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IRENA
International Renewable Energy Agency

REMAP 2030
RENEWABLE ENERGY PROSPECTS FOR UKRAINE

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BACKGROUND PAPER

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international cooperation, a centre of excellence and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

REmap material is available for download through **www.irena.org/remap**

For further information or to provide feedback, please contact the REmap team at **remap@irena.org**

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KEY FINDINGS

- Ukraine has made important progress in recent years in planning the future of its energy system and developing a renewable-energy policy. By the year 2030, the increased use of renewable energy will reduce Ukraine's overall energy system costs.
- If current policies (known as the Reference Case in this study), which are described in the recently approved National Renewable Energy Action Plan (NREAP) are maintained, the share of renewable energy in the total final energy consumption (TFEC) will increase from 3% in 2009 (the plan's base year) to 13.2% by 2030. That total could be boosted to 21.8% using options identified in this study.
- Increasing the renewable-energy share from 13.2% under the Reference Case to 21.8% in REmap 2030 would result in savings of USD 175 million per year in 2030, and when accounting for benefits resulting from reduced health effects and CO_2 emissions savings would increase to USD 1.3 billion per year based on conservative estimates, and yield USD 5.5 billion in savings in 2030 based on more aggressive estimates.
- Ukraine has the potential to increase renewable energy use by ten-fold from 87 petajoules (PJ) in 2009, to 870 PJ of total final renewable energy in REmap 2030.
- 73% of renewable energy potential in 2030 is accounted for by heat, 20% for electricity generation and 7% for transport.
- Nearly 80% of total final renewable energy potential is accounted for by biomass technologies, including for heating buildings and industrial plants (including district heating), power generation and as transport fuels.
- Through its REmap analysis IRENA has identified an additional potential of 26.9 terawatt hours (TWh) of wind energy, 6.2 TWh of biomass and 5.8 TWh of solar photovoltaic (PV) that would boost the share of renewables in the electricity sector from 11.3% under the Reference Case to 25% in REmap 2030, a four-fold increase of the share over 2009 levels.
- If IRENA's REmap Options are used, there would be a significant increase in biomass use by 2030 for various transport and heating applications (industry, buildings, and district heat) compared with expectations under current policies. The total demand for primary biomass would increase to 820 PJ per year.
- REmap Options that are cost-competitive would boost the share of renewables from 11.8% under current policy to 19.0% by 2030. To attain 21.8%, it would require renewables options with incrementally higher costs. However, these options also offer non-monetary benefits, such as improving Ukraine's energy security by reducing its dependence on imported natural gas, and reducing its carbon dioxide (CO_2) emissions.Increasing the renewable energy share to 21.8% would require total investment flows for renewables of USD 5.0 billion per year up to 2030, a doubling from current policy plans.
- The REmap Options would allow Ukraine to cut natural gas demand by 15% by 2030 compared to the Reference Case – a stabilization of demand at current levels. As this report shows there is room to optimize renewable deployment for combating climate change and supply security.
- While renewables play a critical role in realising Ukraine's strategic energy goals, potentials for improving energy efficiency needs to be considered as well, in particular given the objective to reduce natural gas consumption.
- There are barriers to realising the higher renewable energy shares identified in this report. High capital costs create uncertainty for investing in renewable energy. This coupled with a changing renewable energy policy landscape, also reinforces this lack of confidence for investors. Therefore predictable and stable policies should be maintained over long periods to allow for the continuity of investments into renewable energy technologies.

1. INTRODUCTION

Ukraine has a significant renewable energy potential that can be deployed to enhance the trade balance, create jobs and drive economic activity during a time when the country is facing important economic challenges such as the increased dependence in energy imports and an urgent need to rejuvenate the ageing energy capital stock. Deployment of which would importantly also help towards existing policy goals of reducing the dependency on imported natural gas and help towards diversifying the energy supply. An energy supply that is also more secure.

The International Renewable Energy Agency (IRENA)'s REmap programme is a series of renewable-energy roadmaps for individual countries that shows how they boost their use of renewables and in doing so help to double the share of these technologies in the global energy mix by 2030. The findings suggest that all countries, including Ukraine, have the potential to raise their renewable energy share while reaping significant socio-economic and environmental benefits (IRENA, 2014a).

REmap 2030 is the result of a collaborative process between IRENA and country experts. This short report provides detailed background data and results of REmap's Ukraine country analysis, and suggests how renewables potential could be maximised. This working paper uses the Ukrainian government's National Renewable Energy Action Plan (NREAP) as a baseline of renewables to 2020 and 2030, and extrapolates projected gross final energy consumption (GFEC) of 2020 to 2030[1]. The paper then moves on to discuss the realistic potential of renewables in 2030 (so-called REmap Options) beyond this baseline. REmap Options are based on the trends seen in the data provided by Ukraine's government, along with literature review. Costs and benefits of renewables for the Ukrainian energy system are considered in the context of Ukraine's various policy goals.

Addressing Ukraine's energy challenge will require comprehensive actions, in particular to ensure environmentally-sustainable practices. The most likely renewable-energy sources for the country are wind, solar, geothermal energy, biomass and small hydro power (SHP). The right mix of these options can help to reduce a large share of Ukraine's total natural gas demand for power generation. For heating, biogas can be used as well.

This report starts with a brief description of the REmap 2030 methodology (Section 2) and then explains the present energy situation and recent trends for renewable energy use (Section 3). Section 4 provides the findings of Ukraine's Reference Case. Section 5 discusses the current policy framework, and Section 6 the renewables potential. In Section 7 the potential of REmap Options are quantified. The report ends with a discussion of the barriers to scaling up renewable energy in Ukraine and suggestions to overcome them (Section 8). This paper is meant to stimulate discussion in Ukraine on increasing the use of renewable options in its energy mix. These findings are expected to change over time as new developments and fresh data become available.

1 Instead of GFEC, the rest of this paper uses total final energy consumption (TFEC) as the main indicator. TFEC includes the consumption of industry (including blast furnaces and coke ovens, but excluding petroleum refineries and non-energy use), buildings (residential and commercial) and transport sectors.

2. METHODOLOGY

This section explains the REmap 2030 methodology and summarises details about the background data used for the Ukraine analysis. Annexes A and B provide background data in greater detail.

REmap is an analytical approach for assessing the gap between current national renewable energy plans, additional renewable technology options potentially available in 2030 and the SE4All objective of doubling the share of global renewable energy share by 2030.

As of June 2014, REmap 2030 had assessed 26 countries: Australia, Brazil, Canada, China, Denmark, Ecuador, France, Germany, India, Indonesia, Italy, Japan, Malaysia, Mexico, Morocco, Nigeria, Russia, Saudi Arabia, South Africa, South Korea, Tonga, Turkey, **Ukraine**, the United Arab Emirates, the United Kingdom and the United States.

The analysis starts with national-level data covering both end users of energy (buildings, industry and transport) and the electricity and district-heat sectors. Current national plans using 2010 as the base year of this analysis are the starting point. To the extent data availability allows, information for more recent years (*e.g.*, 2012, 2013) were provided where relevant. In each report, a Reference Case features policies in place or under consideration, including energy-efficiency improvements. Reference Case includes TFEC for each end-use sector and the total generation of power and district-heat sectors, with breakdowns by energy carrier for the period from 2010 to 2030. The energy balances for the base year of the analysis, 2009, are based on the data provided by the International Energy Agency (IEA, 2014a). Where relevant, the data are updated with the national energy statistics provided by the SSSU, the State Statistics Service of Ukraine (http://www.ukrstat.gov.ua/)[2]. The Reference Case for Ukraine was based on the NREAP and other data provided by the Ukrainian government. That NREAP was adopted by the Cabinet of Ministers on 1 October 2014 (CoM, 2014), and it includes Ukraine's gross final energy consumption developments to 2020. For 2030, renewable energy use in the Reference Case is based on other data provided by the Ukrainian government. Gross final energy consumption in 2030 is extrapolation of trends between 2009 and 2020 according to the NREAP.

Once the Reference Case was prepared additional technology options were identified, labelled in the report as REmap Options. The choice of options instead of a scenarios-based approach is deliberate: REmap 2030 is an exploratory study and not a target-setting exercise. While the Reference Case is based on the NREAP, the REmap Options for Ukraine came from a variety of sources. These include literature review and the longer-term trends to 2035, according to the data provided by Ukraine's government. IRENA developed a REmap tool that allows staff and external experts to input data in an energy balance for 2010, 2020 and 2030, and then assess technology options that could be deployed by 2030 in an accelerated deployment of renewable energy. In addition to what is being provided in the annexes of this report a detailed list of these technologies and the related background data are provided online. The tool includes the cost (capital, operation and maintenance) and technical performance (reference capacity of installation, capacity factor and conversion efficiency) of renewable and conventional (fossil fuel, nuclear and traditional use of biomass) technologies for each sector analysed: industry, buildings, transport, power, and district heat.

Each renewable energy technology is characterised by its costs, and the cost of each REmap option is represented by its substitution cost. Substitution costs are the difference between the annualised cost of the REmap Option and a conventional technology used to produce the same amount of energy, divided by the total renewable energy use in final energy terms (in 2010 real US Dollar (USD) per gigajoule (GJ)[3] of final re-

2 The comparison of IEA Energy Balances (IEA, 2014a) with the Energy Balance of Ukraine according to the SSSU for the year 2010 yields less than 5% difference in the total energy supply/consumption. The only exception is the transport sector where total demand according to the IEA is 8% higher than the data reported by the SSSU. This is explained by the difference in road transportation items of 13%. With the exception of the transport sector, where data is based on SSSU, the analysis uses IEA data for other sectors.

3 1 gigajoule (GJ) = 0.0238 tonnes of oil equivalent (toe) = 0.238 gigacalories (Gcal) = 278 kilowatt-hour (kWh). 1 USD was on average equivalent to 7.9 Ukranian Hryvinia in 2010.

newable energy). This indicator provides a comparable metric for all renewable energy technologies identified in each sector. Substitution costs are the key indicators for assessing the economic viability of REmap Options. They depend on the type of conventional technology substituted, energy prices and the characteristics of the REmap option. The cost can be positive (incremental) or negative (savings), as many renewable-energy technologies are already or could be cost effective compared to conventional technologies by 2030 as a result of technological learning and economies of scale.

Based on the substitution cost and the potential of each REmap Option, country cost-supply curves were developed from two perspectives for the year 2030: government and business. For the government perspective, costs estimates are as government would have done them, excluding energy taxes and subsidies. The choice of analysis from a government perspective is to ensure a comparison of the cost and benefits across all REmap countries. For the business perspective, the process was repeated to include national prices, including energy taxes and subsidies. This approach shows the cost of the transition as businesses and investors would calculate it. For both government and business perspectives a 10% cost of capital was assumed. By estimating the costs from two perspectives, the analysis shows the effect of accounting for energy taxes and subsidies whereas all other parameters were kept same. Assessment of all additional costs related to complementary infrastructure, such as transmission lines, reserve power needs, energy storage or fuel stations, are excluded from this study.

Throughout this study the renewable-energy share is estimated related to TFEC. Based on TFEC the renewable energy share can be estimated for the total of all end-use sectors of Ukraine or for each of them (industry, transport, residential and commercial, and agriculture sectors), with and without the contribution of renewable electricity and district heat. The share of renewable power and district heat generation is also calculated.

Estimating the renewable energy share based on TFEC is different than estimating it based on gross final energy consumption (GFEC), which is the metric applied in Ukraine's NREAP as defined by the European Community (2009). There are two major differences in estimating the renewable energy share based on TFEC and GFEC: 1) according to GFEC, total renewable energy use includes the quantities of renewable power and district heat consumed by the power and heat generation plants as well as the losses in their distribution, whereas TFEC looks at consumption only, and 2) renewable electricity consumed in the transport sector is added as renewable energy use on top of renewable power generation in GFEC whereas in TFEC it is already accounted for under the total renewable power consumption.

This report also discusses the finance needs and avoided externalities related to increased renewable energy deployment. Three finance indicators are developed, namely net incremental system costs, net incremental investment needs and subsidy needs. These indicators are briefly defined as:

1) Net incremental system costs: This is the sum of the differences between the total capital (in USD/yr) and operating expenditures (in USD/yr) of all energy technologies based on their deployment in REmap 2030 and the Reference Case in the period 2010-2030 for each year.
2) Net incremental investment needs: This is the difference between the annual investment needs of all REmap Options and the investment needs of the substituted conventional technologies which would otherwise be invested in. Investment needs for renewable energy capacity are estimated for each technology by multiplying its total deployment (in gigawatt (GW)) to deliver the same energy service as conventional capacity and the investment costs (in USD per kilowatt (kW)) for the period 2010-2030. This total is then annualised by dividing the number of years covered in the analysis.
3) Subsidy needs: Total subsidy requirements for renewables are estimated as the difference in the delivered energy service costs for the REmap Option (in USD/GJ final energy) relative to its conventional counterpart multiplied by its deployment in a given year (in petajoules (PJ) per year).

External effects related to greenhouse gas (GHG) emission reductions as well as improvements in outdoor and indoor air pollution from the decreased use of fossil fuels have been estimated.

As a first step, for each sector and energy carrier, GHG emissions from fossil fuel combustion are estimated. For this purpose, the energy content of each type of fossil fuel was multiplied by its default emission factors (based on lower heating values, LHV) as provided by the Intergovernmental Panel on Climate Change (Eggleston *et al*., 2006). Emissions were estimated separately for the Reference Case and REmap 2030. The difference between the two estimates yields the total net GHG emission reduction from fossil fuel combustion due to increased renewable energy use. To evaluate the related external costs related to carbon emissions, a carbon price range of USD 20-80 per tonne CO_2 is assumed (IPCC, 2007). This range was applied only to CO_2 emissions, but not other greenhouse gases. According to the IPCC (2007), carbon price should reflect the social cost of mitigating one tonne of CO_2 equivalent GHG emissions.

The external costs related to human health are estimated in a separate step, which excludes any effect related to GHG emissions. Outdoor air pollution is evaluated from the following sources: 1) outdoor emission of sulphur dioxide (SO_2), mono-nitrogen oxides (NO_x) and particulate matter of less than 2.5 micrometres ($PM_{2.5}$) from fossil fuel-based power plant operation, and 2) outdoor emissions of NO_x, and $PM_{2.5}$ from road vehicles. To evaluate the external costs related to outdoor emission of SO_2, NO_x and $PM_{2.5}$ from fossil power plant operation, the following parameters for respective pollutants were used: (a) emission factor (i.e., tonne per kWh for 2010 and 2030 taken from the IIASA GAINS database (ECRIPSE scenario (IIASA, 2014), and (b) unit external costs (i.e., Euro-per-tonne average for the European Union (EU), adapted for the US from the EU CAFE project (AEA, 2005). Potential differences in external effects between the EU and Ukraine values are accounted for based on the difference in gross domestic product (GDP) values.

