015, from RTE Réseau de transport d'électricité, *2015 Bilan Électrique* (Paris: 2015), p. 3, http://www.rte-france.com/sites/default/files/2015_bilan_electrique.pdf.

48 EWEA, op. cit. note 8, pp. 4, 10.

49 Ibid., p. 4. See also Asociación Empresarial Eólica (AEE), "The Spanish wind power sector installs zero megawatts in 2015, an unknown situation since the 80s," press release (Madrid: 26 January 2016), http://www.aeeolica.org/en/new/the-spanish-wind-power-sector-installs-zero-megawatts-in-2015-an-unknown-situation-since-the-80s/.

50 Across the region, 4,366 MW was added for a total of 15,293 MW, from GWEC, op. cit. note 1, p. 11; Latin America installed 4,440 MW for a total of 15,278 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. iv.

51 Brazil's woes from Vanessa Dezem, "Brazil wind-power deals fall short of expectations in auction," *Bloomberg*, 27 April 2015, http://www.bloomberg.com/news/articles/2015-04-27/brazil-wind-power-deals-fall-short-of-expectations-in-auction, and from GWEC, "China wind power blows past EU," press release (Washington, DC/Beijing/Tokyo/Delhi/Cape Town/Mexico City: 10 February 2016), http://www.gwec.net/china-wind-power-blows-past-eu-global-wind-statistics-release/. Brazil added 2,754 MW for a total of 8,715 MW, from GWEC, op. cit. note 1, p. 11, and from WWEA, op. cit. note 1; added 2,754 MW for a total of 8,682 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 25. Share of regional additions based on data from GWEC, op. cit. note 1.

52 Capacity of 356.8 MW from Associação Brasileira de Energia Eólica, provided by Steve Sawyer, GWEC, personal communication with REN21, 28 April 2016; commissioned but not all was grid-connected from GWEC, op. cit. note 1, p. 16.

53 Steve Sawyer, GWEC, personal communication with REN21, 8 September 2015; Brazilian Power Trading Chamber (CCEE), cited in Lucas Morais, "Brazil's installed wind capacity increases 45% y/y in 2015," SeeNews Renewables, 9 March 2016, http://renewables.seenews.com/news/brazils-installed-wind-capacity-increases-45-y-y-in-2015-516207. The top states were Rio Grande do Norte (2,493 MW), Ceara (1,573.5 MW) and Rio Grande do Sul (1,514 MW), from CCEE, op. cit. this note.

54 Other countries adding capacity were Argentina, Chile, Costa Rica, Honduras and Guatemala, all from GWEC, op. cit. note 1, and from WWEA, op. cit. note 1. Mexico passed 3 GW total from Asociación Mexicana de Energía Eólica (AMDEE), "Mexico passes 3,000 MW milestone in 2015," March 2016, http://www.gwec.net/mexico-passes-3000-mw-milestone-2015/; Chile added 169 MW and the Dominican Republic added 50 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis 2015, pp. 4, 67; Uruguay added 375.5 MW for total of 856.8 MW, from Uruguay Secretary of Energy, Ministerio de Industria, Energía y Minería, personal communication with REN21, early 2016; in addition, Jamaica installed 24 MW, from idem; Chile ended 2015 with 904 MW of wind power capacity, from CIFES Ministerio de Energía, Gobierno de Chile, *Reporte CIFES—Energías Renovables en el Mercado Eléctrico Chileno* (Santiago: January 2016), p. 2, http://www.revistaei.cl/reportes/reporte-cifes-energias-renovables-en-el-mercado-electrico-chileno-febrero-2016/.

55 Turkey added 956.2 MW in 2015 (up from 803.65 MW added in 2014) to end 2015 with 4,718.3 MW, from Turkish Wind Energy Association, *Turkish Wind Energy Statistics Report* (Ankara: January 2016), pp. 4, 5, http://www.tureb.com.tr/en/turebsayfa/announcements/turkish-wind-energy-statistics-report-january-2016.

56 Jordan increased its operating capacity from 2 MW to 119 MW in 2015, from GWEC, op. cit. note 1, p. 11. The completed project was the Tafila Wind Farm with 117 MW of capacity, from "King inaugurates Tafila wind farm project," *Jordan News Agency*, 17 December 2015, and from Masdar Clean Energy, "Tafila Wind Farm," http://www.masdar.ae/en/energy/detail/tafila-wind-farm. Jordan also had additional capacity under development, from Tsvetomira Tsanova, "Kuwaiti fund to add 14 MW to Maan wind farm in Jordan – report," SeeNews Renewables, 13 July 2015, http://renewables.seenews.com/news/kuwaiti-fund-to-add-14-mw-to-maan-wind-farm-in-jordan-report-483924, and from Philippa Wilkinson, "Jordan signs wind power purchase agreement," *Middle East Business Intelligence*, 27 May 2015, http://www.nsccme.com/_content/about-us/Jordan%20signs%20wind%20power%20purchase%20agreement.pdf. Jordan added 180 MW, Israel installed 21 MW and the Middle East in total added 296 MW in 2015, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, pp. iv, 74-75.

57 Iran had at least 155 MW in operation at the end of 2015, per Iran Power Generation, Transmission & Distribution Management Company (TAVANIR), *Iran's Electric Power Industry Statistics, Electric Power Production, year 1393* (Tehran: May 2015), p. 27, http://amar.tavanir.org.ir/pages/report/stat93/tafsili/tolid/tolid%201393.pdf; plans for additional capacity from Jan Dodd, "German-Iranian developer plans 106 MW in Iran," *Windpower Monthly*, 3 September 2015, http://www.windpowermonthly.com/article/1362670/german-iranian-developer-plans-106mw-iran, and from Renewable Energy Organization of Iran (SUNA), "Table of contracts concluded with private sector," http://www.suna.org.ir/en/opportunitiestoconstruction/tableofcontractsconcluded, viewed 7 April 2014. Iran had 117.5 MW at year-end from WWEA, *World Wind Energy Report 2015* (Bonn: forthcoming 2016). Kuwait is advancing on a 10 MW demonstration project, from David Weston, "Gamesa to supply first Kuwaiti project," *Windpower Monthly*, 29 September 2015, http://www.windpowermonthly.com/article/1366161/gamesa-supply-first-kuwaiti-project.

58 Sawyer, op. cit. note 24. Nearly 1 GW was added across Africa in 2014, from GWEC, op. cit. note 12.

59 South Africa added 483 MW for a total of 1,053 MW, surpassing Morocco with a total of 787 MW, from GWEC, op. cit. note 1, p. 11; continent-wide figure of 3 GW from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. iv; South Africa added 483 MW for a total of 1,053 MW, and Morocco added no capacity for a total of 795 MW, from WWEA, op. cit. note 57.

60 GWEC, op. cit. note 1, p. 11; Ethiopia also from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 4; Ethiopia added 153 MW for a total of 324 MW, from WWEA, op. cit. note 57; Egypt added 200 MW at Gulf of El-Zayt, bringing total capacity to 745 MW, from Maged Mahmoud, Regional Center for Renewable Energy and Energy Efficiency (RCREEE), personal communication with REN21, 10 April 2016.

61 Both the Kinangop and Lake Turkana wind projects, with combined capacity of 360 MW, were stalled due to disputes over land that have halted the 60 MW Kinangop project and slowed construction of the Lake Turkana wind park, from Maina

Waruru, "East Africa's biggest renewable power projects face land challenges," Renewable Energy World, 22 March 2016, http://www.renewableenergyworld.com/articles/2016/03/east-africa-s-biggest-renewable-power-projects-face-land-challenges.html; Bella Genga, "Lake Turkana Wind Power of Kenya sees electricity supply delayed," *Bloomberg*, 22 March 2016, http://www.bloomberg.com/news/articles/2016-03-22/lake-turkana-wind-power-of-kenya-sees-electricity-supply-delayed.

62 Egypt and Morocco from Sawyer, op. cit. note 24. Countries across the continent included Ethiopia, Ghana, Kenya, Mozambique, Senegal, Sudan and Tanzania, from Steve Sawyer, GWEC, cited in Vince Font, "Wind energy setting records, growing still: the wind energy outlook for 2016," Renewable Energy World, 3 February 2016, http://www.renewableenergyworld.com/articles/2016/02/wind-energy-setting-records-growing-still-the-wind-energy-outlook-for-2016; Tanzania also from "50 MW wind power project in Tanzania to cost more than US$ 132m," Construction Review Online, 11 March 2015, http://constructionreviewonline.com/2015/03/50-mw-wind-power-project-in-tanzania-to-cost-more-than-us-132m/.

63 Australia and Samoa added capacity per GWEC, op. cit. note 1, and per WWEA, op. cit. note 57; Australia (380 MW), New Zealand (7 MW) and Pacific Islands (9 MW) added capacity per FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 4.

64 Australia added 380 MW for total of 4,187 MW, from GWEC, op. cit. note 1, p. 11, and added 380 MW for a total of 4,186 MW, from WWEA, op. cit. note 57. Five wind farms became operational in 2015, adding 196 turbines and 380 MW of generating capacity. These additional projects took the Australian wind industry to a total of 76 wind farms with a capacity of 4,187 MW, made up of 2,062 turbines, from Alicia Webb, Clean Energy Council Australia, personal communication with REN21, April 2016. Figure of 5% from GWEC, op. cit. note 1, p. 26.

65 Figure of 3,398 MW added to the grid for a total of 12,107 MW, from GWEC, op. cit. note 1, p. 49, and adjusted for lower additions in Germany, from BMWi, *Erneuerbare Energien in Deutschland*, op. cit. note 44. A total of 3,856 MW was grid-connected in 2015, using a different methodology from other sources (including Siemens turbines that were not delivered to clients according to the company's project reference list for 2014), from FTI Consulting, op. cit. note 1, Supply-Side Analysis, p. 14.

66 Europe added 3,034.5 MW to its grids for a total of 11,039.3 MW, and decommissioned seven turbines (in the UK and Sweden), from GWEC, op. cit. note 1, p. 49; 10 MW of offshore capacity was decommissioned in Sweden and 6 MW in the UK, from GWEC, op. cit. note 2. Europe added 3,019 MW of net installed, grid-connected capacity in 2015 (108% more than in 2014), for a total of 11,027 MW; most of this capacity (69.4%) was in the North Sea, with the rest in the Irish Sea (17.6%), the Baltic (12.9%) and the Atlantic, from EWEA, *The European Offshore Wind Industry – Key Trends and Statistics 2015* (Brussels: February 2016), pp. 3, 11, http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2015.pdf. Europe (namely Germany, the UK and the Netherlands) added 3,014.6 MW of offshore capacity to its grids, from EurObserv'ER, op. cit. note 1, p. 7.

67 Figure of 2,234 MW from preliminary statistics from BMWi, *Erneuerbare Energien in Deutschland*, op. cit. note 44. Other information based on GWEC, op. cit. note 2. Additions came to 2,282 MW per GWEC, op. cit. note 1, p. 44. Germany brought 2,589 MW online offshore in 2015 and accounted for 67.1% of new offshore capacity, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, pp. v, 8.