Further details of the REmap 2030 methodology can be found online in IRENA's REmap webpage at: www.irena.org/remap

3. PRESENT ENERGY SITUATION AND RECENT DEVELOPMENTS IN THE RENEWABLE ENERGY SECTOR

Ukraine's TFEC reached 3 exajoules (EJ) in 2009[4]. Industry accounted for the largest share of Ukraine's TFEC, at 29% in 2009 (SSSU). Buildings, transport, district heating and electricity were the other sectors with a share of at least 15% (Figure 1). Natural gas accounted for 1.7 EJ, or 36% of Ukraine's total energy supply. Coal and oil products accounted for 31% and 12% of the total in 2009, respectively. Nuclear accounted for 19%. The remaining 2% was related to the use of renewables.

Ukraine has limited fossil-fuel energy reserves. Domestic production of oil, gas and coal is too small to meet demand, so the country is reliant on imports of each. Imported gas accounted for 65% to 70% of its total consumption in 2010 and is the chief contributor to the country's energy-security problem. Additionally, the growing coal deficit is impacting the power generation sector. Although importing fossil fuel energy can help close the deficit, there are financial implications. Also, the existing seaport capacity covers only forty percent of the total coal volume that would need to be imported (EDM, 2014).

The energy intensity of Ukraine's domestic economy is three to four times higher than that of more-developed countries. Until 2006 Ukraine imported natural gas at prices well below international levels, however, since then the price from Ukraine's main supplier, Russia, has increased sharply. The price per 1,000 cubic meters (m^3)[5] rose from USD 95 in 2006 (USD 2.9 per GJ) to USD 229 (USD 7.1 per GJ) in 2009, and surpassed USD 400 (USD 12.4 per GJ) toward the end of 2012 (IEA, 2012b). According to the gas deal between Ukraine and Russia in October 2014, the price of natural gas in the last quarter of 2014 and first quarter of 2015 was USD 378 and USD 365, respectively. This deal is effective until April 2015. After April 2015, the price of natural gas for households will increase three folds reaching the level industry sectors pay (UAH 7,188 or USD 310 per 1,000 m^3). The price of natural gas for district heat companies will grow by 29% to UAH 2994 or USD 130 per 1,000 m^3. The district heating tariffs will increase by 67% and electricity tariffs by 19% and as a result of the tariff increases, it is expected that up to 13 million households will be eligible for targeted social assistance related to municipal services (compared to 1.1 million in 2014)[6]. According to the new International Monetary Fund (IMF) schedule, if Ukraine undertakes the scenarios on phasing out of subsidies, new household tariffs would be equal to the true cost of natural gas import price by 2017, compared to a 56% share in 2014. The natural gas price stabilizes at around USD 345 per 1,000 m^3 by 2015 and stabilizes at this level to 2030 (G7, 2015).

Imported natural gas volume has decreased in recent years as a result: in October 2014, the volume of natural gas stored in Ukraine was 16 billion m^3, some 5 billion m^3 below peak winter demand (Financial Times, 2014). Gas demand is seasonal with a clear winter peak for heating. Overall, these imports results in huge costs for Ukraine because gas is procured during the low demand season (and injected to storages between April and October) to be used in the high demand season. Storage is key for the supply security of gas and currently, Ukraine has a total gas storage capacity of 32 billion cubic meters with five storage facilities in the western part of the country accounting for more than 80% of the total working volume. There are seven other storages in the eastern part of Ukraine (Chyong, 2014).

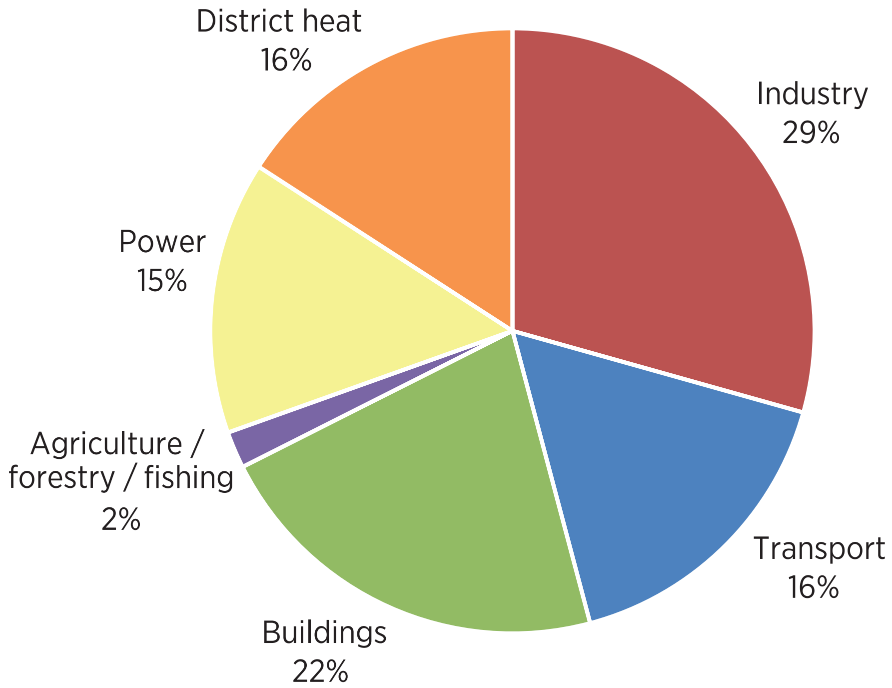
In 2010, total natural gas supply was 2.3 EJ, higher than the figure for coal, at 1.6 EJ. Gas comprised a higher share of Ukraine's total primary energy supply (42%),

4 1 EJ = 1,000 PJ = 10^{18} J. 1 megatonne of oil equivalent (mtoe) = 1,000 kilotonne of oil equivalent (ktoe) = 41.87 PJ. TFEC includes total combustible and non-combustible energy use from all energy carriers as fuel (for the transport sector) and to generate heat (for industry and building sectors) as well as electricity and direct heat. It excludes non-energy use.

5 1 m^3 of natural gas in Ukraine has a gross calorific value between 34 505 MJ and 36 401 MJ. A ratio of 1.1:1 is assumed between gross and net calorific value of natural gas (ECRB, 2014).

6 Households are eligible for targeted social assistance, if more than 15% of the income of a household is paid for municipal services.

Figure 1: Breakdown of Ukraine's total final energy consumption by sector, 2009



Source: Based on SSSU

with about 28% of it used in the power and district-heat sectors. That includes combined heat and power (CHP) plants. Another 26% was used in heating systems for individual buildings. Industry, agriculture and the fisheries sector used 12% of the total in steam boilers or direct heaters. The transport sector accounted for another 6%. The remainder is used in the energy sector (*e.g.*, oil and gas extraction) and stock changes (IEA, 2014a). Total natural gas consumption in Ukraine is decreasing. In the period between 2005 and 2014, total demand for households has decreased by 12% whereas the demand for industry has decreased even further by 49% (G7, 2015). The decline for industry is related to the higher gas pricing, while for households, consumption has been subsidized.

The rest of this section focuses in greater detail on the current situation for power, district heat and the use of renewables in end-use sectors in Ukraine.

Power sector

In 2009, a total of 189 terawatt-hours (TWh) of power was generated in Ukraine. Of this total 90% came from power plants and the remainder 10% from CHPs. About half of the total was nuclear power generation. Generation of renewables was approximately 12 TWh, or 6.8% of the total. Almost all came from hydro facilities (IEA, 2014a; SAEE, 2015). Policy support since 2009 has succeeded in increasing the rate of adoption for renewables technologies.

Ukraine has more than thirty power plants (including large hydro, but excluding renewables) and of which fourteen are thermal and another four are nuclear plants. There are also three large scale cogeneration plants (Korniush, 2012). Table 1 provides an overview of the existing power plants based on different sources for the period between 2011 and 2014. Ukraine had approximately 54 gigawatts (GW) of power generation capacity in 2013. Coal accounted for 40%, and nuclear plants 25% whilst approximately 10% of the total installed capacity was large hydro. Most hydro power plants are situated along Ukraine's major river – Dnipro. Most coal power plants are in the south eastern parts of Ukraine and several others are in the centre and east.

Peak demand on the main grid in 2013 was 22.1 GW and the average baseload in 2013 was 28.4 GW (Hydropow-

Table 1: Operating and planned power plants

	Operation (end of 2011) (MW)	Operation (end of 2012) (MW)	Operation (July 2013) (MW)	Operation (end of 2013) (MW)	Operation (end of 2014) (MW)
Thermal	30 458				
Coal	20 046		22 000		
Gas	6 022		5 400		
Oil	4 390				
CHP			6 500		
Nuclear	13 880		13 800		
Hydro	5 468	73.5 (small hydro)	74 (small hydro)	75.3 (small hydro)	80.3 (small hydro)
Wind	151	277	291	371	497
Solar	265	371.6	569.5	748.4	818.9
Biomass (incl. biogas)	0	6.2	7.3	23.7	49.1
Mine gas	67				
Total	50 306		54 081		

Source: CoM (2014); Platts (2013); IMEPOWER (2013); SAEE (2015)

Note: renewable energy capacities provided for end of 2012, 2013 and 2014 refer to facilities that operate under the green tariff.

er & Dams, 2014). The transmission network consists of 22,900 km of high voltage lines and 135 substations (between 220 and 750 kilovolts). 33 interstate lines connect Ukraine to its seven neighbour countries, and fourteen of these lines are with Russia (Korniush, 2012).

The share of renewables was still relatively low and was dominated by hydro with nearly 5.5 GW in 2011. A majority of hydro power plants are large-scale facilities, with ten at a capacity larger than 10 MW. Eight are on the Dnipro River and have a total capacity of 3.9 GW, and another is on the Dniester River and has 700 MW of capacity. No new plants are under construction (excluding pumped hydro), however the state body Ukrhydroenergo is rehabilitating ten facilities that together can offer 4.6 GW of capacity. These plants are approximately 50 years old (Liu, Masera and Esser, 2013; Hydropower & Dams, 2014). In 2010, only 49 of 150 small and micro hydro plants were in operation (OECD, 2012). According to Liu, Masera and Esser (2013), in 2011 64 small and hydro power plants were in operation. There are another 100 that can be restored. The use of other renewables for power generation is still small.

Ukraine's power system is at risk today because of outdated facilities, inefficient plants and ageing transmission lines. Of the hydro and thermal plants, 95% are too old for use. Most coal plants were built around 1970, which means they will need substantial upgrades or must be replaced before 2030. Nuclear capacity is newer, built after 1980, and is expected to be operational in 2030 (Platts, 2013). These aging plants offer an important opportunity because as these systems are renovated or replaced, investment can be directed to renewables as an alternative. The average annual capacity factor for thermal plants is about 27% and nuclear about 69%. Many of the small-scale hydro plants are also aging, with an average annual capacity factor of about 29%.

By the end of 2012, total renewable-electricity generation capacity in Ukraine had reached 728.3 megawatt (MW). Of this total, wind provided 277 MW, solar photovoltaic (PV) 371.6 MW, small-scale hydro 73.5 MW, and biomass and biogas facilities– 6.2 MW. This capacity generates 780 gigawatt-hour (GWh) per year of electricity, representing 5.8% of the total power generation. Renewable energy capacity is growing in particular for solar technologies because of legislation supporting the industry. Solar capacity surged from 26 MW in December 2011 to 818 MW three years later (Romanko, 2014; SAEE, 2015).

By the end of the first half of 2014 total renewable energy power generation capacity operating under the GT reached 1,419 MW. This included 497 MW of wind, 819 MW of solar PV, 77 MW from SHP and 26 MW of biomass and biogas. There are 18 wind plants in Ukraine, and about 371 MW of the total installed wind capacity is grid-connected (UWEA, 2013). The Crimea peninsula represents about 20% and 40% respectively of total installed wind and solar PV capacities. However by the end of 2014 total installed capacity under GT reached 2,007 MW, an increase of 484 MW, or 32%. Renewable technologies accounted 6.2% of electricity generation in 2014.

District-heat sector

The heating sector in Ukraine can be divided into two main components: the district-heat sector, owned and operated by municipal heating companies; and heating systems to serve industry, such as boilers or direct firing units. Today there are 79,908 boilers for heat generation in Ukraine. The district heat sector is composed of about 7,000 heat-only boilers and another 250 CHPs (Radeke and Kosse, 2013). Today, Ukraine's district heat sector is inefficient for multiple reasons, and addressing them will be important for Ukraine's energy-security goals as well as for the promotion of renewables.

In 2010, heat production from the district heat sector reached 640 PJ, with about one third of the total from CHP plants. Residential and commercial buildings consume 60% of the total district-heat generated, with the remainder going to industry. District heat accounts for nearly a quarter of TFEC in the buildings and industry sectors. About 39% of total households in Ukraine were connected to district heating, which is slightly lower than the 43% in 2011 (7.5 million out of the 17.5 million households) (IEA, 2012b; Radeke and Kosse, 2013). This share is among the highest in the world. All of Kiev's three million residents rely on district heating. In comparison, 41% of the total number of households had individual gas-fired heating units, and 21% had other forms of heating based on either electricity or solid fuels such as coal or wood.

District-heating demand has fallen since the 1990s however, as a result of a decreasing population and increased efficiency, but with urbanisation and higher demand in non-residential sectors, it is expected to grow again (IEA, 2012b). District heating accounts for about one-fifth of Ukraine's total natural gas consumption, and about 80% of the district-heat generation relies on natural gas. In 2010, this meant 18 billion m^3 of natural gas (620 PJ). About half of all citizens live in multi-apartment housing (240,000 buildings with a total area of 464 million m^2) and 80% of that uses gas and district heating. Multi-apartment housing has a large energy efficiency improvement potential.

Biomass accounted for 3.6% of total district-heat generation, with small quantities of aero-thermal, geothermal and hydro-thermal heat pumps in use as well. Only a few of Ukraine's provincial capitals ("oblast" in Ukrainian) have biomass boilers, but new ones are expected to be built starting in 2015.

The role of other renewables is growing for district heat. Between 2008 and 2012, the municipal utility of Mariupolteploset set up three solar thermal district-heat plants in Donetsk. Other municipalities have also announced projects under consideration (GSTEC, 2014).

Low efficiency is the major challenge to Ukraine's district-heat sector. Nearly 60% of the heat produced is lost in production and distribution (Radeke and Kosse, 2013), and both heat-distribution pipelines and generation systems need replacing. One of the reasons for this is that regulated tariffs aren't enough to cover the costs of distribution and capital expenditure on top of that. Total heating cost for generators is about UAH 325 per gigacalorie (Gcal), or USD 7.3, and the tariff is 80% of that cost, at UAH 260. Another problem is that most equipment used is older than its technical life expectancy, sometimes by a factor of two (Radeke and Kosse, 2013). Precise billing is also a challenge because historically individual gas consumption has not been measured by meters. Only six percent of all households have meters, and fewer than 20% of buildings have functioning metering today. Today more meters are being installed and the amount of free gas per consumer is being reduced.

Efficiency improvements to the district-heat sector stand out as one of the most important potential contributions to Ukraine's energy-intensity reduction goal of 50% by 2030. Improvements could include rehabilitation of the boiler houses, replacing network pipes, installation of heat substations and installing heat meters (IEA, 2012b; The World Bank, 2014). Higher heat tariffs can secure necessary investment in energy efficiency, and for the Ukrainian government a possible solution would be to allow tariff increases only if the extra revenue is used for investing in energy efficiency. Tariffs need to be affordable for consumers but increases can gain mass acceptance if they come with assurances of efficiency gains in the future.

The alternative to reforming the district-heat sector is to restructure the overall system in order to promote individual heating systems in buildings or industrial facilities currently connected to the grid.

Solid biomass use for heating

Renewable energy use by consumers (industry, transport, and residential and commercial buildings) is thus far limited. Biomass is the main source of renewable energy in end-use sectors, and Ukraine has focused on it as a domestic resource worth exploiting.

National sources indicate that Ukraine has 750-1,465 PJ (18-35 Mtoe/yr) of primary biomass economic potential that can substitute 21.6-26 billion m^3 of natural gas (Bioenergy, 2014; SAEE, n.d.). There is also additional potential of about 100 PJ annually from biogas (SAEE, n.d). These potential estimates are updated annually, and depend on agricultural yields, cropping patterns, weather and climate conditions etc. Each year, Ukraine produces about 120 million tonnes of biomass feedstock. This includes crop production, waste, animal, wood and food processing residues. 54% of the total production is further processed, 45% is wasted and 1% is used for power and heat generation (ProMarketing Ukraine, 2013).

In 2010, a total of 93 PJ of biomass was used in Ukraine, 48 PJ of which was by end-use sectors (48 PJ per year) (IEA, 2014a). Residential heating and cooking accounted for 47 PJ. For the building sector the share of renewables in the mix in 2010 was about 11.5%, and in the overall heating sector less than 5%.

According to Matveev (2014), total biomass demand was constant at 93 PJ from 2010 to 2012, or 2,231 kilotonnes of oil equivalent (ktoe). Another source found more, however: a report by the Centre for Renewable Energy Sources and Savings. A questionnaire from 2012 estimates total demand at 108.2 PJ for covering the 2009-2010 fiscal year, and 128.4 PJ for 2010-2011 (CRES, 2012). Table 3 displays details for 2009. Firewood is the most common feedstock and is used by 92% of the households reporting biomass consumption. Half of firewood is supplied from biomass supply centres and one third directly from forests. The remainder is from the wood-processing industry.

The CRES survey provides a comprehensive overview of solid bioenergy markets in Ukraine. About 15% of households used some type of biomass for space heating, cooking or water heating, the report found. The share is

Table 2: Usage of biomass for generation of energy in Ukraine, 2013

	Annual volume of consumption[1]		Share of total volume of annual consumption of biomass	Share of economically feasible potential
	Physical units	ktoe		
Straw of cereals and rape	94 000 tonnes	33.6	1.8%	1%
Wood (residential)	5 million m^3	840	45.1%	>90%
Woody biomass (non-residential)	3.2 million tonnes	763	40.9%	
Sunflower shelling	380 000 tonnes	146	7.8%	41%
Bioethanol	65 000 tonnes	42	2.3%	6%
Biodiesel	18 000 tonnes	16	0.9%	4.8%
Biogas from agricultural waste	22.3 million m^3	10	0.5%	4.4%
Biogas from landfills and municipal solid waste	31.2 million m^3	15	0.8%	8.1%
Total		1 864	100%	

Source: SAEE (2015)

1 Values show consumption for energy generation in Ukraine. Export of pellets/briquettes is not included.

Table 3: Biomass boilers in Ukraine, 2009

	Feedstock	Total number of boilers	Total biomass consumption (kt/yr)	Sector
Old boilers	Firewood	1 000	400	Forestry enterprises
Modern boilers	Firewood	100	246	Forestry, woodworking industries, tertiary sectors
Straw-fired water boilers	Straw	25	22	Commercial sector
Straw-fired heat boilers	Straw	20	8	Agricultural companies
Husk-fired boilers	Husk	70	500	Fat and oil industry

Source: CRES (2012)

higher in rural areas: 40% of households reported using biomass for their heating needs, compared with 5% in urban areas (CRES, 2012). Space heating accounts for 58% of the total biomass demand, with 32% from cooking and 10% for heating water. There has been limited uptake of modern stoves, and most biomass use in the building sector is in traditional forms[7].

Ukraine is also a producer of solid biomass products. In 2012, there were 44 pellet producers in Ukraine and 155 making fuel briquettes. Total production is about 289 kilotonnes (kt) per year. These are mainly small companies with production outputs no larger than 2 kt of pellets in a month or 1 kt of briquettes. One company produces pellets and briquettes from straw. Over 90% of solid biofuel products were exported to EU countries, where there are effective incentive programmes for renewable energy (CRES, 2012).

The average cost of firewood in Ukraine is reported at USD 24 per tonne, or about USD 1.4 per GJ. Prices for other solid biomass ranged from USD 0.13 per GJ to 4.9 in 2010. Wood-processing residues represented the low end of this range. Baled straw and firewood were priced around USD 2.2 per GJ including delivery. Wood pellets and briquettes ranged from USD 4.4 to 4.9. In 2012 prices had risen by about 20% from 2010. Depending on the feedstock used, prices for large consumers and traders ranged from USD 4.7 per GJ (straw) to 6.0 (husks). Demand for wood pellets is high in the EU, and domestic prices are typically 10-15% higher in winter (TEBODIN, 2013).

7 According to the IEA (2012a), biomass use in the residential sectors of non-OECD countries should be considered as traditional. However, National Renewable Energy Action Plan of Ukraine counts all biomass use as modern and as part of the renewable energy mix.

Biogas use

When Ukraine was a part of the former Soviet Union (FSU) biogas facilities were often constructed at water treatment and milk-processing plants. Only a few remain operational, but many new facilities are in design. The slow development of biogas plants is attributed to two factors: the expense of the equipment and absence of feed-in tariffs for power from biogas. At the end of 2014 there were seven biogas plants installed in Ukraine (Table 4). As of early 2015 seven additional plants are planned.

Biomass makes up 64% of municipal solid waste (MSW) in Ukraine. There are 6 LFG collection and utilisation systems operating in Ukraine, of which four are commercial systems and two are for demonstration (CRES, 2012).

Liquid biofuels use

Total ethanol production capacity in Ukraine is about 131,000 tonnes per year. Actual production is between 60,000 and 100,000 tonnes per year, in 13 state-owned and 20 private plants. The market price for domestically produced bioethanol in 2012 was between USD 1.85 and 1.93 per tonne (TEBODIN, 2013). Total biodiesel production capacity is about 500,000 tonnes per year, and total production is about 100,000 tonnes per year. About three-quarters of production comes from small-scale plants with capacities ranging between 300 tonnes and 5,000 tonnes annually (ProMarketing Ukraine, 2013).

Other renewables

The most recent data from late 2008 indicates that the total area of installed solar collectors for heating in

Table 4: List of existing and planned biogas plants in Ukraine, end of 2014

Industry type	Start-up year	Feedstock type	Digester volume (m^3/day)	Power capacity (kW)
Operating biogas plants				
Pig farm	1993	Pig manure	595	n.a.
Pig farm	2003	Pig manure, fat from poultry slaughter	2 000	180
Agricultural company	2009	Cattle and pig manure	1 500	250
Cattle farm	2009	Cattle manure	7 200	625
Poultry farm	2012	Poultry manure	35 000	5 000
Pig farm	2013	Pig/poultry manure and agro-waste	13 000	1 000
Sugar mill	2013	Bagasse	40 000	n.a.
Under construction or planned				
Poultry farm		Poultry manure	n.a.	4 000
Poultry farm		Poultry manure	n.a.	3 000
Sugar mill		Bagasse	n.a.	n.a.
Pig farm		Pig manure	n.a.	125
Agricultural company		Cattle manure and corn silage	n.a.	1 360
Agricultural company		Silage and vine vinasse	n.a.	125
Agricultural company		n.a.	16 000	1 200

Source: SAEE (2015)

Ukraine was approximately 45,000 square meters (m^2) (31.5 MW). There is no significant use of solar thermal equipment. Current Ukrainian policy foresees a considerable increase in solar energy use at industrial facilities and for agribusiness.

4. REFERENCE CASE

The current energy policy of Ukraine, approved by government, is called Energy Strategy of Ukraine for the Period until 2030. It states that the use of renewables is important to improve energy security and to reduce the environmental impacts of the energy sector. Renewable energy in Ukraine is important on a national level but also has international implications: to help enhance energy security in Europe and to combat climate change.

Energy Strategy of Ukraine requires periodic adjustments because it is a long-term forecasting document, and in 2011 the government drafted a new edition that was approved in July 2013. Changes focused on the strategy for developing the electricity sector, and in particular development of the domestic coal sector.

The indicative figures until 2030 and increase in energy efficiency proposed in the document were used in the NREAP when calculating Ukraine's Reference Case to 2030 (see Table 5). Values provided for the year 2030 are estimated based on the trends observed between 2014 and 2020 according to the NREAP. The heating

Table 5: Expected gross final energy consumption of Ukraine taking into account energy efficiency improvements according to the NREAP, 2009–2030

	2009	2013	2014	2015	2016	2017	2018	2019	2020[2]	2030[2,3]
Heating / cooling	43 640	44 800	45 570	45 910	46 280	46 680	46 800	46 950	47 100	49 767
Electricity (generation)	13 791	15 950	16 780	17 110	17 440	17 770	18 100	18 930	20 300	24 323
Transport	8 943	9 050	9 260	9 480	9 700	9 930	10 170	10 420	10 680	13 547
GFEC[1]	66 374	69 800	71 610	72 500	73 420	74 380	75 070	76 300	78 070	87 636

Source: CoM (2014).
Note: All data expressed in ktoe per year.

1 The gross final energy consumption comprises final energy consumption, network losses, own use of energy at electricity and heat plants (except consumption of electricity by pumped hydro storage plants for transformation in electric boilers or heat pumps at district heating plants, as defined in Article (2)(f) of Directive 2009/28/EC.

2 The growth rate in GFEC of heating/cooling, electricity generation and transport for the period between 2010 and 2020/2030 is applied to the 2010 TFEC values to estimate the 2020 and 2030 Reference Case TFEC. Renewable energy use by technology and application for the years 2020 and 2030 Reference Case has been taken directly from the NREAP and the Energy Strategy of Ukraine, respectively. The conventional fuel mix is assumed to remain identical to the 2010 situation in the entire period of 2010-2030.

3 In the estimation of the TFEC in 2030, there are slight differences between the REmap analysis and the basic scenario of the Strategy:

- *Electricity: Generation in 2030 will exceed the level of 2010 by 50%. It will be caused mainly by increase of consumption in industry (by 55%) and in services (by 100%) (CoM, 2014). The basic scenario of demand for electricity envisages a decrease of gross domestic product (GDP) electricity intensity by approximately 40%. To reach this level it is necessary to achieve 20% of decrease of specific consumption of electricity. This study assumes the same level of growth for electricity generation in the same period.*
- *Heating: According to the basic scenario of the Strategy, total consumption of heat should grow up to 271 million Gcal in 2030 (1,134 PJ/yr), compared with 212 million Gcal in 2009. This represents a 28% growth between 2009 and 2030. Growth in the residential building sector is 12%, from 146 million Gcal to 161 million Gcal. Growth in industry is from 38 million Gcal to 57 million Gcal. If 2008 is taken as base year (56 million Gcal), this would, however, mean no growth in demand. In the commercial building sector, growth is from 28 million Gcal to 53 million Gcal (UABio, 2013a). This study assumes that heating demand will follow the trends that are projected between 2015 and 2020. As a result, total demand for fuels in industry and buildings sectors for heating would increase from 1,264 PJ in 2010 to 1,425 PJ in 2030. This is similar to the magnitude of growth projected for the residential buildings between 2009 and 2030. Total district heat demand would grow from 509 PJ to 590 PJ in the same period. These developments would imply a total growth of 14% in the same period.*
- *Transport: In basic scenario of development of transport fleet, the total domestic demand for main light oil in 2030 will be about 17.4 million tonnes (of those petrol – 6.3 million tonnes, diesel fuel – 10.1 million tonnes, kerosene – 1.0 million tonnes). This is equivalent to 744 PJ per year liquid fuel use in 2030. This study assumes a lower growth in transport sector fuels to 560 PJ per year in 2030. According to the basic scenario of the Strategy, consumption of electricity in transport sector will reach 14 terawatt-hours per year (TWh/yr), which is also assumed in the REmap study.*
- *As a result of these developments, TFEC of Ukraine grows from 3.2 EJ in 2010 to 4.0 EJ in 2030 according to the REmap analysis. This growth is also in line with the findings of a study by Podolets and Diachuk (2013) which estimates the growth in Ukraine's TFEC for the same time period based on the national TIMES-Ukraine model.*

and cooling sectors will account for about 60% to 65% of the Ukraine GFEC between 2009 and 2030, and about 20% to 25% will be accounted for by the power generation sector. The transport sector's share will be between 13% and 14% for the period. GFEC would increase by 1.3% per year in the period 2009 and 2030. This is opposite to the trend which has been observed in the past decade where Ukraine's total demand for energy is decreasing on average by 1% per year.

The NREAP to 2020 was drafted by the State Agency of Ukraine for Energy Efficiency and Energy Saving (SAEE). This draft has been approved by the State Committee in 2014 (CoM, 2014). As part of the Energy Strategy of Ukraine, SAEE also provides the power generation and the related capacities from renewable sources for the year 2030 as well as the developments in the heating and transport sectors by technology.