68 The UK (572.1 MW), China (361 MW) and the Netherlands (180 MW) from GWEC, op. cit. note 1, p. 49; Japan from Japan Wind Power Association, provided by Feng Zhao, FTI Consulting, personal communication with REN21, 11 April 2016. The UK added 773.7 MW, China added 361 MW and the Netherlands added 129 MW, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. v; the UK added an estimated 617 MW based on 4,501 MW offshore at end-2014 and a preliminary figure of 5,188 MW at end-2015, from UK DECC, op. cit. note 47. Note that Vietnam also had an offshore (intertidal) wind farm operating by end-2015, but it was not commissioned until 17 January 2016, per Steve Sawyer, GWEC, personal communication with REN21, 10 April 2016. Vietnam added 62 MW of offshore capacity for total of 92 MW (and 114 MW of wind overall), from Peter Cattelaens, REN21 country contributor and GIZ Energy Support Programme Vietnam, personal communication with REN21, February 2016. Vietnam saw 83.2 MW commissioned in late December for Phase 2 of the Bac Lieu project, for a total capacity of 99.2 MW; feasibility studies for a further 300 MW offshore were under way in early 2016, from "Vietnam commissions Bac Lieu phase two," 4COffshore, 29 December 2015, http://www.4coffshore.com/windfarms/vietnam-inaugurates-bac-lieu-phase-two-nid3056.html. Some offshore capacity also was decommissioned in 2015, with 10 MW removed in Sweden and 6 MW in the UK, from FTI Consulting, op. cit. note 1, Demand-Side Analysis, p. 8.

69 Policy changes in the UK from Steve Sawyer, GWEC, personal communication with REN21, 7 October 2015. An announcement regarding the UK Contract for Difference, the country's support mechanism for renewables, was missed, causing uncertainty in the industry and the loss of around six months of work, from Giorgio Corbetta, EWEA, personal communication with REN21, 30 March 2016. Total year-end offshore capacity in the UK was 5,066 MW, followed by Germany (3,295 MW), Denmark (1,271 MW), China (1,015 MW), Belgium (712 MW), the Netherlands (427 MW), Sweden (202 MW), Japan (53 MW), Finland (26 MW), Ireland (25 MW), the Republic of Korea and Spain (5 MW each), Norway (2 MW), Portugal (2 MW) and the United States (0.02 MW), from GWEC, op. cit. note 1, p. 49. The UK added 566.1 MW in 2015 for a total of 5,061 MW, from Giorgio Corbetta, WindEurope, personal communication with REN21, 28 April 2016; Germany had a total of 3,283 MW, from preliminary statistics from BMWi, *Erneuerbare Energien in Deutschland*, op. cit. note 44; the UK had 5,188 MW at end-2015, based on preliminary data from UK DECC, op. cit. note 47; China had a total of 1,015 MW offshore at end-2015, including 612 MW of inter-tidal capacity, from Shi, op. cit. note 15.

70 IEA, *World Energy Outlook 2015* (Paris: OECD/IEA, 2015), p. 346.

71 Delay and causes from Yang Jianxiang, "Analysis: China to reevaluate offshore in new Five-Year Plan," Windpower Offshore, 16 June 2015, http://www.windpoweroffshore.com/article/1351718/analysis-china-reevaluate-offshore-new-five-year-plan; Vince Font, "Creating an offshore wind industry," *Renewable Energy World Magazine*, November/December 2015, pp. 20-25; Militsa Mancheva, "China Longyuan plugs in 4 turbines at 400-MW offshore wind park," SeeNews Renewables, 5 January 2016, https://renewables.seenews.com/news/china-longyuan-plugs-in-4-turbines-at-400-mw-offshore-wind-park-507775.

72 Press Trust of India, "Tenders to lease sea blocks for wind farms early next year," *Business Standard*, 6 October 2015, http://www.business-standard.com/article/economy-policy/tenders-to-lease-sea-blocks-for-wind-farms-early-next-year-115100600330_1.html.

73 Deepwater Wind, "Block Island wind farm caps off successful first offshore construction season," press release (Providence, RI: 8 December 2015), http://dwwind.com/press/block-island-wind-farm-caps-off-successful-first-offshore-construction-season/; Herman K. Trabish, "Feds approve North Carolina ocean tract for offshore wind developments," Utility Dive, 21 September 2015, http://www.utilitydive.com/news/feds-approve-north-carolina-ocean-tract-for-offshore-wind-developments/405896/; Fatima Maria Ahmad, "White House recognizes momentum for offshore wind," GWEC, October 2015, http://www.gwec.net/white-house-recognizes-momentum-for-offshore-wind/. *As of late 2015, the continental United States had 21 offshore wind projects totalling 15.65 GW of potential capacity in various stages of development, from* Aaron Smith, Tyler Stehly, and Walter Musial, *2014-2015 Offshore Wind Technologies Market Report* (Golden, CO: National Renewable Energy Laboratory: September 2015), p. 33, http://energy.gov/sites/prod/files/2015/09/f26/2014-2015-offshore-wind-technologies-market-report-FINAL.pdf. See also Michael Copley, "Offshore wind advocates try to broaden debate beyond straight economics," SNL, 30 September 2015, https://www.snl.com/Interactivex/article.aspx?CdId=A-34033675-12846.

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86 Orrell and Foster with Morris, op. cit. note 82, pp. i, 3. US small-scale turbine sales totalled 3.7 MW (over 1,600 units and USD 20 million investment) in 2014, down from 5.6 MW in 2013 (2,700 units and USD 36 million), from idem. Leasing models in the United States from Nichola Groom, "UPDATE 1-Wind power startup nabs $200 mln for projects on homes, farms," *Reuters*, 5 January 2016, http://af.reuters.com/article/commoditiesNews/idAFL1N14P12P20160105; Diane Cardwell, "Wind power spreads through turbines for lease," *New York Times*, 18 December 2015, http://www.nytimes.com/2015/12/19/business/energy-environment/wind-power-spreads-through-turbines-for-lease.html?_r=0.

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117 Based on FTI Consulting, op. cit. note 1, Supply-Side Analysis.

118 FTI Consulting, op. cit. note 1, Supply-Side Analysis. A slightly different ranking shows Goldwind passing GE (first place in 2014), followed by Vestas, GE, Siemens, Gamesa and Enercon, with Chinese companies Guodian, Ming Yang, Envision and CSIC also among the top 10, from BNEF, cited in Cusick, op. cit. note 115, and in "Xinjiang Goldwind ranks No. 1 in commissioned wind turbines in 2015, BNEF says," Renewable Energy World, 22 February 2016, http://www.renewableenergyworld.com/articles/2016/02/chinese-firm-ranks-no-1-in-commissioned-wind-turbines-bnef-says.html. See also EWEA, op. cit. note 66, p. 5, http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2015.pdf.

119 Rankings of Chinese companies based on CWEA, provided by Shi, op. cit. note 15; FTI Consulting, op. cit. note 1, Supply-Side Analysis. **Figure 25** based on data from idem.

120 FTI Consulting, op. cit. note 1, Supply-Side Analysis, p. 3.

121 Based on data from FTI Consulting, op. cit. note 1, Supply-Side Analysis, p. 4. Note that the top 15 accounted for over 82% of the total market (based on volumes of MW installed by vendors who sell turbines with rated capacities of at least 200 kW per unit). Also, there were 51 such wind turbine manufacturers producing turbines in 2015. All from idem, pp. iv, 2.

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INVESTMENT FLOWS

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POLICY LANDSCAPE

1 This section is intended to be only indicative of the overall landscape of policy activity and is not a definitive reference. Policies listed are generally those that have been enacted by legislative bodies. Some of the policies listed may not yet be implemented, or are awaiting detailed implementing regulations. It is obviously difficult to capture every policy, so some policies may be unintentionally omitted or incorrectly listed. Some policies also may be discontinued or very recently enacted. This report does not cover policies and activities related to technology transfer, capacity building, carbon finance and Clean Development Mechanism projects, nor does it highlight broader framework and strategic policies – all of which are still important to renewable energy progress. For the most part, this report also does not cover policies that are still under discussion or formulation, except to highlight overall trends. Information on policies comes from a wide variety of sources, including the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) Global Renewable Energy Policies and Measures Database, the US Database of State Incentives for Renewables & Efficiency (DSIRE), RenewableEnergyWorld.com, press reports, submissions from REN21 regional- and country-specific contributors and a wide range of unpublished data. Much of the information presented here and further details on specific countries appear on the "Renewables Interactive Map" at www.ren21.net. It is unrealistic to be able to provide detailed references for all sources here. **Table 4** and **Figures 38** through **41** are based on idem and on numerous sources cited throughout this section.

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ENERGY EFFICIENCY

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BACK

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1 **Table R1** from the following sources: **Bio-power** based on 2015 forecast data in International Energy Agency (IEA), *Medium-Term Renewable Energy Market Report 2015* (Paris: 2015), https://www.iea.org/bookshop/708-Medium-Term_Renewable_Energy_Market_Report_2015, except for the following: US Federal Energy Regulatory Commission, "Office of Energy Projects Energy Infrastructure Update for December 2015," http://www.ferc.gov/legal/staff-reports/2015/dec-infrastructure.pdf; Brazilian Electricity Regulatory Agency (ANEEL), "Banco de informacoes de geração," http://www.aneel.gov.br/aplicacoes/capacidadebrasil/Combustivel.cfm, viewed 9 May 2016; China National Renewable Energy Centre, provided by Amanda Zhang, Chinese Renewable Energy Industries Association, personal communication with REN21, 26 April 2016; Germany preliminary statistics from Bundesministerium für Wirtschaft und Energie (BMWi), *Erneuerbare Energien in Deutschland, Daten zur Entwicklung im Jahr 2015* (Berlin: February 2016), http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/erneuerbare-energien-in-zahlen-2015.pdf; UK Department of Energy & Climate Change (DECC), "Energy Trends Section 6 – Renewables" (London: March 2016), Table 6.1, https://www.gov.uk/government/statistics/energy-trends-section-6-renewables, viewed 22 April 2016; Government of India, Ministry of New and Renewable Energy (MNRE), "Physical progress (achievements) – up to the month of December 2015," http://www.mnre.gov.in/mission-and-vision-2/achievements/; MNRE, "Physical progress (achievements) – up to the month of December 2014," http://www.mnre.gov.in/mission-and-vision-2/achievements/; Japan from Hironao Matsubara, Institute for Sustainable Energy Policies, Japan, personal communication with REN21, 10 April 2016. **Geothermal power** from Geothermal Energy Association (GEA), supplied by Benjamin Matek, GEA, personal communication with REN21, March–May 2016. **Hydropower** from sources in endnote 5 of this section. **Ocean power** from Ocean Energy Systems (OES), *Annual Report 2015* (Lisbon: April 2016), http://www.ocean-energy-systems.org; see Ocean Energy section and related endnotes for more information. **Solar PV** from sources in endnote 6 of this section. **CSP** from CSP Today, "Projects tracker," http://social.csptoday.com/tracker/projects, viewed on numerous dates leading up to 23 March 2015; US National Renewable Energy Laboratory, "Concentrating solar power projects by project name," http://www.nrel.gov/csp/solarpaces/by_project.cfm, viewed on numerous dates leading up to 23 March 2015; Luis Crespo, European Solar Thermal Electricity Association (ESTELA), Brussels, CSP technology questionnaire provided to REN21, 21 February 2016; REN21, *Renewables 2015 Global Status Report* (Paris: 2015), pp. 64–65, http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf. **Wind power** from sources in endnote 9 of this section. **Modern bio-heat** based on the following: 297 GW_{th} of bioenergy heat plant capacity installed as of 2008, from Helena Chum et al., "Bioenergy," in Ottmar Edenhofer et al., eds., *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* (Cambridge, UK and New York, NY: Cambridge University Press, 2011), http://www.ipcc.ch/pdf/special-reports/srren/Chapter%202%20Bioenergy.pdf. Projections based on this number have been made for past GSRs. The combination of the Chum et al. data, plus past GSR projections, was used to estimate 2014 values of 305 GW_{th} using a linear regression. The 2015 value presented here assumes a 3.5% growth rate from that 305 GW_{th} value, based on the same percent increase for modern heat generation as presented in IEA, *Medium-Term Renewable Energy Market Report 2015*, op. cit. this note, p. 242. Note that accurate heat data, including from bioenergy, are very difficult to obtain as most capacity installations and output are not metered. Even if plant capacities are known, there is often no knowledge of whether a 1 MWth plant, for example, is used for 80 hours or 8,000 hours per year. **Geothermal heating** capacity derived from John W. Lund and Tonya L. Boyd, "Direct utilization of geothermal energy: 2015 worldwide review," in *Proceedings of the World Geothermal Congress 2015* (Melbourne, Australia: 19–25 April 2015), and from Luis C.A. Gutiérrez-Negrín, International Geothermal Association and Mexican Geothermal Association, personal communication with REN21, March 2015. Capacity figure for 2015 is extrapolated from 2014 values (from sources) by weighted-average growth rate across eight categories of geothermal direct use: space heating, bathing and swimming, greenhouse heating, aquaculture, industrial use, snow melting and cooling, agricultural drying and other. The weighted-average five-year annual growth rate for capacity is 6.0% compared to 5.9% simple growth rate for the same period. The weighted-average five-year annual growth rate for utilisation is 3.5% compared to 3.3% simple growth rate for the same period. **Solar collectors for water heating** estimates based on Franz Mauthner, AEE – Institute for Sustainable Technologies (AEE INTEC), personal communication with REN21, April 2016, and on Franz Mauthner, Werner Weiss, and Monika Spörk-Dür, *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2014* (Gleisdorf, Austria: IEA Solar Heating and Cooling Programme, May 2016). See Solar Thermal Heating and Cooling section and related endnotes for more details. **Ethanol, biodiesel and HVO production** data from sources in endnote 3 of this section.

2 **Table R2** from the following sources: **For all global data,** see endnote 1 for this section and other relevant reference tables. For more-specific data and sources, see Global Overview chapter and Market and Industry Trends chapter and related endnotes. **EU-28:** Hydropower from the following sources: International Journal on Hydropower & Dams (IJHD), *Hydropower & Dams World Atlas 2015* (Wallington, Surrey, UK: 2015), Table "World Hydro Potential and Development," pp. 15–17; BMWi and Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), "Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)," February 2016, p. 8, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf; Gestore dei Servizi Energetici S.p.A. (GSE), "Energia da fonti rinnovabili in Italia, Dati preliminari 2015," 29 February 2016, http://www.gse.it/it/Statistiche/RapportiStatistici/Pagine/default.aspx; Red Eléctrica de España (REE), "Potencia instalada nacional (MW)," 8 April 2016, www.ree.es; UK DECC, "Energy Statistics, Section 6 – Renewables" (London: March 2016), p. 51, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511939/Renewables.pdf; Réseau de transport d'électricité (RTE), *2015 Bilan Électrique* (Paris: 2015), pp. 3, 13, http://www.rte-france.com/sites/default/files/2015_bilan_electrique.pdf; RTE, *Panorama de L'Électricité Renouvelable 2014* (Paris: 2014), http://www.rte-france.com/sites/default/files/panorama_des_energies_renouvelables_2014.pdf; Eurostat database, http://ec.europa.eu/eurostat/data/database?node_code=nrg_113a, viewed April 2016. Wind power from European Wind Energy Association (EWEA), *Wind in Power: 2015 European Statistics* (Brussels, February 2016), p. 4, http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2015.pdf, and from Global Wind Energy Council (GWEC), *Global Wind Report: Annual Market Update 2015* (Brussels: April 2016), http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_19_04.pdf. Solar PV from Gaëtan Masson, International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) and Becquerel Institute, personal communications with REN21, March–April 2016, and from IEA PVPS, *Snapshot of Global PV Markets 2015* (Brussels: 2016), http://www.iea-pvps.org/fileadmin/dam/public/report/national/IEA-PVPS_-_Trends_2015_-_MedRes.pdf. Bio-power based on data from IEA, op. cit. note 1; preliminary statistics from BMWi, op. cit. note 1; UK DECC, op. cit. this note. Geothermal power based on data from GEA, unpublished database, provided by Benjamin Matek, GEA, personal communication with REN21, 9 May 2016, and from Ruggero Bertani, "Geothermal Power Generation in the World: 2010-2014 Update Report," in *Proceedings of the World Geothermal Congress 2015* (Melbourne, Australia: 19–25 April 2015). CSP from the following sources: Luis Crespo, op. cit. note 1; REE, *El Sistema Eléctrico Español: Avance 2015* (Madrid: 2015), p. 5, http://www.ree.es/sites/default/files/downloadable/avance_informe_sistema_electrico_2015_v2.pdf; NREL, op. cit. note 1; CSP Today, op. cit. note 1, continuously updated and viewed on numerous occasions leading up to 22 April 2016. Ocean energy from OEC, op. cit. note 1, from UK DECC, op. cit. this note, and from International Renewable Energy Agency (IRENA), *Renewable Capacity Statistics 2016* (Abu Dhabi: April 2016), http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Capacity_Statistics_2016.pdf. **BRICS** based on the following: **Brazil:** Hydropower based on data from ANEEL, "Resumo geral dos novos empreendimentos de geração," http://www.aneel.gov.br/arquivos/zip/Resumo_Geral_das_Usinas_março_2015.zip, updated February 2016; wind power from GWEC, op. cit. this note, and from World Wind Energy Association (WWEA), *World Wind Energy Report 2015* (Bonn: May

2016); solar PV from Becquerel Institute, April 2016, and from ANEEL, op. cit. note 1, viewed 16 February 2016, provided by Maria Beatriz Monteiro and Suani Teixeira Coelho, February 2016; bio-power from idem. **Russian Federation:** Hydropower from System Operator of the Unified Energy System of Russia, *Report on the Unified Energy System in 2015* (Moscow: 1 February 2016), http://www.so-ups.ru/fileadmin/files/company/reports/disclosure/2016/ups_rep2015.pdf; wind power from EWEA, op. cit. this note; solar PV from Federal Grid Company of Unified Energy System, http://so-ups.ru/fileadmin/files/company/reports/ups-review/2015/ups_review_dec15.pdf, provided by Maria Ryabova, Center for Strategic Research and Geopolitics in Energy, International Institute of Energy Policy and Diplomacy, Moscow State Institute of International Relations (MGIMO University), personal communication with REN21, February 2016, and from Becquerel Institute, April 2016; bio-power from IEA, *Medium-Term Renewable Energy Market Report*, op. cit. note 1; 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bio-power from MNRE, "Physical progress (achievements)," op. cit. this note, both sources; geothermal from idem; CSP from NREL, "Concentrating solar power projects in India," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=IN, updated 17 February 2014; CSP Today, op. cit. note 1; "India's PV-led solar growth casts eyes on performance of CSP projects," CSP Today, http://social.csptoday.com/markets/india%E2%80%99s-pv-led-solar-growth-casts-eyes-performance-csp-projects, updated 9 November 2015. **China:** Hydropower from National Energy Agency of China, National Electric Power Industry Statistics, sourced from China National Energy Board, 15 January 2016, http://www.nea.gov.cn/2016-01/15/c_135013789.htm, and from International Hydropower Association (IHA), "2016 Key Trends in Hydropower" (London: March 2016), http://www.hydropower.org, and IHA, personal communication with REN21, February–April 2016; wind power from Chinese Wind Energy Association, cited in GWEC, op. cit. this note, and from China National Energy Board, cited in China National Energy Administration, "Energy Board: 2015 national wind power industry to continue to maintain strong growth momentum," 4 February 2016, www.nea.gov.cn/2016-02/04/c_135073627.htm (using Google Translate); 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Note that bio-power data are lower according to data from US EIA, *Electric Power Monthly with Data for December 2015* (Washington, DC: February 2016), p. 129, Table 6.1, www.eia.gov/electricity/monthly/pdf/epm.pdf; geothermal from GEA, op. cit. this note; CSP from NREL, "Concentrating solar power projects in the United States," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=US, updated 17 February 2014; CSP Today, op. cit. note 1; Parthiv Kurup and Craig Turchi, "NREL CSP Data - US plants V2," presentation (Golden, CO: NREL, 19 February 2016), p. 2; OES, op. cit. this note. **Germany:** Hydropower from BMWi and AGEE-Stat), op. cit. this note, p. 8; wind power from BMWi, op. cit. note 1 from BMWi, *Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland* (Berlin: February 2016), p. 7, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf, and from EWEA, op. cit. this note; solar PV from BMWi, op. cit. note 1; bio-power from idem; geothermal power from GEA database, op. cit. this note; CSP from NREL, "Concentrating solar power projects in Germany," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=DE, updated 17 February 2014; CSP Today, op. cit. note 1. **Japan:** Hydropower based on data from Japan Ministry of Economy Trade and Industry (METI), "Announcement regarding the present status of introduction of facilities generating renewable energy as of October 30, 2015" (Tokyo: February 2016), provided by Hironao Matsubara, Institute for Sustainable Energy Policies (ISEP), personal communication with REN21, February 2016; wind power from Japan Wind Power Association, "Installed capacity of wind power generation at the end of 2015: 3,038 MW, 2,077 units," 25 January 2016, provided by Matsubara, op. cit. this note, from GWEC, op. cit. this note, and from WWEA, op. cit. this note; solar PV from IEA PVPS, op. cit. this note; bio-power from METI, op. cit. this note; geothermal power from ISEP, *Renewables 2015 Japan Status Report* (Tokyo: January 2016), based on feed-in tariff data by end of October 2015, with total end-2015 capacity estimated based on monthly installation, and provided by Matsubara, op. cit. this note. **Italy:** Hydropower from Gestore dei Servizi Energetici – GSE S.p.A., "Energia da fonti rinnovabili in Italia, Dati preliminari 2015," 29 February 2016, http://www.gse.it/it/Statistiche/RapportiStatistici/Pagine/default.aspx; wind power from EWEA, *Wind in Power: 2015 European Statistics* (Brussels: February 2016), p. 4; solar PV from IEA-PVPS, *Snapshot of Global PV Markets 2015* (Paris: 2016), and from GSE, op. cit. this note; bio-power from idem; geothermal power from idem, and from GEA database, op. cit. this note; CSP (all pilots) from NREL, "Concentrating solar power projects in Italy," http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=IT, updated 17 February 2014, and from CSP Today, op. cit. note 1; ocean power from OES, op. cit. note 1. **Spain:** Hydropower from REE, "Potencia instalada nacional (MW)," op. cit. this note; wind power from EWEA, op. cit. this note; solar PV from IEA PVPS, op. cit. this note; bio-power from REE, *El Sistema Eléctrico Español: Avance 2015*, op. cit. this note, p. 5; CSP from Crespo, op. cit. note 1; also from REE, *El Sistema Eléctrico Español: Avance 2015*, op. cit. this note, p. 5; ocean power from OES, op. cit. note 1. **Per capita data** based on capacity data provided in Reference Table R2 and on 2014 country population data from World Bank, "Population, total," World Development Indicators, http://data.worldbank.org/

indicator/SP.POP.TOTL, updated 17 February 2016.