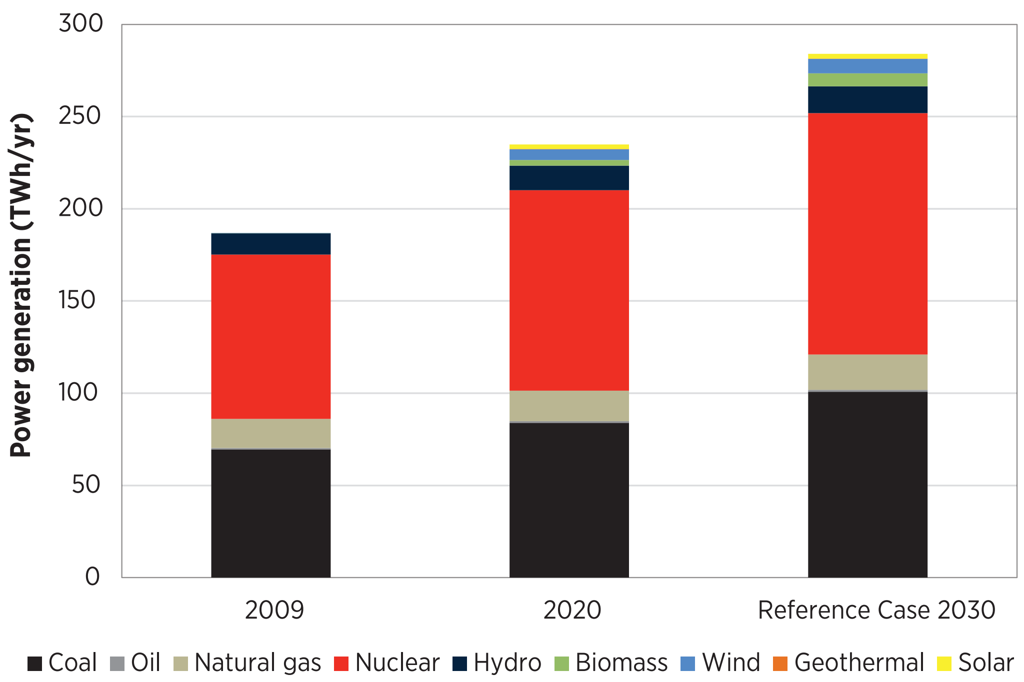
According to the NREAP, renewable energy's share in the Ukraine GFEC needs to reach 11% by 2020, which implies a total renewable energy use of 8,530 ktoe/yr (357 PJ/yr). In 2030 estimated renewable energy use would be 15,500 ktoe/yr (649 PJ/yr) in the business as usual. That would represent 17.7% of the estimated GFEC of 87,636 ktoe/yr. The GFEC of Ukraine would grow by 32% in the period between 2009 and 2030 whereas total renewable energy use would jump by six-fold.

Figure 2 shows the developments in power production between 2009 and 2030. Total production will increase by 48.1% in the entire period, from 189 TWh to 284 TWh. This is faster than the total growth of TFEC, indicating the increasing importance of power in Ukraine. Future additions in generation capacity are expected primarily from coal, hydro, nuclear and other renewables.

According to Figure 3 the share of renewable energy in the power sector is projected to nearly double, from 6.9% in 2010 to 11.4% in 2030, with increases across all categories. For industry the share should jump from 0.2% to 13.3%, and in building from 6.8% to 12.3%. For transport, the number would go from zero to 6.7%.

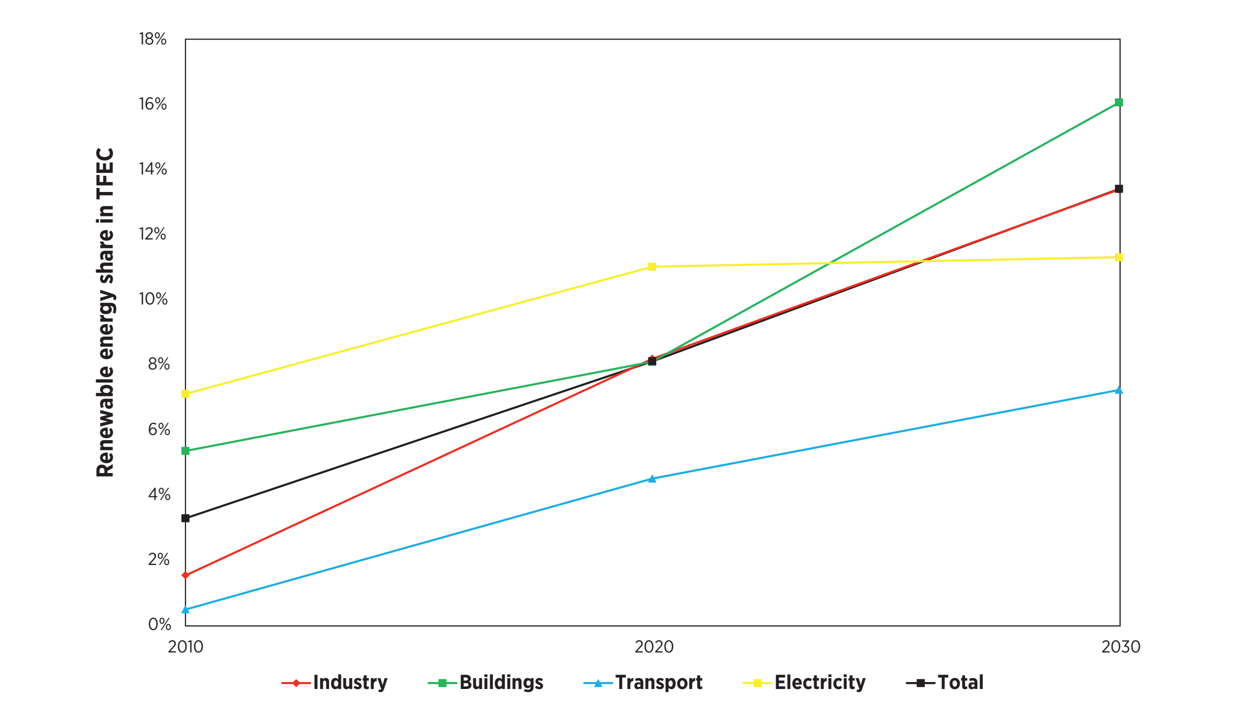
Figure 4 shows the projections for renewable-energy use in TFEC. Overall use is projected to increase from 87 PJ in 2009 to 535 PJ in 2030. Bioenergy continues to dominate the mix, with its share expected to remain between 67% and 84% in the 2009-2030 period. Hydro's portion will drop from 33% to 7% because of growth in wind and solar. However in the power sector specifically

Figure 2: Power generation mix under the current policies, 2009-2030



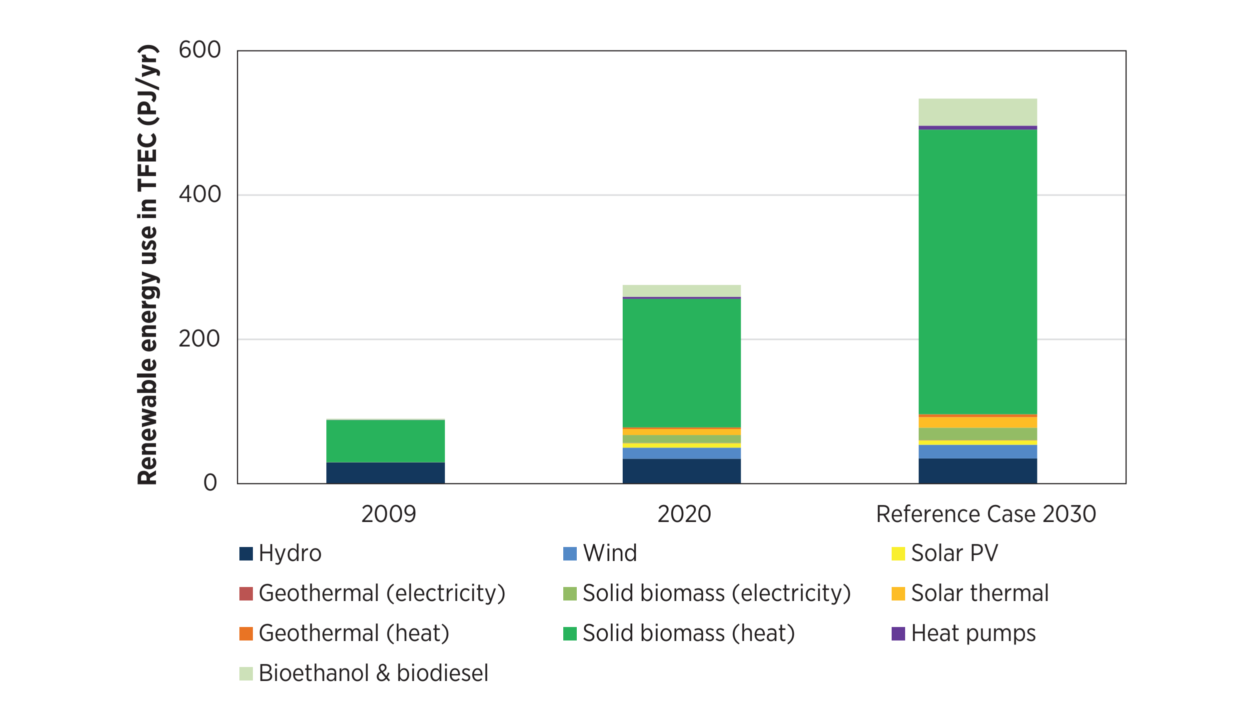
hydro and wind will dominate (70% of total renewable power production), followed by biomass and solar PV. Biomass will be the main source for the heating and transport sectors.

Figure 3: Projected development of renewable energy share under current policies, 2010-2030



Note: compared to other parts of this study, this figure shows the renewable energy share developments starting with 2010, not 2009.

Figure 4: Business as usual projected renewable energy mix, 2010-2030



5. CURRENT POLICY FRAMEWORK

Increasing the usage of renewable-energy sources and alternative fuels counts as an important part of Ukraine's strategy to save on traditional fuel and energy resources and to reduce the related environmental impacts. The policy seeks to lower both supply and demand by pursuing efficiencies. It will also diversify fuel sources, therefore contributing to the energy independence of the state. The Ukrainian government has taken important steps for transforming the country's energy sector, with the aim of increasing energy efficiency and improving energy security.

In September 2010, the Protocol on Accession of Ukraine to the Energy Community Treaty was signed and in 2011 Ukraine became the full member of the Energy Community, which means it is expected to participate in integrating its energy sector with those of EU countries. Directives on renewable energy sources set mandatory national goals, offer investment guarantees and encourage to development of advanced technologies and innovation. Ukraine assumed the obligation to source 11% level of energy from renewable sources by 2020.

Participation in the Energy Community gives Ukraine opportunities to enhance competition in the domestic market, learn about and adopt European technical standards and transparent regulations and improve its investment climate. It also offers deeper integration of the Ukrainian energy sector with EU countries, enhancing its own energy security. Membership also increases access to international loans and technical assistance. In response to Ukraine's Energy Community obligations, Ukraine drafted the NREAP for the period until 2020 (SAEE, 2012). The NREAP has been approved by the State Committee in 2014 (CoM, 2014).

In 2010, the Ukrainian government released the Programme of Economic Reforms for 2010-2014. This covers energy, among other sectors of the economy. The programme addresses key energy issues and the need for reform in various areas. The programme also to attract investments and move to a tariff regime that covers all production costs. The Energy Strategy of Ukraine is key in realising these reforms. In the 2006 edition of the Energy Strategy of Ukraine, it was mentioned that renewable energy would be essential to improve Ukraine's energy sector. The strategy requires periodic adjustments, because it is a long-term forecasting document, and in 2011 the Ukrainian government decided to draft a new edition. The revised version was released in 2012, and it was subsequently approved in July 2013 (IEA, 2012b; SAEE, 2015).

A number of institutions have responsibility regarding Ukraine's energy policy, which is coordinated by the Cabinet of Ministers (CoM), which also has oversight of state energy companies. For example, the Ministry of Energy and Coal is responsible for power sector planning and energy supply policies. Ministry of Agriculture is responsible for liquid biofuels (IEA, 2012b; SAEE, 2015).

As a transit country to Europe for both natural gas and crude oil, Ukraine plays an important role in the energy security of European Union as well. Around 15% of Europe's total gas supply is met through the Urengoy-Pomary-Uzhgorod (Brotherhood) pipeline (running through Ukraine and entering Slovakia). A total of 83 billion m^3 natural gas entered Europe in 2013 from this pipeline (IEA, 2014b).

Overview of institutional, regulatory and legal frameworks for renewable energy

The following bodies have briefs that directly or indirectly impact the energy sectors of Ukraine:

The Ministry of Regional Development, Construction and Housing is the main body in charge of developing and implementing national regional policy, with areas of responsibility including:

- energy efficiency;
- renewable energy and alternative fuels;
- field surveying and mapping activities;
- land management;
- land protection (except for the use and protection of agricultural land);

- geodesy, cartography and cadastre services through its ***State Service of Geodesy, Cartography and Cadastre*** *(SSGCC).*

The State Agency of Ukraine for Energy Efficiency and Energy Saving (SAEE) in accordance with its tasks shall, in particular:

- create the system of monitoring of efficient usage of fuel and energy resources, renewable energy sources and alternative fuels;
- confirm, under the established procedure, the fact that fuel is an alternative;
- conduct qualification of co-generation installations;
- develop state norms, rules and standards in terms of efficient usage of fuel and energy resources, energy saving, renewable energy sources and alternative fuels, it can act as a client of scientific and technical studies as well as design work;
- draft state target programmes, approve sectoral and regional programmes in terms of efficient usage of fuel and energy resources, energy saving, renewable energy sources and alternative fuels, carry out control of fulfilment of state target programmes in this area.

The **National Commission for State Energy and Public Utilities Regulation** (NCSEPUR) is a state collective body that is subordinate to the President of Ukraine and reports to Ukraine's parliament, the Verkhovna Rada. Until 2014 this body was known as the National Electricity Regulatory Commission (NERC). Its main areas of oversight are:

- regulation of activity of entities of natural monopolies and business entities carrying out activity in the areas of electricity, including power plants of all types;
- supervising natural gas markets, including upstream assets such as associated-gas fields, coalbed methane and shale gas (hereinafter referred to as the natural gas);
- oil and oil products;
- pricing and tariff policy for energy, including GT;
- as recycling and disposal of waste.

The **Ministry of Energy and Coal Industry of Ukraine,** through the State Enterprise Ukrenergo, provides technical conditions and concluding agreements on the connection of renewable energy facilities to power networks.