3 **Table R3** from the following sources: ethanol data from F.O. Licht, "Fuel Ethanol: World Production by Country," 2016, and biodiesel data for Argentina, China, Germany, France, Indonesia, Malaysia, Spain and Thailand from F.O. Licht, "Biodiesel: World Production, by Country," 2016, both with permission from F.O. Licht / Licht Interactive Data; biodiesel data for Belgium, Canada, Colombia, India, Netherlands and Singapore from IEA, op. cit. note 1, p. 261; biodiesel data for United States from US EIA, *Monthly Energy Review*, April 2016, Table 10.4, p. 156, http://www.eia.gov/totalenergy/data/monthly/archive/00351604.pdf; biodiesel data for Brazil from Brazil Ministry of Mines and Energy, based on Ministry of Agriculture statistics, "Produção nacional de biodiesel puro - B100 (metros cúbicos)," http://www.anp.gov.br/?dw=8740. Preliminary 2014 data that appeared in GSR 2015 have been updated where possible. Netherlands HVO production assumes that the Neste Oil facility in Rotterdam produced the same amount of HVO as in prior years, with data from F.O. Licht, 2015.

4 **Table R4** from the following sources: Inventory of existing capacity and installed capacity in 2015 from GEA, from Benjamin Matek, GEA, personal communication with REN21, March–May 2016; additional information on Japan from Toshihiro Uchida, Geological Survey of Japan (AIST), via Marietta Sander, International Geothermal Association, personal communication with REN21, April 2016.

5 **Table R5** from the following sources: Global capacity estimate based on IHA, *2016 Hydropower Status Report* (London: May 2016), http://www.hydropower.org/2016-hydropower-status-report, and on IHA, personal communication with REN21, February–April 2016. Total installed capacity of 1,212 GW (33.7 GW added), less 145 GW of pumped storage (2.5 GW added), yields 1,067 GW (31.2 GW added). The difference of 3 GW relative to the values reported here pertains to data for China. Due to uncertainty about full station commissioning dates falling between 2014 and 2015, IHA's *Hydropower Status Report* is reporting 19 GW added in 2015, and REN21's *Global Status Report* is reporting 16 GW. Country data from the following sources: **China:** China National Energy Agency, summary of national electric industry statistics for 2015, http://www.nea.gov.cn/2016-01/15/c_135013789.htm. **Brazil:** 2,506 MW (2,299 MW large hydro, 117 MW small hydro and around 90 MW very small hydro) added in 2015, per ANEEL, op. cit. note 2; "Resumo Geral dos Novos Empreendimentos de Geração," March 2016, http://www.aneel.gov.br/arquivos/zip/Resumo_Geral_das_Usinas_março_2015.zip; cumulative large hydro capacity is listed as 86,366 MW at end-2015, small hydro (1–30 MW) at 4,886 MW and very small hydro (<1 MW) at 398 MW (compared to 308 MW in the previous year), for a total of 91,650 MW. **United States:** US EIA, *Electric Power Monthly,* March 2016, Table 6.2.B, http://www.eia.gov/electricity/monthly. **Canada:** IHA, op. cit. this note; Statistics Canada, "Table 127-0009 Installed Generating Capacity, by Class of Electricity Producer," http://www5.statcan.gc.ca/cansim, viewed March 2016. **Russian Federation:** System Operator of the Unified Energy System of Russia, op. cit. note 2. **India:** installed capacity in 2015 (units larger than 25 MW) of 42,623.42 MW from Government of India, Ministry of Power, Central Electricity Authority, "All India Installed Capacity (in MW) of Power Stations," 13 December 2015, http://www.cea.nic.in/reports/monthly/installedcapacity/2015/installed_capacity-12.pdf; capacity additions in 2015 (>25 MW) of 1,606 MW from Government of India, Ministry of Power, Central Electricity Authority, "Executive Summary of the Power Sector (monthly)," http://www.cea.nic.in/monthlyarchive.html, viewed January–December 2015; installed capacity in 2015 (<25 MW) of 4,176.9 MW from MNRE, op. cit. note 1, viewed 1 February 2016; capacity additions in 2015 (<25 MW) of 186 MW based on difference of year-end 2015 figure (above) and year-end 2014 figure (3,990.83 MW), from idem; an additional 150 MW completed in 2015 but not counted in official capacity total until January 2016, from Government of India, Ministry of Power, Central Electricity Authority, "Executive Summary of the Power Sector (monthly)," January 2016, http://www.cea.nic.in/reports/monthly/executivesummary/2016/exe_summary-01.pdf. **Turkey:** capacity at end-2015 of 25,867.8 MW from Turkish Electricity Transmission Company (TEİAŞ), "Türkiye elektrik enerjisi kuruluş ve yakit cinslerine göre kurulu güç," http://www.teias.gov.tr/yukdagitim/kuruluguc.xls, viewed 28 March 2016; capacity at end-2014 of 23,643 MW from TEİAŞ, *Stratejik Plan 2015–2019* (Ankara: 2015), http://www.teias.gov.tr/dosyalar/stratejik_plan2015_2019.pdf. **Vietnam:** IHA, op. cit. this note. **Malaysia:** IHA, op. cit. this note.

6 **Table R6** from the following sources: Unless noted otherwise, data for 2014 from IEA PVS, *Trends 2015 in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2014* (Paris: 2015), http://www.iea-pvps.org/fileadmin/dam/public/report/national/IEA-PVPS_-_Trends_2015_-_MedRes.pdf, and from SolarPower Europe, *Global Market Outlook for Solar Power 2015–2019* (Brussels: 2015); data for 2015 from IEA PVPS, *Snapshot of Global Photovoltaic Markets 2015* (Paris: April 2016), http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/IEA-PVPS_-__A_Snapshot_of_Global_PV_-_1992-2015_-_Final.pdf, from Gaëtan Masson, Becquerel Institute and IEA PVPS, personal communications with REN21, March–May 2016, and from SolarPower Europe, *Solar Market Report & Membership Directory 2016 Edition* (Brussels: April 2016), as well as from sources provided below. Note that some countries (e.g., Canada, Japan, Spain) report data officially in alternating current (AC); these data were converted to direct current (DC) for consistency across countries. This report attempts to report all solar PV data in DC units. Additional country sources include: **China:** China National Energy Board, cited in China Electricity Council, "2015 PV-related statistics," 6 February 2016, http://www.cec.org.cn/yaowenkuaidi/2016-02-05/148942.html (using Google Translate). **United States:** GTM Research and SEIA, *US Solar Market Insight Report: 2014 Year in Review*, Executive Summary (Washington, DC: 2015), pp. 4–5, https://www.greentechmedia.com/research/ussmi; GTM Research and SEIA, *US Solar Market Insight: 2015 Year-in-Review*, Executive Summary (Washington, DC: March 2016), p. 4. **United Kingdom:** UK DECC, "Energy Trends: Section 6 – Renewables" (London: March 2016), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511939/Renewables.pdf. **India:** 2014 from Bridge to India, May 2015, provided by Sinead Orlandi, Becquerel Institute, personal communication with REN21, 11 May 2015; 2015 from MNRE, "Physical progress (achievements)," multiple issues, http://mnre.gov.in/mission-and-vision-2/achievements/, and from Bridge to India, all provided by Shaurya Bajaj, Bridge to India, personal communication with REN21, 13 April 2016. **Germany:** BMWI, op. cit. note 1, p. 4. See Solar PV section in the Market and Industry Trends chapter and related endnotes for additional statistics and details.

7 **Table R7** from the following sources: CSP Today, op. cit. note 1, viewed on numerous dates leading up to 23 March 2015; NREL, op. cit. note 1, viewed on numerous dates leading up to 23 March 2015; Crespo, op. cit. note 1; REN21, *Renewables 2015 Global Status Report* (Paris: 2015), pp. 64–65, http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf.

8 **Table R8** from the following sources: Cumulative solar thermal capacity in operation nationally and globally at end-2014 from Franz Mauthner, AEE INTEC, Gleisdorf, Austria, personal communications with REN21, April 2016, and from Mauthner, Weiss, and Spörk-Dür, op. cit. note 1; worldwide gross additions for 2015 estimated by Mauthner, op. cit. this note; preview for world 2015 data based on the latest market data from Australia, Austria, Brazil, China, Germany, Israel, Mexico, Turkey and the United States, which represented 87% of cumulated installed capacity in operation in 2014, and other countries were projected accordingly. Gross additions on a national level from the following associations and experts: David Ferrari, School of Engineering at RMIT University, former Sustainability Victoria, Australia; Klaus Mischensky, Austria Solar, Austria; Marcelo Mesquita, the Solar Heating Department of the Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating (DASOL ABRAVA), Brazil; Hongzhi Cheng, Shandong SunVision Management Consulting, China; Denmark from Jan Erik Nielsen, PlanEnergi, Denmark, and Jan-Olof Dalenbäck, Chalmers University of Technology, Sweden; Richard Loyen, Enerplan, France; Marco Tepper, BSW Solar, Germany; Costas Travasaros, Greek Solar Industry Association (EBHE), Greece; Jaideep Malaviya, Solar Thermal Federation of India (STFI), India; Eli Shilton, Elsol, Israel; Kumiko Saito, Solar System Development Association (SSDA), Japan; Daniel Garcia, Solar Thermal Manufacturers Organisation (FAMERAC), Mexico; Janusz Staroscik, Association of Manufacturers and Importers of Heating Appliances (SPIUG), Poland; Pascual Polo, Spanish Solar Thermal Association (ASIT), Spain; David Stickelberger, Swissolar, Switzerland; Kutay Ülke, Ezinç Metal, Turkey; Les Nelson, Solar Heating & Cooling Programs, International Association of Plumbing and Mechanical Officials (IAPMO), United States.