The Ministry of Ecology and Natural Resources of Ukraine reviews ecological concerns and approves construction plans for renewable energy facilities. These laws, codes and directives, resolutions and regulatory frameworks also shape the energy sectors of Ukraine:

1. Law of Ukraine "On Alternative Fuels": specifies legal, social, economic, ecological and institutional principles for generation and use of alternative fuels as well as incentives to increase use.

2. Law of Ukraine "On Alternative Energy Sources": specifies legal, economic, ecological and institutional principles for using alternative energy sources and promotes increased use.

3. Law of Ukraine "On Combined Generation of Thermal Energy and Electricity (Cogeneration) and Usage of Waste Potential": specifies legal principles for improving the efficiency of fuel use in the processes of energy generation or other technological processes; for developing and applying electricity and thermal energy combined-generation technologies; for increasing reliability and security of power supply at a regional level, and for attracting investment to construct cogeneration installations.

4. Law of Ukraine "On Electricity Sector": specifies legal, economic and institutional principles and relationships for generating, transmitting, supplying and using energy; addresses energy security, competition and protects the consumers and employees of the industry.

5. Tax Code of Ukraine: specifies peculiarities of taxation and the granting of privileges to business entities that develop, generate, introduce and use renewable-energy sources. At the time of this report (February 2015) all tax incentives for facilities in renewable power have been cancelled, save for these exceptions:

- according to subparagraph 213.2.8, paragraph 213.2, Article 2013 of Ukrainian Tax Code, electricity generated by qualified CHP units and from renewables is exempt from excise duty

- The following operations are exempt from VAT tax until January 1st, 2019: under Article Seven of the Law of Ukraine "About Alternative Fuels"
  - The supply of machinery, equipment and facilities
  - The production and reconstruction of vehicles not available currently in Ukraine that would consume biofuels, including self-propelled agricultural machines

6. Customs Code of Ukraine: sets rules for importing equipment, machinery and materials for renewable-energy projects.

7. Resolution of the Cabinet of Ministers of Ukraine "On Adoption of the State Target Economic Programme for Energy Efficiency and Development of Generation of Fuels from Renewable Energy Sources and Alternative Fuels for 2010-2015": outlines conditions to decrease the level of energy use as a percentage of GDP from 2010 to 2015 by 4% annually, for a total of 20%, and to increase the share of renewable energy sources and alternative fuels in Ukraine's energy mix.

8. Instruction of the Cabinet of Ministers of Ukraine "On Approval of Energy Strategy of Ukraine for the Period until 2030": this long-term planning document was most-recently updated and approved on 24 July 2013. Its goal is to increase the share of renewables in the country's energy mix as a way to improve energy security and reduce environmental impacts associated with energy consumption. Specific objectives to reach that goal include:

- determining strategies and creating the conditions for a safe, reliable and sustainable energy sector that is developed to the greatest extent possible;
- ensuring the energy security of the state;
- decreasing the technogenic burden on Ukraine's environment and ensuring civil protection in the area of fuel security;
- decreasing generation losses and using energy products through efficient consumption, introducing energy-saving technologies and equipment, streamlining the structure of public generation and reducing reliance on energy-intensive technologies;
- integrating the Unified Power System of Ukraine with the European Power Network and progressively increasing electricity imports, which would strengthen the position of Ukraine as a transit country for oil and gas.

9. Instruction of the Cabinet of Ministers of Ukraine of 03.09.2014 # 791-r "Plan of measures to implement the Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC".

10. Instruction of the Cabinet of Ministers of Ukraine of 01.10.2014 # 902-r "On National Renewable Energy Action Plan for the period until 2020".

11. Instruction of the Cabinet of Ministers of Ukraine of 16.10.2014 # 1014-r "*On approving the plan of short- and medium-term measures to reduce natural gas consumption for the period until 2017*".

The system of respective financial preferences for energy conservation and renewable-energy sources was created in Ukraine and explained in the tax and customs codes and in the Law of Ukraine "On Electricity Sector", namely:

- introducing the GT;
- decreasing land-tax rates for renewable energy enterprises;
- tax exemptions for:
  - profit from the generating of electricity from renewable sources;
  - profit from the sale of biofuel but its producers;
  - profit from CHP facilities or the generation of thermal energy using biological fuels;
  - profit from manufacturing machinery and equipment required to build or rebuild vehicles powered by biological fuels;
  - value-added activities related to importing of certain types of renewable-energy equipment;
  - exemption from import duties for certain types of renewable-energy equipment;

The Law of Ukraine "on Electricity Sector" stipulates some exceptions to which the GT cannot be applied. Amongst alternative energy sources these are blast-furnace and coke gases. In the hydro sector large-scale plans do not qualify. For electricity producers using re-

Table 6: Green tariff coefficients for facilities commissioned

	Until 31.03.2013 inclusive	From 01.04.2013 until 31.12.2014	From 01.01.2015 until 31.12.2019	From 01.01.2020 until 31.12.2024	From 01.01.2025 until 31.12.2029
Wind energy <600 kW	1.20	1.20	1.08	0.96	0.84
Wind energy 600 – 2 000 kW	1.40	1.40	1.26	1.12	0.98
Wind energy >2 000 kW	2.10	2.10	1.89	1.68	1.47
Biomass	2.30	2.30	2.07	1.84	1.61
Biogas	2.30	2.30	2.07	1.84	1.61
Ground mounted solar	4.80	3.50	3.15	2.80	2.45
Rooftop solar >100 kW	4.60	3.60	3.24	2.88	2.52
Rooftop solar <100 kW	4.40	3.70	3.33	2.96	2.59
Micro hydro power	1.20	2.00	1.80	1.60	1.40
Mini hydro power	1.20	1.60	1.44	1.28	1.12
Small hydro power	1.20	1.20	1.08	0.96	0.84

Table 7: Actions related to renewable energy to reduce natural gas consumption of Ukraine

Regulatory legal act of the Government	Key concept	Progress stage
Actions already implemented by the Government		
On stimulation of the natural gas substitution in the area of heat supply (for population)	Investment attractive tariff	Approved and promulgated
Determined compensation procedure and allocated funds for the stimulation mechanism of the natural gas replacement in the area of heat supply (for population)	Determined procedure and allocated 118 million UAH	Adopted at the Government session
On the action plan approval of implementation of the European Parliament and the Council Directive 2009/28/EC	European approaches to the alternative types of fuels development	Approved and promulgated
On making amendments to the State Target Economic Program for energy efficiency and development of the energy production from renewable energy sources and alternative fuels for 2010-2015	Financing activities for the natural gas substitution in the amount of 493 million UAH	Adopted at the Government session
On stimulation of natural gas substitution in the heat energy production for the public sector institutions and organisations	Investment attractive tariff setting for the public sector conversion to the alternative types of fuel	Adopted at the Government session, promulgated
The nearest future initiatives		
Plan of short-and medium-term actions to reduce natural gas consumption, including its substitution by energy supplies, obtained from renewable energy and alternative types of fuel for the heat supply enterprises, industrial consumers, state-financed organisations and population by 2017	Combination of all urgent legislative initiatives on the natural gas replacement	Approved by the State Committee and is being prepared for the Government consideration
The procedure of funds use to stimulate economic entities to modernise boiler houses, including their conversion to alternative types of fuel	Premium to investors for the gas substitution in heat production in housing and communal services and public sector (443 million UAH)	Is being prepared for the State Committee consideration

Source: Adapted from Savchuk (2014)

newables, the GT is set at the retail tariff for consumers of second class of voltage as of January 2009 and then multiplied by the GT coefficient. After 2014, 2019 and 2024 these will decrease by 10%, 20% and 30% of their basic values respectively (Table 6).

For electricity produced using alternative energy sources (except for blast-furnace and coke gases), and construction of which started after 1 January 2012, GT is applied only when requirements for local content are met. Local-content thresholds do not apply to the generating installations of private households and micro, mini and small hydro power plants, and therefore qualify for the GT regardless of local content.

Table six outlines the actions Ukraine has taken to promote energy efficiency and reduce its natural gas usage by 50% within the next decade (Savchuk, 2014).

6. RENEWABLES POTENTIAL

As of February 2015 the annual technically achievable energy potential of renewable energy sources of Ukraine was 68.6 million tonnes of oil equivalent (Mtoe) per year. This is equivalent to 98 million tonnes of fuel equivalent. This would be sufficient to replace approximately half of the total energy consumption in Ukraine today (Table 8) (SAEE, 2015).

Wind power

Ukraine's total wind potential is between 16 GW and 24 GW (DTEK, n.d.; WWEA, 2012), with 16 GW considered economically feasible. The most promising regions are the southern and south-western regions, where average annual wind speed at the height of 80 meters exceeds 7.5 meters per second (m/s) (CoM, 2014; SAEE, 2015).

Hydro power

Technically feasible potential is 21.5 TWh annually (Hydropower & Dams 2014, more than double the 10.4 TWh generated in 2013. Annual technical achievable potential for SHP is estimated at 20.1 TWh. The current SHP capacity is 77 MW. Because it is a minor element of the total energy balance (0.2%), SHP cannot influence the structure of energy supply, however. Within this sector small rivers in Ukraine, mainly in western regions, comprise almost 28% of total SHP potential from rivers. Micro, mini and small hydro power potential are found in all regions of western Ukraine but in particular in the provinces of Zakarpatska and Chernivetska.

SHP can help save fuel and energy resources and contribute to the decentralisation of the energy system. That would address energy-supply issues in remote areas, contributing to energy security in the process.

Ukraine has sufficient scientific and technical potential and considerable experience needed to address challenges in the development of SHP, as turbines and other equipment can be designed and developed by the domestic industry sector (CoM, 2014; SAEE, 2015).

Solar power

The average annual amount of total energy from solar irradiation in Ukraine ranges from 1,070 kilowatt hours (kWh)/m^2 in northern regions to as much as 1,400 kWh/m^2 to the south, and higher in the Crimea peninsula. Solar PV equipment can be efficiently operated throughout the year but the months of peak effi-

Table 8: Potential of renewable sources in Ukraine

	Annual technically achievable energy potential	
	(TWh/yr)	**(Mtoe/yr)**
Wind	60	15
Solar	38.2	4.2
Electricity	5.7	1.4
Thermal	32.5	2.8
Hydro	28.9	7
Small	20.1	4.9
Large	8.6	2.1
Bioenergy	178	21.7
Electricity	27	7.2
Thermal	151	14.5
Geothermal	98.6	8.4
Energy of environment	146.3	12.6

Source: SAEE (2015)

Table 9: Breakdown of solar thermal potential

	Area (million m²)	Share (%)
Water heating in technological processes	9	15
Drying and air conditioning	2	10
Hot water supply	12.5	60
Solar heating and supply	2	10
Passive solar heating	1	5

ciency are from April to October in southern regions and May to September in northern ones. Based on various studies, there is a 4 GW reasonable potential in Ukraine for solar power.

The transformation of solar energy into electricity in Ukraine should be mainly through the use of solar PV devices. The raw materials and the industrial and intellectual capacity to manufacture them locally would meet domestic demand and also open up export opportunities (CoM, 2014; SAEE, 2015).

Solar thermal

Flat plate collectors that can utilize both the direct and dispersed solar radiation, are the most suitable option for Ukraine, in particular in the north parts. In contrast, concentrating solar collectors would be effective in the southern parts. There is an estimated potential of 20-22 million m^2 (Table 9).

Biomass

Ukraine has high potential to expand biomass use for energy purposes, primarily for heating. The country has abundant agricultural and forestry waste, and this is a key resource for the development of biomass-based heat and power generation capacity. There is 42.8 million hectares of land that is equivalent to 71% of the country's total area. 32.5 million hectares of the total agricultural land is arable. Furthermore, it has one of the most fertile soils in the world, the so-called "chernozem". This helps to maintain sufficient agricultural productivity rates in Ukraine, despite the low use of fertilizers (ProMarketing Ukraine, 2013).

According to the estimates from SAEE economically feasible bioenergy potential exceeds 800 PJ/yr – equivalent to a quarter of Ukraine's TFEC. This supply potential consists half from agricultural waste and woody biomass and half from energy crops and biogas (Table 10).

The resource potential of woody biomass in Ukraine amounts to 4 Mt annually. It includes sawmill waste, wood-cutting waste (branches, crowns), firewood and some technical timber, which is currently exported. It is unlikely for this structure to change significantly in the near future. While there is additional forest potential, road transportation of the lumber is a limiting factor for heating and power generation. More than 10 megatonnes (Mt) of surplus straw remains in farmers' fields every year, and collecting it for use is a challenge. Most agricultural enterprises are not able to gather, bundle and adequately store straw.

Wood residues are mostly available in the northern and western parts of Ukraine. In comparison, primary agricultural waste is available in the centre and eastern parts whilst, energy crops can be grown in the eastern parts of Ukraine (van der Hilst *et al.*, 2013). Both wood biomass and agricultural residues can replace aging power generation in the eastern, northern and southern parts of Ukraine (Black & Veatech, 2011).

IRENA has been preparing biomass-potential studies with an outlook to the year 2030 for each of the REmap countries (IRENA, 2014b). In Ukraine the potential is estimated to be between 1,115 PJ and 1,780 PJ. The high end of this range is nearly double the supply potential in 2013. Agricultural residues and waste (biogas) would account for 53% to 58% of this potential, and wood residues and waste about 12%. The share of energy crops

Table 10: Biomass energy potential in Ukraine, 2013

Biomass type	Technical potential	Share available for energy production (%)	Economic potential (PJ)
Cereal crops straw	31 Mt	30	131
Rape straw	4 Mt	40	25
Maize processing waste (footstalks, leaves, cobs)	40 Mt	40	129
Sunflower wastes (footstalks, heads)	21 Mt	40	50
Agricultural secondary wastes (sugar-beet pulp, sunflower husk, rice hush)	7 Mt	75	33
Woody biomass	4 Mt	90	52
Energy crops – willow, poplar, miscanthus, acacia, alder	11.5 Mt	90	184
Bioethanol	–	–	30
Biodiesel	–	–	14
Biogas from manure, food residue, sugar waste	1.6 billion m^3	50	29
Landfill gas	0.6 billion m^3	34	8
Sewage gas	1.0 billion m^3	23	8
Energy crops – biogas from corn silage	3.3 billion m^3	90	108
Peat	–	–	12
TOTAL	–	–	813

Source: SAEE (2015)

and fuel wood would range from 19% to 31% and 0% to 15% respectively.