9 **Table R9** from the following sources: GWEC, op. cit. note 2;

FTI Consulting, *Global Wind Market Update—Demand & Supply 2015, Demand-Side Analysis* (London: 2016); WWEA, op. cit. note 2; EWEA, op. cit. note 2, p. 4; Additional sources listed where relevant. **China**: 2014 official data from China National Energy Administration (CNEA), provided by Shi Pengfei, Chinese Wind Energy Association (CWEA), personal communication with REN21, 15 March 2016; 2015 official data from China National Energy Board, cited in CNEA, "Energy Board: 2015 national wind power industry to continue to maintain strong growth momentum," 4 February 2016, www.nea.gov.cn/2016-02/04/c_135073627.htm (using Google Translate); unofficial 2014 and 2015 data based on CWEA, provided in GWEC, op. cit. note 2. **United States:** Based on data from AWEA, "US Wind Industry 2015 Annual Market Update: US Wind Power Capacity and Generation Growth in 2015" (Washington, DC: April 2016), http://awea.files.cms-plus.com/Annual%20Report%20Capacity%20and%20Generation%202015.pdf. **Germany:** 2014 total from Working Group on Renewable Energy-Statistics (AGEE-Stat) and Bundesministerium für Wirtschaft und Energie (BMWi), *Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland* (Berlin: February 2016), p. 8, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf; data for 2015 based on preliminary statistics from BMWi, op. cit. note 1, and from BMWi, *Development of Renewable Energy Sources in Germany 2015*, Statistical data from AGEE-Stat, as at February 2016, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/development-of-renewable-energy-sources-in-germany-2015.pdf?__blob=publicationFile&v=8. **Brazil**: 2014 year-end total from Associação Brasileira de Energia Eólica (ABEEólica), "Boletim de Dados," January 2016, http://abeeolica.org.br/pdf/Boletim-de-Dados-ABEEolica-Janeiro-2016-Publico.pdf, pp. 2, 4. **India:** Data for 2014 and 2015 based on MNRE, "Physical progress (achievements) up to the month of December 2015," www.mnre.gov.in/mission-and-vision-2/achievements, viewed 21 January 2015, and on MNRE, "Physical progress (achievements) up to the month of December 2015," www.mnre.gov.in/mission-and-vision-2/achievements, viewed 1 February 2016. **Canada:** Data for 2014 and 2015 from Canadian Wind Energy Association, "Wind energy continues rapid growth in Canada in 2015," press release (Ottawa, ON: 12 January 2016), http://canwea.ca/wind-energy-continues-rapid-growth-in-canada-in-2015/. **France**: Data for 2014 and 2015 from EWEA, op. cit. note 2, and preliminary data from RTE Réseau de transport d'électricité, *2015 Bilan Électrique* (Paris: 2015), p. 3, http://www.rte-france.com/sites/default/files/2015_bilan_electrique.pdf. **Italy**: EWEA, op. cit. note 2. Note that Italy had 8,703 MW at end-2014, with 423 MW in net additions in 2015 for an end-2015 total of 9,126 MW, based on preliminary data from Gestore Servizi Energetici (GSE), "Energie da fonti rinnovabili in Italia Dati preliminari 2015," 29 February 2015, http://www.gse.it/it/Statistiche/RapportiStatistici/Pagine/default.aspx. **United Kingdom:** 2014 and 2015 data based on EWEA, op. cit. note 2, and preliminary data from UK DECC, op. cit. note 1. **Spain:** Asociación Empresarial Eólica, "The Spanish wind power sector installs zero megawatts in 2015, an unknown situation since the 80s," press release (Madrid: 26 January 2016), http://www.aeeolica.org/en/new/the-spanish-wind-power-sector-installs-zero-megawatts-in-2015-an-unknown-situation-since-the-80s/. **Turkey:** 2014 and 2015 data from Turkish Wind Energy Association, *Turkish Wind Energy Statistics Report* (Ankara: January 2016), pp. 4, 5, http://www.tureb.com.tr/files/bilgi_bankasi/turkiye_res_durumu/turkiye_ruzgar_enerji_istatistik_raporu_ocak_2016.pdf. See Wind Power section in Market and Industry Trends chapter and related endnotes for further statistics and details.

10 **Table R10** derived from IEA, World Energy Outlook 2015, Energy Access Database, http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase, and from submissions from report contributors.

11 **Table R11** derived from IEA, World Energy Outlook 2014, Energy Access Database, http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/, and from submissions from report contributors**.**

12 **Table R14** from Frankfurt School-UNEP Centre and Bloomberg New Energy Finance (BNEF), Global Trends in Renewable Energy Investment in 2016 (Frankfurt: March 2016), http://fs-unep-centre.org/publications/global-trends-renewable-energy-investment-2016.

13 **Table R15** from the following sources: REN21 database; submissions by report contributors; various industry reports; EUROSTAT, "Energy from Renewable Sources: Shares" (Brussels: 2016), http://ec.europa.eu/eurostat/web/energy/data/shares. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

14 **Table R16** from the following sources: REN21 database; submissions by report contributors; various industry reports; EUROSTAT, op. cit. note 15. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

15 **Table R17** from the following sources: REN21 database; submissions by report contributors; various industry reports; EUROSTAT, op. cit. note 15. Targets for the EU-28 were set in each country's National Renewable Energy Action Plan (NREAP), available at http://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans; certain NREAP targets have been revised subsequently. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

16 **Table R18** from the following sources: REN21 database; submissions by report contributors; various industry reports; EurObserv'ER. Targets for the EU-28 were set in each country's NREAP, available at http://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans; certain NREAP targets have been revised subsequently. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

17 **Table R19** from the following sources: REN21 database; submissions by report contributors; various industry reports. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

18 **Table R20** from the following sources: All available policy references, including the IEA/IRENA online Global Renewable Energy Policies and Measures database, published sources as given in the endnotes for the Policy Landscape chapter of this report, and submissions from report contributors.

19 **Table R21** from Ibid.

20 **Table R22** from Ibid.

21 **Table R23** from the following sources: REN21 database, compiled from all available policy references plus submissions from report contributors; EU targets and shares from EUROSTAT, op. cit. note 15. Targets for the EU-28 and Energy Community countries were set in each country's NREAP. Certain NREAP targets have been revised subsequently. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

22 **Table R24** from the following sources: REN21 database; submissions by report contributors; various industry reports; EUROSTAT, op. cit. note 15. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

23 **Table R25** from the following sources: REN21 database; submissions by report contributors; various industry reports; EUROSTAT, op. cit. note 15; IRENA; Jim Lane, "Biofuels Mandates Around the World: 2015," Biofuels Digest, 3 January 2016, http://www.biofuelsdigest.com/bdigest/2016/01/03/biofuels-mandates-around-the-world-2016/. For online updates, see the "Renewables Interactive Map" at www.ren21.net.

24 **Table R26** from the following sources: For selected targets and policies, see: EU Covenant of Mayors; ICLEI–Local Governments for Sustainability; REN21, *Global Futures Report* (Paris: 2013); REN21, Institute for Sustainable Energy Policies, and ICLEI, 2011 *Global Status Report on Local Renewable Energy Policies* (Paris: May 2011). For selected examples in urban planning, see: City of Malmö, "Environmental Programme for the City of Malmö 2009-2020" (Malmö, Sweden: 2009), http://malmo.se/download/18.6301369612700a2db9180006227/1383649554552/Environmental-Programme-for-the-City-of-Malmo-2009-2020.pdf; IRENA, *Renewable Energy Policy in Cities: Selected Case Studies – Malmö*, Sweden (Abu Dhabi: January 2013), https://www.irena.org/Publications/RE_Policy_Cities_CaseStudies/IRENA%20cities%20case%207%20Malmo.pdf; City of Sydney, *Decentralised Energy Master Plan Renewable Energy* (Sydney: 2013), http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0003/153282/Renewable-Energy-Master-Plan.pdf.

METHODOLOGICAL NOTES

This 2016 report is the 11th edition of the *Renewables Global Status Report* (GSR), which has been produced annually since 2005 (with the exception of 2008). Readers are directed to the previous GSR editions for historical details.

Most 2015 data for national and global capacity, output, growth and investment portrayed in this report are preliminary. Where necessary, information and data that are conflicting, partial or older are reconciled by using reasoned expert judgment. Endnotes provide additional details, including references, supporting information and assumptions where relevant. (For information on renewable energy data and related challenges, see Sidebar 4 in GSR 2015, and Sidebar 1 in GSR 2014.)

Each edition draws from thousands of published and unpublished references, including: reports from international organisations and industry associations; input from the GSR community via hundreds of questionnaires submitted by country, regional and technology contributors as well as feedback from several rounds of formal and informal reviews; additional personal communications with scores of international experts; and a variety of electronic newsletters, news media and other sources.

Much of the data found in the GSR is built from the ground up by the authors with the aid of these resources. This often involves extrapolation of older data, based on recent changes in key countries within a sector or based on recent growth rates and global trends. Other data, often very specific and narrow in scope, come more-or-less prepared from third parties. The GSR attempts to synthesise these datapoints into a collective whole for the focus year.

The GSR endeavours to provide the best data available in each successive edition; as such, data should not be compared with previous versions of this report to ascertain year-by-year changes.

Note on Accounting and Reporting

A number of issues arise when counting renewable energy capacities and energy output. Some of these are discussed below:

1. Capacity versus Energy Data

The GSR aims to give accurate estimates of capacity additions and totals, as well as of electricity, heat and transport fuel production in the past year. These measures are subject to some uncertainty, which varies by technology. The chapter on Market and Industry Trends includes estimates for energy produced where possible, but it focuses mainly on electricity or heat capacity data. This is because capacity data generally can be estimated with a greater degree of confidence than generation data. Official heat and electricity generation data often are not available within the production time frame of the GSR.

2. Constructed Capacity versus Connected Capacity and Operational Capacity

Over the past few years, the solar PV and wind power markets have seen increasing amounts of capacity that was connected to the electricity grid but not yet deemed officially operational, or constructed capacity that was not connected to the grid by year-end. This phenomenon has been particularly evident for wind power installations in China (2009–2015), as well as for solar PV in some European countries in past years.

Starting with the 2012 edition, the GSR has aimed to count only capacity additions that were grid-connected or that otherwise went into service (e.g., capacity intended for off-grid use) during the previous calendar (focus) year. However, there may be exceptions related to data availability and other factors (as with China, for example). Known deviations to this approach are outlined in the text or endnotes for the technology sections.

3. Other general notes on Capacity Data

Data on capacity retirements and replacements (re-powering) is incomplete for many technologies, although data on several technologies do attempt to account for these directly. It is not uncommon for reported new capacity installations to exceed the implied net increase in capacity, which in some instances may be explained by revisions to data on installed capacity as well as the effect of capacity retirements and replacements.

Specifically with regard to solar PV, some countries (e.g., Canada, Japan and Spain) report official capacity data on the basis of output in alternating current (AC); these capacity data were converted to direct current (DC) output for consistency across countries. This report attempts to report all solar PV data on the basis of DC output.

4. Bio-power Data

Given existing complexities and constraints (see Figure 6 in GSR 2015, and Sidebar 2 in GSR 2012), the GSR strives to provide the best and latest available data regarding biomass energy developments. The reporting of biomass-fired combined heat and power (CHP) systems varies among countries, which adds to the challenges experienced when assessing total heat and electricity capacities and total bioenergy outputs. Wherever possible, the bio-power data presented include capacity and generation from both electricity-only and CHP systems using solid biomass, landfill gas, biogas and liquid biofuels.

5. Hydropower Data Revision and Treatment of Pumped Storage

Starting with the 2012 edition, the GSR has made an effort to report hydropower generating capacity without including pure pumped storage capacity (the capacity used solely for shifting water between reservoirs for storage purposes). The distinction is made because pumped storage is not an energy source but rather a means of energy storage. It involves conversion losses and potentially is fed by all forms of electricity, renewable and non-renewable. However, some conventional hydropower facilities do have pumping capability that is not separate from, or additional to, their normal generating capability. It is the aim of the GSR to distinguish and separate only the pure (or incremental) pumped storage component.

6. Solar Thermal Heat Data

Starting with GSR 2014, the GSR includes all solar thermal collectors that use water as the heat-transfer medium (or heat carrier) in global capacity data and ranking of top countries. Previous GSRs focused primarily on glazed water collectors (both flat plate and evacuated tube); the GSR now also includes unglazed water collectors, which are used predominantly for swimming pool heating. Data for solar air collectors (solar thermal collectors that use air as the heat carrier) are far more uncertain, and these collector types play a minor role in the market overall. Solar thermal air collectors are included where specified.

7. Other

Editorial content of this report closed by 17 May 2016 for technology data, and by 1 May 2016 or earlier for other content. The Policy Landscape chapter covers policy developments through the end of 2015.

Growth rates in the GSR are calculated as compound annual growth rates (CAGR) rather than as an average of annual growth rates.

All exchange rates in this report are as of 31 December 2015 and are calculated using the OANDA currency converter (http://www.oanda.com/currency/converter/).

Corporate domicile, where noted, is determined by the location of headquarters.

GLOSSARY

Absorption chillers. Chillers that use heat energy from any source (solar, biomass, waste heat, etc.) to drive air conditioning or refrigeration systems. The heat source replaces the electric power consumption of a mechanical compressor. Absorption chillers differ from conventional (vapour compression) cooling systems in two ways: 1) the absorption process is thermochemical in nature rather than mechanical, and 2) the substance that is circulated as a refrigerant is water rather than chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs), also called Freon. The chillers generally are supplied with district heat, waste heat or heat from co-generation, and they can operate with heat from geothermal, solar or biomass resources.

Adsorption chillers. Chillers that use heat energy from any source to drive air conditioning or refrigeration systems. They differ from absorption chillers in that the adsorption process is based on the interaction between gases and solids. A solid material in the chiller's adsorption chamber releases refrigerant vapour when heated; subsequently, the vapour is cooled and liquefied, providing a cooling effect at the evaporator by absorbing external heat and turning back into a vapour, which is then readsorbed into the solid.

Auction. (See Tendering.)

Biodiesel. A fuel produced from oilseed crops such as soy, rapeseed (canola) and palm oil, and from other oil sources such as waste cooking oil and animal fats. Biodiesel is used in diesel engines installed in cars, trucks, buses and other vehicles, as well as in stationary heat and power applications. Also see Hydrotreated vegetable oil.

Bioenergy. Energy derived from any form of biomass (solid, liquid or gaseous) for heat, power and transport. (See Biofuels.)

Biofuels. A fuel derived from biomass that may include liquid fuel ethanol and biodiesel, as well as biogas. Biofuels can be combusted in vehicle engines as transport fuels and in stationary engines for heat and electricity generation. They also can be used for domestic heating and cooking (for example, as ethanol gels). Advanced biofuels are made from feedstocks derived from the lignocellulosic fractions of biomass sources or from algae. They are made using non-traditional biochemical and thermochemical conversion processes.

Biogas/Biomethane. Biogas is a gaseous mixture consisting mainly of methane and carbon dioxide produced by the anaerobic digestion of organic matter (broken down by micro-organisms in the absence of oxygen). Organic material and/or waste is converted into biogas in a digester. Suitable feedstocks include agricultural residues, animal wastes, food industry wastes, sewage sludge, purpose-grown green crops and the organic components of municipal solid wastes. Raw biogas can be combusted to produce heat and/or power; it also can be transformed into biomethane through a process known as scrubbing that removes impurities including carbon dioxide, siloxanes and hydrogen sulphides, followed by compression. Biomethane can be injected directly into natural gas networks and used as a substitute for natural gas in internal combustion engines without fear of corrosion.

Biomass. Any material of biological origin, excluding fossil fuels or peat, that contains a chemical store of energy (originally received from the sun) and that is available for conversion to a wide range of convenient energy carriers.

Biomass energy, modern. Energy derived from combustion of solid, liquid and gaseous biomass fuels in high-efficiency conversion systems, which range from small domestic appliances to large-scale industrial conversion plants. Modern applications include heat and electricity generation, combined heat and power (CHP) and transport.

Biomass, traditional. Solid biomass including fuel wood, charcoal, agricultural and forest residues, and animal dung, that typically is used in rural areas of developing countries with traditional technologies such as open fires for cooking, kilns, and ovens for cooking and residential heating as well as small-scale agricultural and industrial processing. Often the use of traditional biomass leads to high pollution levels, forest degradation and deforestation.

Biomass pellets. Solid biomass fuel produced by compressing pulverised dry biomass, such as waste wood and agricultural residues. Pellets typically are cylindrical in shape with a diameter of around 10 millimetres and a length of 30–50 millimetres. Pellets are easy to handle, store, and transport and are used as fuel for heating and cooking applications, as well as for electricity generation and CHP. (Also see Torrefied wood.)

Building codes and standards. Rules specifying the minimum standards for buildings and other structures for increasing energy efficiency. These can refer to new and/or renovated and refurbished buildings.

Capacity. The rated capacity of a heat or power generating plant, which refers to the potential instantaneous heat or electricity output, or the aggregate potential output of a collection of such units (such as a wind farm or set of solar panels). Installed capacity describes equipment that has been constructed, although it may or may not be operational (e.g., delivering electricity to the grid, providing useful heat or producing biofuels).

Capacity factor. The ratio of the actual output of a unit of electricity or heat generation over a period of time (typically one year) to the theoretical output that would be produced if the unit were operating without interruption at its rated capacity during the same period of time.

Capital subsidy. A subsidy that covers a share of the upfront capital cost of an asset (such as a solar water heater). These include, for example, consumer grants, rebates or one-time payments by a utility, government agency or government-owned bank.

Combined heat and power (CHP) (also called co-generation). CHP facilities produce both heat and power from the combustion of fossil and/or biomass fuels, as well as from geothermal and solar thermal resources. The term also is applied to plants that recover "waste heat" from thermal power generation processes.

Community energy. An approach to renewable energy development that involves a community initiating, developing, operating, owning, investing and/or benefitting from a project. Communities vary in size and shape (e.g., schools, neighbourhoods, partnering city governments, etc.); similarly, projects vary in technology, size, structure, governance, funding and motivation.

Competitive bidding. (See Tendering.)

Concentrating photovoltaics (CPV). Technology that uses mirrors or lenses to focus and concentrate sunlight onto a relatively small area of photovoltaic cells that generate electricity (see Solar photovoltaics). Low-, medium- and high-concentration CPV systems (depending on the design of reflectors or lenses used) operate most efficiently in concentrated, direct sunlight.

Concentrating solar thermal power (CSP) (also called concentrating solar power or solar thermal electricity, STE). Technology that uses mirrors to focus sunlight into an intense solar beam that heats a working fluid in a solar receiver, which then drives a turbine or heat engine/generator to produce electricity. The mirrors can be arranged in a variety of ways, but they all deliver the solar beam to the receiver. There are four types of commercial CSP systems: parabolic troughs, linear Fresnel, power towers and dish/engines. The first two technologies are line-focus systems, capable of concentrating the sun's energy to produce temperatures of 400°C, while the latter two are point-focus systems that can produce temperatures of 800°C or higher.

Conversion efficiency. The ratio between the useful energy output from an energy conversion device and the energy input into it. For example, the conversion efficiency of a PV module is the ratio between the electricity generated and the total solar energy received by the PV module. If 100 kWh of solar radiation is received and 10 kWh electricity is generated, the conversion efficiency is 10%.

Crowdfunding. The practice of funding a project or venture by raising money – often relatively small individual amounts – from a relatively large number of people ("crowd"), generally using the Internet and social media. The money raised through crowdfunding does not necessarily buy the lender a share in the venture, and there is no guarantee that money will be repaid if the venture is successful. However, some types of crowdfunding reward backers with an equity stake, structured payments and/or other products.

Curtailment. A reduction in the output of a generator, typically on an involuntary basis, from what it could produce otherwise given the resources available. Curtailment of electricity generation has long been a normal occurrence in the electric power industry and can occur for a variety of reasons, including a lack of transmission access or transmission congestion.

Degression. A mechanism built into policy design establishing automatic rate revisions, which can occur after specific thresholds are crossed (e.g., after a certain amount of capacity is contracted, or a certain amount of time passes).

Distributed generation. Generation of electricity from dispersed, generally small-scale systems that are close to the point of consumption.

Distributed renewable energy. Energy systems are considered to be distributed if 1) the systems of production are relatively small and dispersed (such as small-scale solar PV on rooftops), rather than relatively large and centralised; or 2) generation and distribution occur independently from a centralised network. Specifically for the purpose of the chapter on Distributed Renewable Energy for Energy Access, "distributed renewable energy" meets both conditions. It includes energy services for electrification, cooking, heating and cooling that are generated and distributed independent of any centralised system, in urban and rural areas of the developing world.

Energy. The ability to do work, which comes in a number of forms including thermal, radiant, kinetic, chemical, potential and electrical. Primary energy is the energy embodied in (energy potential of) natural resources, such as coal, natural gas and renewable sources. Final energy is the energy delivered for end-use (such as electricity at an electrical outlet). Conversion losses occur whenever primary energy needs to be transformed for final energy use, such as combustion of fossil fuels for electricity generation.

Energy audit. Analysis of energy flows in a building, process or system, conducted with the goal of reducing energy inputs into the system without negatively affecting outputs.

Energy efficiency. The measure that accounts for delivering more services for the same energy input, or the same amount of services for less energy input. Conceptually, this is the reduction of losses from the conversion of primary source fuels through final energy use, as well as other active or passive measures to reduce energy demand without diminishing the quality of energy services delivered.

Energy efficiency mandate/obligation. A measure that requires designated parties (consumers, suppliers, generators) to meet a minimum, and often gradually increasing, target for energy efficiency. Mandates can include, for example, energy efficiency portfolio standards (EEPS) and/or building codes or obligations.