There is a rapid growth in energy crops expected in Ukraine, and by 2015-2020 output could reach the level of output of straw and overtake it after 2020. Energy crops are planned for cultivation on non-agricultural lands such as river valleys, reclaimed municipal solid waste (MSW) areas, mine sites, etc. Most available plant resources for energy biomass production are expected to be commercialised by 2020. Organic matter recycling for biogas, heat and power production is expected to continue growing, but there is unlikely to be significant expansion in landfill gas.

Table 11: Biomass supply potential in Ukraine, 2030

Feedstock type	Supply potential in 2030 (PJ/yr)	Supply costs in 2030 (PJ/yr)
Energy crops	345	8.9
Harvesting residue	250-400	4.9
Processing residue	210-365	2.7
Biogas	185	2.7
Fuel wood	0-270	7.9
Wood residue	75-160	11.5
Wood waste	50-55	11.5
Total	1 115-1 780	6.1-6.3

Source: IRENA (2014b)

Geothermal

Ukraine has a sufficient number of geothermal deposits with high temperature potential, between 120 degrees Celsius (°C) and 180°C. These temperature are sufficient for power generation.

Based on various estimates the economically viable energy resource of thermal waters in Ukraine is about 8.4 Mtoe/yr. Geothermal water heating is already in effect in the Crimea peninsula, where 11 geothermal-circulation systems are operating. These systems comply with modern technologies for extraction of geothermal heat, and plants are operating at both pilot and industrial stages.

Large reserves of thermal waters are found also in the provinces of Chernihivska, Poltavska, Kharkivska, Luhanska and Sumska. Hundreds of wells containing thermal water are currently mothballed and could be renewed and used for geothermal heat.

7. REMAP OPTIONS

This section explains the REmap Options, which are renewable sources that can be used in addition to those in the Reference Case. Table 12 contrasts renewable energy use in 2009, the base year of the Ukraine NREAP, with what is expected in 2030. Results for the year 2030 are provided separately for the Reference Case and for REmap 2030.

With all REmap Options implemented total renewable energy use in Ukraine's TFEC would reach 872 PJ. One-fifth of this would be for renewable power consumption (188 PJ) and four-fifths for renewable gas, heat and fuels (684 PJ). Total renewable energy use in Ukraine's TFEC would reach 21.8% in REmap 2030, compared to 3.0% in 2009 and 13.2% in 2030 Reference Case. Installed renewable-energy capacity would increase from 13.2 GW in the Reference Case to 29.1 GW, a difference of 15.9 GW. The increase comes from wind (an additional 9 GW), solar PV (5.5 GW) and biomass power (1.4 GW). All of the additional biomass power capacity in REmap 2030 is assumed to be used for industrial CHP. No capacity additions are assumed for hydro or for geothermal power.

Total installed wind power capacity with REmap Options would be about 12 GW, requiring 380 MW of new capacity installation annually between 2009 and 2030. That is a pace similar to what has already been established in recent years in Ukraine. Total installed solar PV capacity would climb to 8 GW which would require 570 MW year of new capacity every year in that same period. This annual installation rate would be higher than the pace in 2012 and 2013, of 430 MW per year.

Total biomass power capacity would reach 3 GW with the REmap Options, from a level of about 1.6 GW. All of installed capacity would be used for CHP. About 1.4 GW of the total CHP capacity is used by the industry sector, with 1.6 GW for district heat CHP.

As a result of these additions total renewable energy power generation would increase to 70.9 TWh/yr in comparison with the Reference Case. This is equivalent to a 25% share for renewable energy in Ukraine's power generation sector, and more than four-fold increase compared to the 2009 level.

There would be significant new capacity in the heating and transport sectors as well. The largest increase would be from biomass. Total final biomass demand for transport fuels and for heating, including district heat, would jump by 45% to 761 PJ/yr with the REmap Options, compared with 522 PJ in the Reference Case.

Other sources for heat would increase as well for the residential, industrial and district-heat sectors. Biomass' share in the fuel mix for the district heat sector reaches 21%, from a previous 17% in the Reference Case 2030. In the building sector the share would also be 22% (excluding the use of electricity and district heat from biomass and other renewable energy sources). In the residential sector, total solid biomass use would be about 134 PJ per year, and biogas use about 27 PJ per year. This is equivalent to 8 Mt/yr of solid biomass and 3.3 billion m^3 biogas use by 2030. Solid biomass use in the industry sector is expected to be higher. For heat generation in biomass-fired CHP and heat-only boilers, a total of 92 PJ and 160 PJ biomass, respectively would be required. Biogas demand is lower, estimated at 10 PJ per year with the REmap Options implemented.

Total installed capacity for solar thermal could increase to 19 million m^2 (13 GW). About 2 million m^2 would be in the industrial sector (about 1.8 MW capacity) and the remaining 17 million m^2 in the residential sector (11.5 GW capacity). Solar thermal would account for about 3% of Ukraine's building sector TFEC.

The Reference Case sees significant growth in electrification for heating with heat pumps, and partly through other technologies such as electric boilers and resistance heating. With REmap Options used no further electrification technology options are needed.

Total liquid biofuel use in the transport sector would reach 63 PJ if Remap Options are used. About a quarter of total consumption would come from advanced biofuels produced from non-food crops. The remainder would come from food-based crops. Total demand for

Table 12: Renewable energy use in 2010, Reference Case 2030 and REmap 2030

1. Electricity generation		**Unit**	**2009**	**Reference Case 2030[1]**	**REmap 2030**
Installed Capacity	**Renewable energy**	GW	**4.6**	**13.2**	**29.1**
	Hydro	GW	4.5	6.0	6.0
	Wind onshore	GW	0.1	3.0	12.0
	Biomass and biogas[2]	GW	<0.01	1.6	3.0
	Solar PV utility scale	GW		2.5	8.0
	Geothermal	GW		0.02	0.02
Electricity Generation	**Renewable energy**	TWh/yr	**11.6**	**32.1**	**70.9**
	Hydro	TWh/yr	11.4	14.5	14.5
	Wind onshore	TWh/yr	0.04	7.8	34.7
	Biomass and biogas	TWh/yr	0.14	7.0	13.2
	Solar PV utility scale	TWh/yr	0	2.63	8.4
	Geothermal	TWh/yr	0	0.1	0.1
2. Total biogas supply					
Total		PJ/yr	0	44	61
3. Heat generation					
Solar thermal industry[3]		PJ/yr			5
Solar water heater[3]		PJ/yr	0	15	36
Geothermal energy for heating[4]		PJ/yr	0	4	10
Heat pumps		PJ/yr	2	50	50
Biomass district heating generation[5,8]		PJ/yr	11	116	137
Total		PJ/yr	13	185	239
4. Biofuels					
Solid biomass & biogas for buildings[6,8]		PJ/yr	47	126	186
Solid biomass & biogas for industry[7,8]		PJ/yr	2	167	263
Liquid biofuels transport[9]		PJ/yr	0	37	63
Total		PJ/yr	49	3 330	512
5. Ratio of electricity generation					
Gross power generation		TWh/yr	189	284	284
Generation ratio of renewables		%	6.2%	11.3%	25.0%
6. Total final energy consumption					
TFEC		PJ/yr	2 943	4 067	4 008
Renewable electricity		PJ/yr	29	85	188
Renewable gas, heat and fuel		PJ/yr	58	450	684
All renewable energy		PJ/yr	87	535	872
Modern renewable energy in TFEC		%	3.0%	13.2%	21.8%

1 NREAP 2020 is the basis for the renewable energy use to 2020 in the Reference Case. Estimates for 2030 power capacity and generation as well as for growth in the heating and transport sectors are based on SAEE estimates.

2 All biomass generation according to NREAP 2020 is assumed to be CHP. It is assumed that this trend will continue to 2030 as well in the Reference Case. In the Reference Case all biomass-CHP plants are assumed to be used for generating power and district heat, hence the deployment of industrial biomass-CHP is excluded from the Reference Case. To estimate the related district-heat generation, a power-to-heat ratio of 0.3 and 0.75 are assumed for solid biomass- and biogas-fired CHPs, respectively (UABio, 2013b). Total power generation in 2030 is slightly higher than the estimates of UABio (2013b) of 12 TWh per year (including solid biomass and biogas, but excluding co-firing). UABio (2013b) estimates a total installed CHP capacity of 1.6 GW compared to 3 GW in this study for the year 2030. The difference in total capacity is explained by the higher potential estimated for industrial CHP (see notes 6 to 8 of this table) and the lower capacity factors used in REmap 2030 (50% compared to 60-70%).

3 Solar thermal heating in the industry and building sectors is assumed to grow at an annual installation rate of about 600 MWth per year between 2009 and 2030, close to the recent trends that are seen in Australia, Germany and the United States (AEE-INTEC, 2014).

4 *For industrial-process heating a modest capacity increase growth in REmap 2030 is assumed of 6 PJ (140 ktoe/yr), compared with the economic potential of about 350 PJ per year (see Section 6).*

5 *Compared with biomass-fired CHP district heat systems (coupled with renewable power generation), growth in heat–only district heat systems in the Reference Case is rather modest. They accounted for 17% of the total district heat generation as of February 2015. A potential fifty percent higher than the Reference Case is assumed for heat alone systems, that would take their share in total biomass-based district heat generation to 50 percent. Total installed heat-only district heat systems in REmap 2030 reaches 2.5 GW as opposed to UABio (2013a,c) estimates of about 4 GW. Instead, a larger capacity of heat-only systems are estimated for the building and industry sectors in REmap 2030.*

6 *NREAP 2020 indicates the use of renewables for heating in households separately. All capacity was assumed to be solid biomass use in stand-alone boilers. In REmap 2030 an additional biomass potential of 60 PJ was assumed for buildings, adding 5 PJ in the commercial sector, 38 PJ of solid biomass for households and 17 PJ of biogas for households. Together with deployment in industry, these additions would increase the annual rate of biomass capacity implementation for end-use sectors by 50% between 2009 and 2030. These estimates are in line with SAEE's projections to 2035 if policies were to remain the same as they currently are.*

7 *All additional solid biomass-based power generation capacity in REmap 2030 is assumed to be industrial CHP, a technology which sees no growth in the Reference Case. This adds about 90 PJ biomass use to the industry sector to co-generate heat. An additional potential of 4 PJ is assumed for direct heat and steam generation.*

8 *Total heating capacity in REmap 2030 reaches 32.2 GW (6.9 GW for district heating, 13.6 GW for the residential sector, and 11.7 GW for industrial and commercial sectors). This total can be disaggregated to 9 GW CHP (thermal capacity) and 23.2 GW heat-only systems. REmap 2030 estimates are double the capacity estimated by the UABio (2013a,c) for 2030 (17.7 GW). There are a number of reasons for the differences. Total industrial CHP capacity is 4.7 GW in REmap 2030 compared to 1.5 GW according to UABio (2013a,c). Total heat-only industrial heat generation capacity is 7 GW in REmap 2030 compared to 1.5 GW according to UABio (2013a,c). This study assumes a quarter of all low and medium temperature heat generation in the industrial sector of Ukraine would be from biomass-fired industrial CHPs (92 PJ). It further assumes about 25% of total clinker production and 5% of iron/steel production heat demand to be supplied with biomass and waste (36 PJ) (both high temperature heat applications). The remainder (124 PJ) is consumed to generate process heat in (steam and direct heat) boilers for varying temperature levels that represents about 20% of all low and medium temperature process heat demand in Ukraine's industry.*
Total residential heat generation capacity in REmap 2030 is 13.6 GW compared to 5.1 GW in UABio (2013a,c). The difference is to large extent explained by the lower capacity factor used in REmap 2030 compared to UABio (2013a,c) (30% versus 45%).
Total district heat generation capacity in REmap 2030 is 6.9 GW compared to 9.7 GW in UABio (2013a,c). These are estimated assuming 50% capacity factor for CHP in REmap 2030, compared to 90% in UABio (2013a,c). When REmap 2030 capacity factor is used, the UABio (2013a,c) total capacity would be even higher at 13.9 GW.
For biomass-based heating, REmap 2030 assumes the use of more decentralised heat generation in the industry and residential sectors as opposed to the UABio (2013a,c) study which assumes more centralised district heat generation.

9 *In the Reference Case, ethanol and biodiesel represent about 15% and 6% of the total gasoline and diesel volumes respectively. Additions in REmap 2030 take ethanol's share to 19% (1.7 billion litres) and that of diesel to more than 20% (0.8 billion litres). The estimates for REmap 2030 are slightly higher than what is envisioned for Ukraine by 2035 according to its Reference Case, where ethanol is at 1.5 billion litres, and biodiesel at 0.63 billion litres.*

conventional bioethanol production would use about one-third of Ukraine's total energy-crop supply potential.

Table 13 shows renewable-energy developments by sector between 2010 and 2030 as well as total renewable energy use by sector with REmap Options used. The building and industry sectors would have the largest renewable energy share, at about 22-27% not including renewable electricity and district heat uses. When these are accounted for the sectors' renewable energy share is estimated at 22.2% and 25.0%, respectively. The transport sector's renewable-energy share would rise to 11.3% from nearly zero in 2010. The industry sector

Table 13: Renewable energy share and total renewable energy use by sectors, 2010-2030

		Renewable energy shares			Total RE use in REmap 2030 (PJ/yr)
		2010	Reference Case 2030	REmap 2030	
Industry	Excl. electricity & DH	0.2%	13.3%	21.8%	414
	Incl. electricity and DH	1.5%	13.4%	22.2%	
Buildings	Excl. electricity & DH	6.8%	12.3%	27.1%	374
	Incl. electricity and DH	5.4%	16.1%	25.0%	
Transport	Excl. electricity	0%	6.7%	11.3%	83
	Incl. electricity	0.5%	7.2%	12.8%	
Power	generation	6.9%	11.3%	25.0%	255
District heat	generation	1.8%	16.9%	17.7%	137
TFEC	Excl. electricity & DH	2.7%	13.2%	21.4%	872
	Incl. electricity and DH	3.3%	13.2%	21.8%	

would account for about half of the total renewable energy use in Ukraine's TFEC, followed by buildings (43%) and transport (10%).

In terms of resource use, biomass would be the most important source of renewables in Ukraine, with a total share of 76% of the total renewable energy use in REmap 2030 (see Figure 5). Solar and wind would account for 7% and 10%, respectively. The share of hydro would drop to 4% by 2030, compared with 32% in 2009, because of the substantial growth in all other renewable energy sources in the 2009-2030 period.

Total primary biomass demand would be 820 PJ/yr in REmap 2030 (Figure 6). That suggests that 45% to 75% of domestic potential will be utilised. Domestic potential is between 1,100 PJ and 1,800 PJ. Almost 70% would be supplied from two sources: agricultural residues (360 PJ) and from wood and wood residues (200 PJ).

The heating sector would account for 77% of total biomass demand in 2030, with the balance coming from the transport sector (15%) and power generation (8%). About 60% of all biomass use for heating would be a part of industrial and agricultural processes, with the remainder for buildings and district heating.

Total biogas demand would be 61 PJ, compared to Ukraine's estimated supply potential of about 185 PJ per year in 2030.

Costs of renewables in Ukraine

Table 14 provides an overview of the substitution costs by sector for the business and government perspectives for the year 2030. The business perspective is based on a discount rate of 10% and takes into account energy tax and subsidies in energy prices in Ukraine. In comparison, the government perspective also uses a 10% discount rate but is based on international and regional energy prices that exclude tax and subsidies.

The cost of REmap Options are more expensive from the perspective of business than from government. For business the most cost-effective options are found in

Figure 5: Renewable energy use in TFEC, 2010-2030

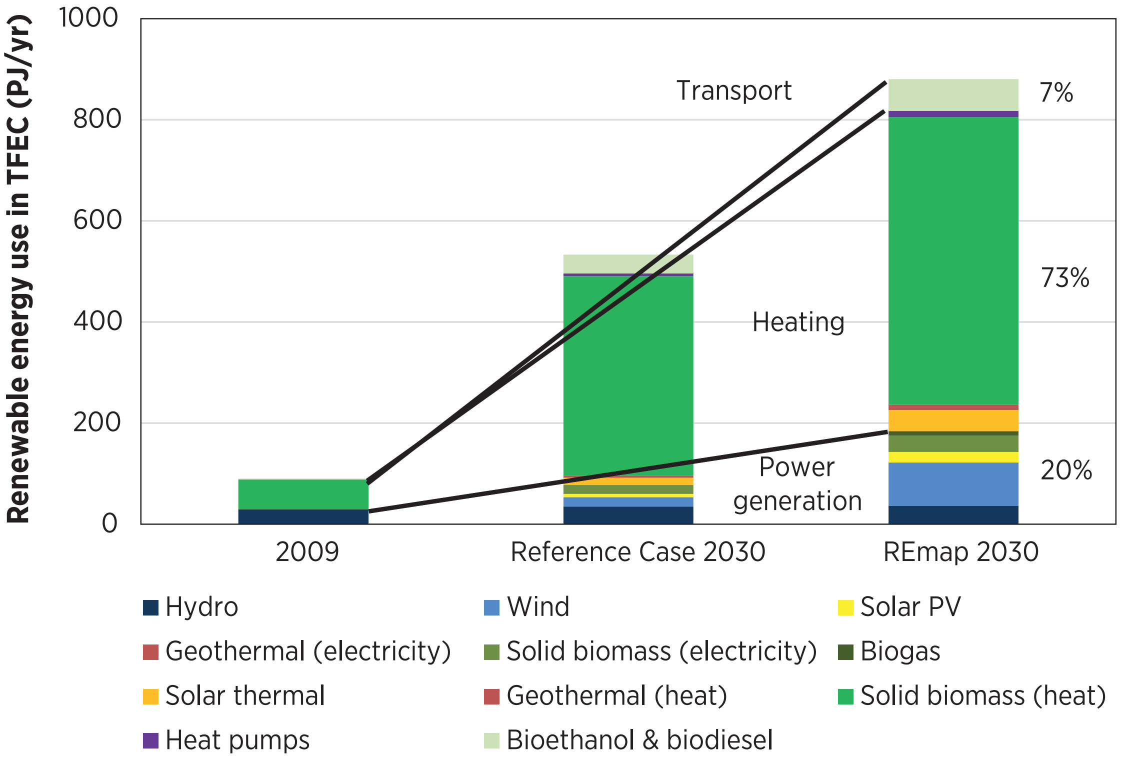
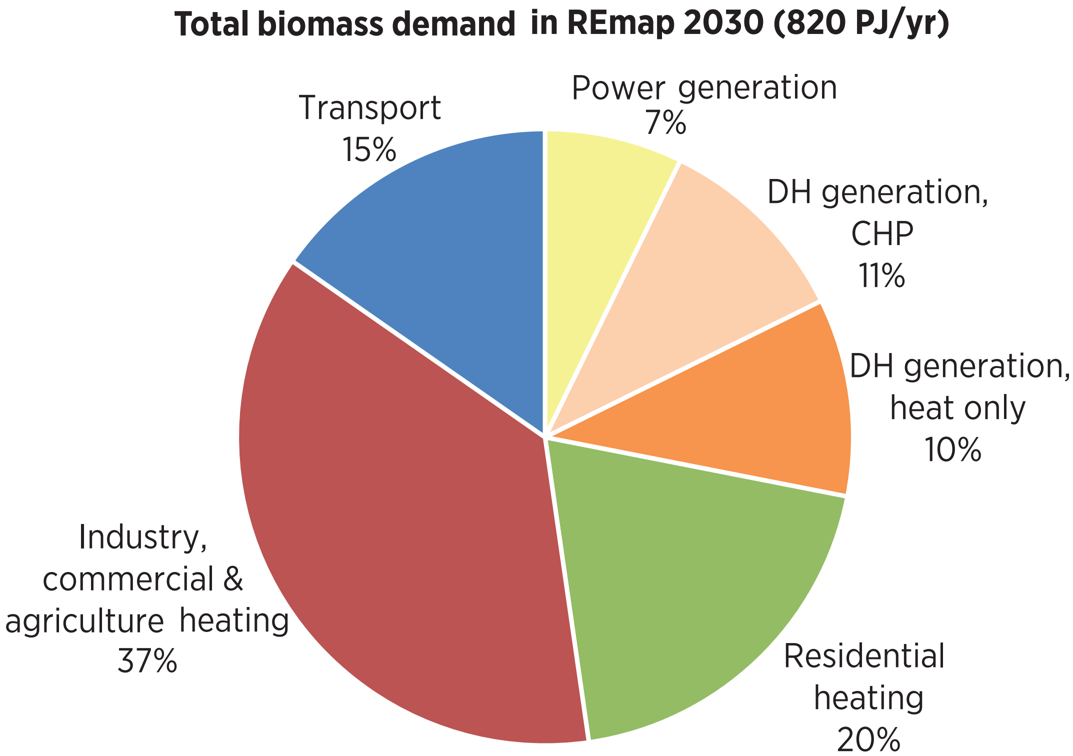


Figure 6: Breakdown of primary biomass use in Ukraine, 2030



the industry and district heat sectors, whereas fulfilling needs in transport and power sectors would be more expensive. From a government perspective the Remap Options are less expensive because unless of Ukraine's subsidy regime. More renewables means importing less natural gas, which is comparatively expensive.

Figure 7 and Figure 8 ranks the costs of substitution of REmap Options and shows their contributions to the potentially increased share of renewable energy.

Table 15 shows the substitution costs of REmap Options in 2030 for Ukraine (same information plotted in Figure 7 and Figure 8). From a government perspective many biomass, biogas or biofuel technologies are cost competitive. The ones that are incrementally more expensive are biomass for industry and district heat, and solar technologies for buildings. From the business perspective, subsidised natural gas costs less and results in high substitution costs, particularly for the buildings sector.

Table 14: Substitution costs of REmap Options by sector, 2030

	Business perspective (national prices) (USD/GJ)	Government perspective (international prices) (USD/GJ)
Industry	1.3	3.7
Buildings	12.0	-4.8
Transport	0.6	-4.3
Power	-2.4	0.3
District heat	-0.5	-6.3
Average of all sectors	2.6	-0.5

Figure 7: Renewable energy cost supply curve by renewable energy resource in 2030 from the business perspective

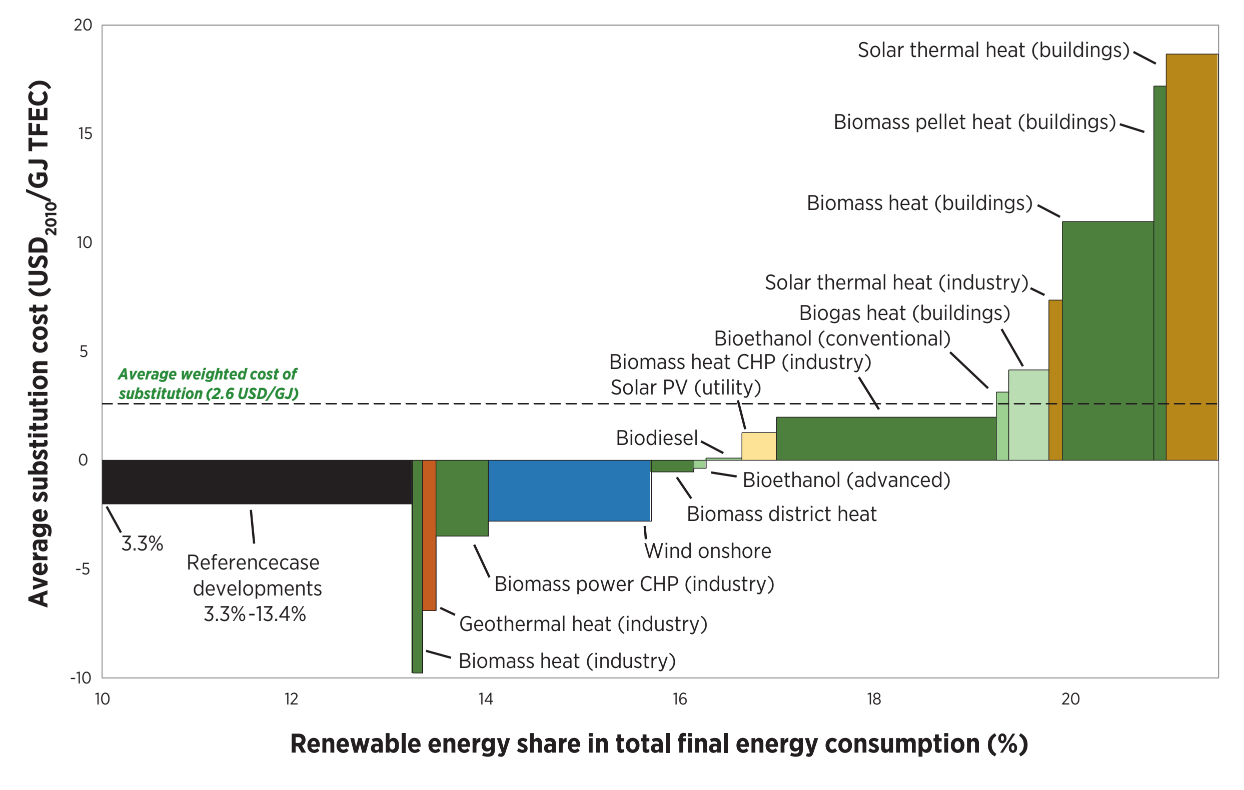


Figure 8: Renewable energy cost supply curve by renewable energy resource in 2030 based on the government perspective

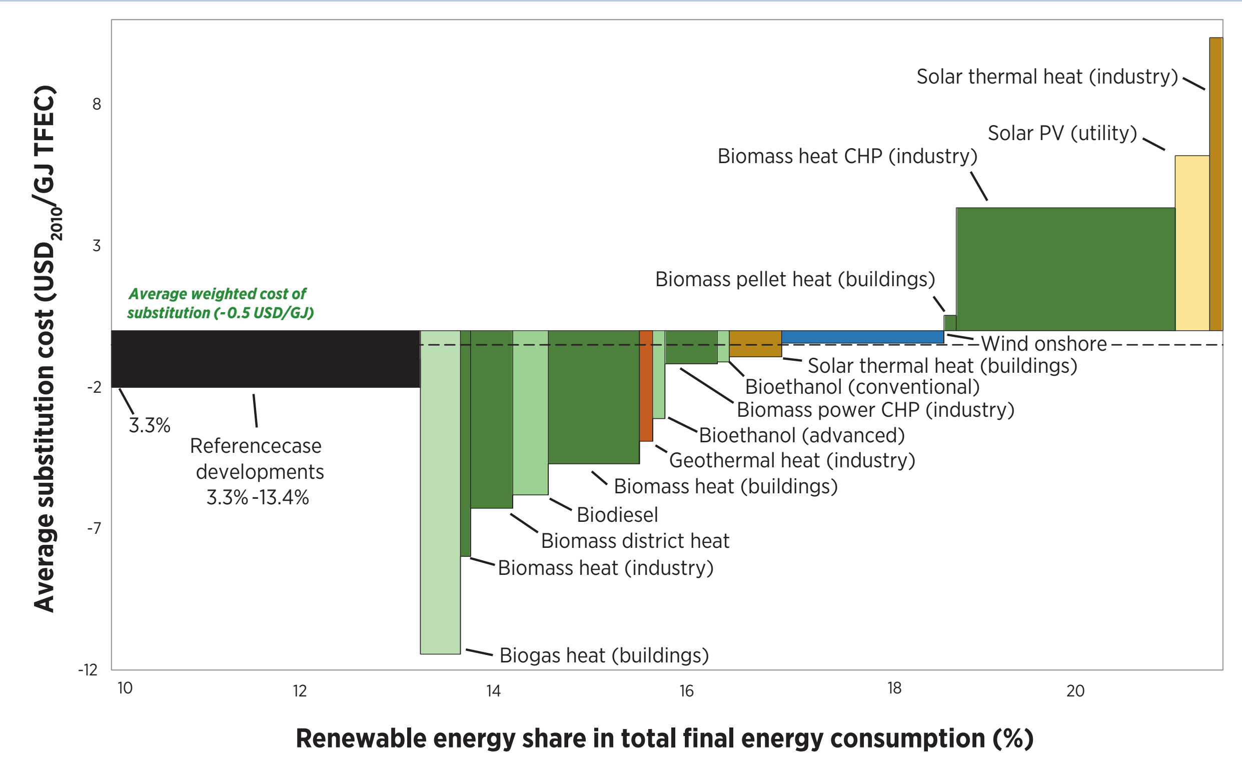


Table 15: Substitution costs of REmap Options by technology in 2030 based on the perspectives of government and business

	Government perspective (USD/GJ)	Business perspective (USD/GJ)
Heating sector		
Biomass steam cycle (district heating)	-6.3	-0.5
Biomass boilers (industry)	-8.0	-9.8
Industrial CHP	4.3	2.0
Space heating: Biogas (households)	-11.4	4.2
Water heating: Biomass (households)	-4.7	11.0
Space heating: Pellet burners (households)	0.5	17.2
Solar thermal (industry)	10.4	7.4
Water heating: Solar (households)	-0.9	18.7
Geothermal (industry)	-3.9	-6.9
Power generation sector		
Wind onshore	-0.4	0.1
Solar PV (utility-scale)	6.2	1.3
Industrial CHP	-1.2	-3.5
Transport sector		
Biodiesel	-5.8	-0.4
Conventional bioethanol	-1.1	3.1
Advanced bioethanol	-3.1	-0.5

The only renewable option for power generation that would be costlier is wind power, however by only a small increment. Utility-scale solar PV results in a higher cost largely because of low capacity factors.