Energy efficiency target. An official commitment, plan, or goal set by a government (at the local, state, national or regional level) to achieve a certain amount of energy efficiency by a future date. Targets may be backed by specific compliance mechanisms or policy support measures. Some targets are legislated, while others are set by regulatory agencies, ministries or public officials.

Energy intensity. Primary energy consumption per unit of economic output. Energy intensity is typically used as a proxy for energy efficiency in macro-level analyses due to the lack of an internationally agreed-upon high-level indicator for measuring energy efficiency.

Energy service company (ESCO). A company that provides a range of energy solutions including selling the energy services from a (renewable) energy system on a long-term basis while retaining ownership of the system, collecting regular payments from customers and providing necessary maintenance service. An ESCO can be an electric utility, co-operative, NGO or private company, and typically installs energy systems on or near customer sites. An ESCO also can advise on improving the energy efficiency of systems (such as a building or an industry) as well as methods for energy conservation and energy management.

Energiewende. German term that means "transformation of the energy system". It refers to the move away from nuclear and fossil fuels towards an energy system based primarily on energy efficiency improvements and renewable energy.

Ethanol (fuel). A liquid fuel made from biomass (typically corn, sugar cane or small cereals/grains) that can replace petrol in modest percentages for use in ordinary spark-ignition engines (stationary or in vehicles), or that can be used at higher blend levels (usually up to 85% ethanol, or 100% in Brazil) in slightly modified engines, such as those provided in "flex-fuel" vehicles. Ethanol is also used in chemical and beverage industries.

Feed-in policy (feed-in tariff or feed-in premium). A policy that typically guarantees renewable generators specified payments per unit (e.g., USD/kWh) over a fixed period. Feed-in tariff (FIT) policies also may establish regulations by which generators can interconnect and sell power to the grid. Numerous options exist for defining the level of incentive, such as whether the payment is structured as a guaranteed minimum price (e.g., a FIT), or whether the payment floats on top of the wholesale electricity price (e.g., a feed-in premium).

Final energy. The part of primary energy, after deduction of losses from conversion, transmission and distribution, that reaches the consumer and is available to provide heating, hot water, lighting and other services. Final energy forms include electricity, district heating, mechanical energy, liquid hydrocarbons such as kerosene or fuel oil, and various gaseous fuels such as natural gas, biogas and hydrogen. Final energy accounts only for the conversion losses that occur upstream of the end-user, such as losses at refineries and power plants.

Final energy consumption. Energy that is supplied to the consumer for all final energy services such as cooling and lighting, building or industrial heating or mechanical work including transportation.

Fiscal incentive. An incentive that provides individuals, households or companies with a reduction in their contribution to the public treasury via income or other taxes.

Generation. The process of converting energy into electricity and/or useful heat from a primary energy source such as wind, solar radiation, natural gas, biomass, etc.

Geothermal energy. Heat energy emitted from within the earth's crust, usually in the form of hot water and steam. It can be used to generate electricity in a thermal power plant or to provide heat directly at various temperatures.

Green bond. A bond issued by a bank or company, the proceeds of which will go entirely into clean energy and other environmentally friendly projects. The issuer will normally label it as a green bond. There is no internationally recognised standard for what constitutes a green bond.

Green energy purchasing. Voluntary purchase of renewable energy – usually electricity, but also heat and transport fuels – by residential, commercial, government or industrial consumers, either directly from an energy trader or utility company, from a third-party renewable energy generator or indirectly via trading of renewable energy certificates (such as renewable energy credits, green tags and guarantees of origin). It can create additional demand for renewable capacity and/or generation, often going beyond that resulting from government support policies or obligations.

Heat pump. A device that transfers heat from a heat source to a heat sink using a refrigeration cycle that is driven by external electric or thermal energy. It can use the ground (geothermal/ground-source), the surrounding air (aerothermal/air-source) or a body of water (hydrothermal/water-source) as a heat source in heating mode, and as a heat sink in cooling mode. A heat pump's final energy output can be several multiples of the energy input, depending on its inherent efficiency and operating condition. The output of a heat pump is at least partially renewable on a final energy basis. However, the renewable component can be much lower on a primary energy basis, depending on the composition and derivation of the input energy; in the case of electricity, this includes the efficiency of the power generation process. The output of a heat pump can be fully renewable energy if the input energy is also fully renewable.

Hydropower. Electricity derived from the potential energy of water captured when moving from higher to lower elevations. Categories of hydropower projects include run-of-river, reservoir-based capacity and low-head in-stream technology (the least developed). Hydropower covers a continuum in project scale from large (usually defined as more than 10 MW of installed capacity, but the definition varies by country) to small, mini, micro and pico.

Hydrotreated vegetable oil (HVO). A "drop-in" biofuel produced by using hydrogen to remove oxygen from waste cooking oils, fats and vegetable oils. The result is a hydrocarbon fuel that blends more easily with diesel and jet fuel than does biodiesel produced from triglycerides as fatty acid methyl esters (FAME).

Inverter (and micro-inverter), solar. Inverters convert the direct current (DC) generated by solar PV modules into alternating current (AC), which can be fed into the electric grid or used by a local, off-grid network. Conventional string and central solar inverters are connected to multiple modules to create an array that effectively is a single large panel. By contrast, micro-inverters convert generation from individual solar PV modules; the output of several micro-inverters is combined and often fed into the electric grid. A primary advantage of micro-inverters is that they isolate and tune the output of individual panels, reducing the effects that shading or failure of any one (or more) module(s) has on the output of an entire array. They eliminate some design issues inherent to larger systems and allow for new modules to be added as needed.

Investment. Purchase of an item of value with an expectation of favourable future returns. In this report, new investment in renewable energy refers to investment in: technology research and development, commercialisation, construction of manufacturing facilities and project development (including the construction of wind farms and the purchase and installation of solar PV systems). Total investment refers to new investment plus merger and acquisition (M&A) activity (the refinancing and sale of companies and projects).

Investment tax credit. A fiscal incentive that allows investments in renewable energy to be fully or partially credited against the tax obligations or income of a project developer, industry, building owner, etc.

Joule. A joule (J) is a unit of work or energy equal to the energy expended to produce one Watt of power for one second. The potential chemical energy stored in one barrel of oil and released when combusted is approximately 6 gigajoules (GJ); a tonne of oven-dry wood contains around 20 GJ of energy.

Labelling. System in which the energy efficiency of the product/ appliance is rated/listed on a label to inform customers of product energy performance so that they can select among various models. Labelling systems can be voluntary or mandatory.

Levelised cost of energy (LCOE). The unique cost price of energy outputs (e.g., USD/kWh or USD/GJ) of a project that makes the present value of the revenues equal to the present value of the costs over the lifetime of the project.

Long-term strategic plan. Strategy to achieve energy savings over a specified period of time (i.e., several years), including specific goals and actions to improve energy efficiency, typically spanning all major sectors.

Mandate/Obligation. A measure that requires designated parties (consumers, suppliers, generators) to meet a minimum, and often gradually increasing, target for renewable energy, such as a percentage of total supply, a stated amount of capacity, or the required use of a specified renewable technology. Costs generally are borne by consumers. Mandates can include renewable portfolio standards (RPS); building codes or obligations that require the installation of renewable heat or power technologies (often in combination with energy efficiency investments); renewable heat purchase requirements; and requirements for blending specified shares of biofuels (biodiesel or ethanol) into transport fuel.

Market concession model. A model in which a private company or NGO is selected through a competitive process and given the exclusive obligation to provide energy services to customers in its service territory, upon customer request. The concession approach allows concessionaires to select the most appropriate and cost-effective technology for a given situation.

Merit order. A way of ranking available sources of energy (particularly electricity generation) in ascending order based on short-run marginal costs of production, such that those with the lowest marginal costs are the first ones brought online to meet demand, and those with the highest are brought on last. The merit-order effect is a shift of market prices along the merit-order or supply curve due to market entry of power stations with lower variable costs (marginal costs). This displaces power stations with the highest production costs from the market (assuming demand is unchanged) and admits lower-priced electricity into the market.

Micro-grids. These are similar to mini-grids, but there is no universal definition differentiating the two (see Mini-grids). For distributed renewable energy in developing countries, micro-grids typically refer to independent grid networks operating on a scale of 1–10 kW. In the United States, for example, micro-grids also refer to larger networks (up to several MW) that can operate independently of, or in conjunction with, an area's main power grid. It can be intended as back-up power or to bolster main grid power during periods of heavy demand. It often is used to reduce costs, to enhance reliability and/or as a means of incorporating renewable energy.

Mini-grids. Grids that provide small-scale generation (10 kW to 10 MW) and distribution of grid-quality electricity to a relatively small and concentrated group of customers, most commonly in remote areas. They often are managed locally and can operate with or without interconnection to the wider external transmission grid.

Monitoring. Energy use is monitored to establish a basis for energy management and to provide information on deviations from established patterns.

Net metering / Net billing. A regulated arrangement in which utility customers with on-site electricity generators can receive credits for excess generation, which can be applied to offset consumption in other billing periods. Under net metering, customers typically receive credit at the level of the retail electricity price. Under net billing, customers typically receive credit for excess power at a rate that is lower than the retail electricity price. Different jurisdictions may apply these terms in different ways, however.

Ocean energy. Energy captured from ocean waves, tides, currents, salinity gradients and ocean temperature differences. Wave energy converters capture the energy of surface waves to generate electricity; tidal stream generators use kinetic energy of moving water to power turbines; and tidal barrages are essentially dams that cross tidal estuaries and capture energy as tides ebb and flow.

Off-take agreement. An agreement between a producer of energy and a buyer of energy to purchase/sell portions of the producer's future production. An off-take agreement normally is negotiated prior to the construction of a renewable energy project or installation of renewable energy equipment in order to secure a market for the future output (e.g., electricity, heat). Examples of this type of agreement include power purchase agreements (PPAs) and FITs.

Off-taker. The purchaser of the energy from a renewable energy project or installation (e.g., a utility company) following an off-take agreement. See Off-take agreement.

Power. The rate at which energy is converted into work, expressed in watts (joules/second).

Primary energy. The theoretically available energy content of a naturally occurring energy source (such as coal, oil, natural gas, uranium ore, geothermal and biomass energy, etc.) before it undergoes conversion to useful final energy delivered to the end-user. Conversion of primary energy into other forms of useful final energy (such as electricity and fuels) entails losses. Some primary energy is consumed at the end-user level as final energy without any prior conversion.

Primary energy consumption. The direct use of energy at the source, or supplying users with unprocessed fuel.

Product and sectoral standards. Rules specifying the minimum standards for certain products (e.g., appliances) or sectors (industry, transport, etc.) for increasing energy efficiency.

Production tax credit. A tax incentive that provides the investor or owner of a qualifying property or facility with a tax credit based on the amount of renewable energy (electricity, heat or biofuel) generated by that facility.

Prosumer. The idea that citizens are not just consumers but also have potential to be energy producers, particularly of renewable energy, playing an active role in the generation of energy, energy storage and demand-side management.

Public financing. A type of financial support mechanism whereby governments provide assistance, often in the form of grants or loans, to support the development or deployment of renewable energy technologies.

Pumped-storage hydropower. Plants that pump water from a lower reservoir to a higher storage basin using surplus electricity, and that reverse the flow to generate electricity when needed. They are not energy sources but means of energy storage and can have overall system efficiencies of around 80–90%.

Regulatory policy. A rule to guide or control the conduct of those to whom it applies. In the renewable energy context, examples include mandates or quotas such as renewable portfolio standards, FITs and technology/fuel specific obligations.

Renewable energy certificate (REC). A certificate awarded to certify the generation of one unit of renewable energy (typically 1 MWh of electricity but also less commonly of heat). In systems based on RECs, certificates can be accumulated to meet renewable energy obligations and also provide a tool for trading among consumers and/or producers. They also are a means of enabling purchases of voluntary green energy.

Renewable energy target. An official commitment, plan or goal set by a government (at the local, state, national or regional level) to achieve a certain amount of renewable energy by a future date. Targets may be backed by specific compliance mechanisms or policy support measures. Some targets are legislated while others are set by regulatory agencies, ministries or public officials.

Renewable portfolio standard (RPS). An obligation placed by a government on a utility company, group of companies or consumers to provide or use a predetermined minimum targeted renewable share of installed capacity, or of electricity or heat generated or sold. A penalty may or may not exist for non-compliance. These policies also are known as "renewable electricity standards", "renewable obligations" and "mandated market shares", depending on the jurisdiction.

Reverse auction. (See Tendering.)

Smart energy system. A smart energy system aims to optimise the overall efficiency and balance of a range of interconnected energy technologies and processes, both electrical and non-electrical (including heat, gas and fuels). This is achieved through dynamic demand- and supply-side management; enhanced monitoring of electrical, thermal and fuel-based system assets; control and optimisation of consumer equipment, appliances and services; better integration of distributed energy (on both the macro and micro scales); as well as cost minimisation for both suppliers and consumers.

Smart grid. Electrical grid that uses information and communications technology to co-ordinate the needs and capabilities of the generators, grid operators, end-users and electricity market stakeholders in a system, with the aim of operating all parts as efficiently as possible, minimising costs and environmental impacts and maximising system reliability, resilience and stability.

Solar collector. A device used for converting solar energy to thermal energy (heat), typically used for domestic water heating but also used for space heating, industrial process heat or to drive thermal cooling machines. Evacuated tube and flat-plate collectors that operate with water or a water/glycol mixture as the heat-transfer medium are the most common solar thermal collectors used worldwide. These are referred to as glazed water collectors because irradiation from the sun first hits a glazing (for thermal insulation) before the energy is converted to heat and transported away by the heat transfer medium. Unglazed water collectors, often referred to as swimming pool absorbers, are simple collectors made of plastics and used for lower-temperature applications. Unglazed and glazed air collectors use air rather than water as the heat-transfer medium to heat indoor spaces or to pre-heat drying air or combustion air for agriculture and industry purposes.

Solar home system (SHS). A stand-alone system composed of a relatively small-power photovoltaic module, a battery and sometimes a charge controller, that can power small electric devices and provide modest amounts of electricity to homes for lighting and radios, usually in rural or remote regions that are not connected to the electricity grid.

Solar photovoltaics (PV). A technology used for converting light into electricity. Solar PV cells are constructed from semi-conducting materials that use sunlight to separate electrons from atoms to create an electric current. Modules are formed by interconnecting individual cells. Monocrystalline modules typically are slightly more efficient but relatively more expensive than multicrystalline silicon modules, although these differences have narrowed with advances in manufacturing and technology. Thin film solar PV materials can be applied as flexible films laid over existing surfaces or integrated with building components such as roof tiles. Building-integrated PV (BIPV) generates electricity and replaces conventional materials in parts of a building envelope, such as the roof or façade.

Solar photovoltaic-thermal (PV-T). A solar PV-thermal hybrid system that includes solar thermal collectors mounted beneath PV modules to convert solar radiation into electrical and thermal energy. The solar thermal collector removes waste heat from the PV module, enabling it to operate more efficiently.

Solar pico system (SPS). A very small solar PV system – such as a solar lamp or an information and communication technology (ICT) appliance – with a power output of 1–10 W that typically has a voltage up to 12 volts.

Solar water heater (SWH). An entire system consisting of a solar collector, storage tank, water pipes and other components. There are two types of solar water heaters: pumped solar water heaters use mechanical pumps to circulate a heat transfer fluid through the collector loop (active systems), whereas thermosyphon solar water heaters make use of buoyancy forces caused by natural convection (passive systems).

Subsidies. Government measures that artificially reduce the price that consumers pay for energy or reduce production costs.

Tendering (also called auction/reverse auction or tender). A procurement mechanism by which renewable energy supply or capacity is competitively solicited from sellers, who offer bids at the lowest price that they would be willing to accept. Bids may be evaluated on both price and non-price factors.

Torrefied wood. Solid fuel, often in the form of pellets, produced by heating wood to 200–300°C in restricted air conditions. It has useful characteristics for a solid fuel including relatively high energy density, good grindability into pulverised fuel and water repellency.

Vehicle fuel standards. Rules specifying the minimum fuel economy of automobiles to reduce energy consumption.

Watt. A unit of power that measures the rate of energy conversion or transfer. A kilowatt is equal to one thousand (10^3) Watts; a megawatt to one million (10^6) Watts; and so on. A megawatt-electrical (MW_e) is used to refer to electric power, whereas a megawatt-thermal (MW_{th}) refers to thermal/heat energy produced. Power is the rate at which energy is consumed or generated. A kilowatt-hour is the amount of energy equivalent to steady power of 1 kW operating for one hour.

Yield company (yieldco). Renewable energy yieldcos are publicly traded financial vehicles created when power companies spin off their renewable power assets into separate, high-yielding entities. They are formed to reduce risk and volatility, and to increase capital and dividends. Shares are backed by completed renewable energy projects with long-term PPAs in place to deliver dividends to investors. They attract new types of investors who prefer low-risk and dividend-like yields, and those who wish to invest specifically in renewable energy projects. The capital raised is used to pay off debt or to finance new projects at lower rates than those available through tax equity finance.

LIST OF ABBREVIATIONS

AC	Alternating current
AREI	Africa Renewable Energy Initiative
BIPV	Building-integrated solar photovoltaics
BNEF	Bloomberg New Energy Finance
BRICS	Brazil, Russian Federation, India, China and South Africa
BRT	Bus Rapid Transit
CDM	Clean Development Mechanism
CHP	Combined heat and power
CO_2	Carbon dioxide
COP21	Conference of the Parties, 21st meeting
CPV	Concentrating solar photovoltaic
CSP	Concentrating solar (thermal) power
DC	Direct current
DNI	Direct normal insolation
DRE	Distributed renewable energy
DSM	Demand-side management
EC	European Commission
ECOWAS	Economic Community of West African States
EEG	German Renewable Energy Law – "Erneuerbare-Energien-Gesetz"
EJ	Exajoule
EMEC	European Marine Energy Centre
EnDev	Energising Development
EPC	Engineering, procurement and construction
ESCO	Energy service company
EU	European Union (specifically the EU-28)
EV	Electric vehicle
FIT	Feed-in tariff
GACC	Global Alliance for Clean Cookstoves
GDP	Gross domestic product
GEF	Global Environment Facility
GFR	Global Futures Report
GSR	Renewables Global Status Report
GW/GW_{th}	Gigawatt/Gigawatt-thermal
GWh	Gigawatt-hour
HVAC	Heating, ventilation and air conditioning
HVO	Hydrotreated vegetable oil
IEA	International Energy Agency
IEA SHC	Solar Heating and Cooling Programme of the International Energy Agency
IFC	International Finance Corporation
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producer
IPS	Industrial and provident society
IRENA	International Renewable Energy Agency
ITC	Investment tax credit
kW/kWh	Kilowatt/kilowatt-hour
LCOE	Levelised cost of electricity
LED	Light-emitting diode
LLC	Limited liability company
m^2	Square metre
m^3	Cubic metre
M&A	Mergers and acquisitions
MENA	Middle East and North Africa
MEPS	Minimum Energy Performance Standards
MSW	Municipal solid waste
MW/MWh	Megawatt/megawatt-hour
NGO	Non-governmental organisation
nZEB	Nearly zero energy building
NZEB	Net zero energy building
OECD	Organisation for Economic Co-operation and Development
O&M	Operations and maintenance
OMC	Omnigrid Micropower Company
OPIC	US Overseas Private Investment Corporation
PAYG	Pay As You Go
PE	Private equity
PJ	Petajoule
PPA	Power purchase agreement
PPP	Public-private partnership
PTC	Production tax credit
PV	Photovoltaic
R&D	Research and development
RPS	Renewable portfolio standard(s)
SE4All	United Nations Sustainable Energy for All initiative
SHS	Solar home system(s)
SIDS	Small-island developing states
SME	Small and medium-sized enterprise
STE	Solar thermal electricity
SWH	Solar water heater/heating
T&D	Transmission and distribution
TES	Thermal energy storage
TFEC	Total final energy consumption
toe	Tonne of oil equivalent
TW/TWh	Terawatt/Terawatt-hour
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USAID	US Agency for International Development
USD	United States dollar
VAT	Value-added tax
Wh	Watt-hour
WTO	World Trade Organization
yieldcos	yield companies

ENERGY UNITS AND CONVERSION FACTORS

METRIC PREFIXES

kilo (k) = 10^3
mega (M) = 10^6
giga (G) = 10^9
tera (T) = 10^{12}
peta (P) = 10^{15}
exa (E) = 10^{18}

VOLUME

1 m^3 = 1,000 litres (l)
1 US gallon = 3.78 l
1 Imperial gallon = 4.55 l

Example: 1 TJ = 1,000 GJ = 1,000,000 MJ = 1,000,000,000 kJ = 1,000,000,000,000 J = 1012 J
1 J = 0.001 MJ = 0.000001 GJ = 0.000000001 TJ

ENERGY UNIT CONVERSION

Multiply by:	GJ	Toe	MBtu	MWh
GJ	1	0.024	0.948	0.278
Toe	41.868	1	39.683	11.630
MBtu	1.055	0.025	1	0.293
MWh	3.600	0.086	3.412	1

Toe = tonnes oil equivalent
1 Mtoe = 41.9 PJ

Example: 1 MWh x 3.600 = 3.6 GJ

HEAT OF COMBUSTION (HIGH HEAT VALUES)

1 l ethanol = 84,530 Btu / US gallon = 21.2 MJ / l
1 l biodiesel = 127,960 Btu / US gallon = 32.1 MJ / l

Example: 1) These values can vary with fuel and temperature.
2) Around 1.5 litres of ethanol is required to equate to 1 litre of gasoline.
3) Heat values from U.S. Department of Energy Alternative Fuels Data Center.

SOLAR THERMAL HEAT SYSTEMS

1 million m^2 = 0.7 GW_{th}
Used where solar thermal heat data have been converted from square metres (m^2) into gigawatts thermal (GW_{th}), by accepted convention.

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