Transport sector biofuel technologies are the most cost-competitive compared to all other REmap Options, when compared to expensive gasoline and diesel.

Benefits of REmap Options

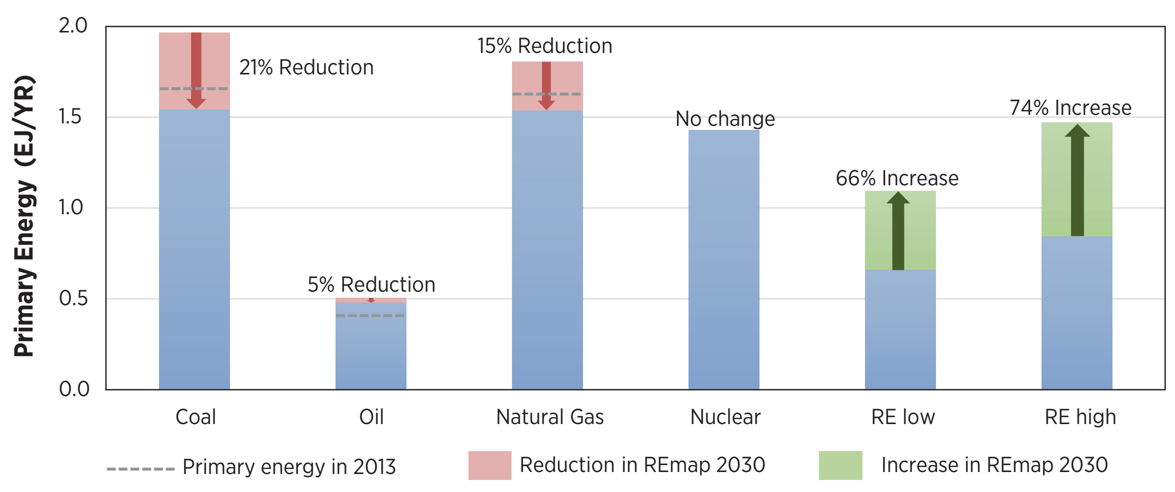
Table 16 shows the developments in fossil fuel demand between 2010 and 2030 in Ukraine. REmap Options would reduce total fossil fuel demand by 17% compared to the Reference Case. The savings range from 5% for oil products to 21% for coal. Total natural gas use in REmap 2030 would be similar to the 2012 level (approximately

Table 16: Fossil fuel saving effects of REmap Options

	Coal (PJ/yr)	Oil (PJ/yr)	Natural gas (PJ/yr)	Total (PJ/yr)	CO_2 emissions (Mt/yr)
2010	1 557	448	1 660	3 665	274
2012	1 745	429	1 520	3 695	283
2030 Reference Case	1 986	506	1 805	4 297	325
REmap 2030	1 545	480	1 539	3 564	268
Reductions:					
Compared to Reference Case	22%	5%	15%	17%	18%
Compared to 2012 level	11%	-12%	-1%	4%	5%

Sources: data for 2010 and 2012 are based on IEA (2014a)

Figure 9: Fossil fuel savings and the growth in total renewable energy use, 2030



43 billion m³), and 16% lower than the Reference Case (7.6 billion m³ savings). Coal use would be 11% lower compared to 2012 levels and oil products use 1%. Renewables will play an important role to reduce the demand for coal and natural gas by 2030.

The table also shows an 18% reduction in carbon dioxide (CO_2) emissions from REmap Options compared to the Reference Case or 57 Mt per year. Of this total, 70% of the savings is from power generation. The remainder is split between 20% heating and 10% transport.

Figure 9 shows the same information about the savings in fossil fuel use as a result of the REmap Options and also highlights the change in total renewable energy use between the Reference Case and REmap 2030. If all REmap Options identified in this study are to be implemented by 2030, renewable energy use would grow by between 66% and 74% compared to the Reference Case. As a result, renewables would be the third largest source of energy following coal and natural gas.

Table 17 shows a number of financial indicators for Ukraine (all from a government perspective). REmap Options result in savings of USD 175 million per year in 2030. Externalities related to human health can increase these savings by USD 0.1 billion to USD 0.3 billion per year. Based on a price range of USD 20 to USD 80 per tonne for CO_2, related externalities can save another USD 1 billion to USD 5 billion per year. Therefore, when accounting for externalities REmap Options can result in total savings of up to USD 5.5 billion per year in 2030.

Total investment needs in renewables to 2030 will amount to USD 5.0 billion per year on average. Spending at USD 2.5 billion per year is required to fulfil the Reference Case, and an extra USD 2.5 billion per year would be needed to develop the REmap Options. Technologies which require a subsidy (positive substitution costs from the government perspective) lie in solar thermal for heating, solar PV, onshore wind and various biomass-based heat generation technologies. The subsidy need per MWh of final renewable energy is equivalent to USD 11, excluding the effect of any carbon price.

The table also shows that Ukraine can cut its energy bill by USD 4.7 billion a year by implementing REmap Options that use less fossil fuels. Of that total, USD 2.9 billion, or about 60% of the savings, would be from lowering natural gas imports. Remap Options would increase costs for biomass however, by USD 1.5 billion per year. Hence the net fuel savings in 2030 with REmap Options is estimated at USD 3.2 billion per year over the Reference Case.

Implications of renewables on Ukraine's natural gas use

The government's aim is to halve gas consumption through various measures, and by 2018 eliminate its dependence on imported gas (Figure 10). Ukraine would also meet all its potential demand, 21.5 billion cubic meters, with domestic production. About 40% of the total would be used for industry, but that supply would

Table 17: Financial indicators for renewable energy use in Ukraine from the government perspective

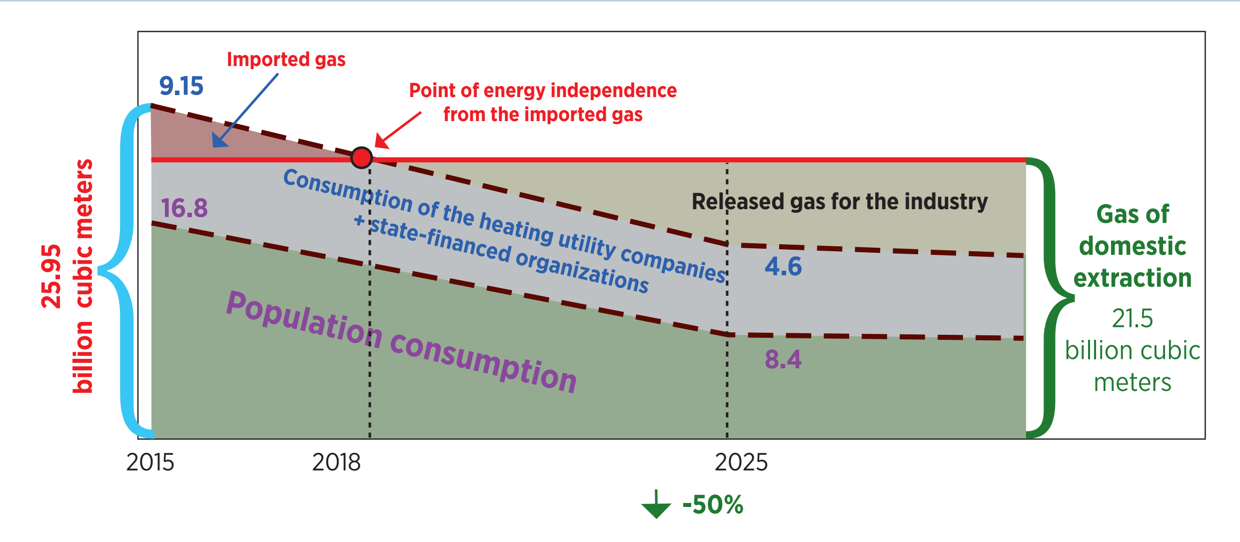
Energy system costs in 2030 (USD bln/yr)	
Incremental system cost in 2030	-0.2
reduced human health externalities	from 0.1 to 0.3
reduced CO_2 externalities	from 1 to 5
System costs with externalities in 2030	from -1.3 to -5.5
Incremental subsidy needs in 2030	4.7
Investment needs, average in the period 2010-2030 (USD bln/yr)	
Investment needs (REmap Options)	2.5
Total renewable energy investment needs (REmap Options and Reference Case)	5.0
Savings from fuel-use reductions compared to 2030 Reference Case (USD bln/yr)	
Coal (saving)	1.3
Oil (saving)	0.5
Natural gas (saving)	2.9
Biomass (additional)	1.5
Total savings	3.2

Note: Energy bill savings are estimated based on national end-user prices.

not be available without the actions adopted by the government. The remaining 60% would be used by retail consumers and utility companies.

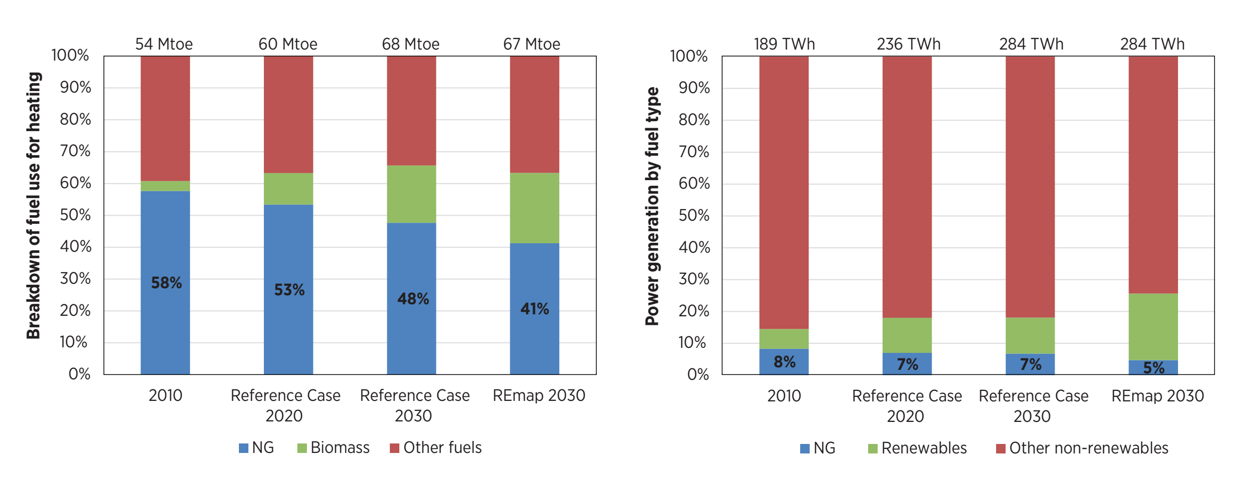
Based on the assumptions made in this study Figure 11 shows the evolution of the fuel mix for Ukraine for heating and power generation between 2010 and 2030. The main assumption is that as Ukraine's TFEC grows, there will be no change in conventional-fuel use mix between 2010 and 2030 in the Reference Case (including fossil fuels and nuclear power). Natural gas would continue to account for half of the total fuel demand for heating, a share that is only slightly lower than the 2010 level of 58%. Consumption of gas for heating would increase by 4% between 2010 and 2030, but biomass by more than seven times. Natural gas use for power generation would remain at the 2010 level in 2030, whereas demand for renewables and non-renewables would increase by three times and 45%, respectively. Natural gas would account for 7% of the total power generation by 2030 compared to 8% in 2010.

Figure 10: Roadmap for halving natural gas consumption in Ukraine



Source: Savchuk (2014)

Figure 11: Developments in Ukraine's total primary energy mix for heating and power generation, 2010-2030



If the current policies remained unchanged there would be fewer factors shrinking natural gas demand in the period to 2030. However with all REmap Options implemented demand for natural gas for heating and power generation would drop by 15% by 2030 compared to 2010 levels. This estimate assumes that renewables displace mostly natural gas for heating and to some extent for power generation. Exceptions would be onshore wind and biomass for CHP, both of which would displace coal. Some natural gas would be required still to maintain the flexibility of the power system at higher levels of renewable-based power generation. Reducing gas demand by 50% through the use of renewables would require energy-efficiency enhancements and continued fuel switching. Furthermore, increasing domestic gas production and storage, and diversifying supply (*through* LNG imports for example) could also help.

8. BARRIERS AND OPPORTUNITIES FOR RENEWABLE ENERGY TRANSITION

Ukraine's energy system offers a number of commercial opportunities for both new construction and refurbishments, given the outdated power-and-heat production capacities and the demand growth expectations. There is also a growing business case for renewables for district heating and industry, as both of these sectors are increasingly paying high prices for their natural gas. The NREAP to 2020 and the longer-term Ukrainian energy strategy are promising steps to planning and target setting that will help to accelerate the uptake of renewable energy in Ukraine. However barriers remain that could inhibit the greater use of renewable-energy resources in Ukraine.

Overcoming these barriers starts with increased understanding of renewables, their potential, cost and benefits. In terms of resource assessment capabilities, Ukraine enjoys advanced capacity to measure biomass flows and estimate annual availability for energy use. In the case of wind, Ukraine's second-largest renewable energy resource, a lack of national wind measurements in accordance with international standards creates a challenge. Comprehensive measurement campaigns are essential for ensuring investor confidence and developing bankable projects. For example, waste streams offer an important alternative to fossil fuels in the agro-food sector but awareness of opportunities for utilising their energy content is low. Developing bankable projects also requires management and planning among suppliers of equipment and potential users.

The share of variable renewables in total power generation increases to 15% in REmap 2030. According to the local power industry estimates, there is a potential to cover 6 GW of variable renewables with dispatch capacity, which is lower than the 20 GW capacity estimated in REmap 2030. It will be necessary to plan for the potential growth in variable renewables as part of the modernization of the transmission and grid infrastructure. Replacement of the aging power plant capacity in the short-term also offers an important opportunity as new capacity can be designed by considering the need for flexibility to maintain a higher share of variable renewables in the power system. Additionally, enhanced interconnection capacity could be considered with neighbouring countries.

From government there is a need for streamlined permitting procedures and improving electricity-market access for renewables producers. There is also a lack of cost-recovery mechanisms and clear procedures for grid connection. More knowledge about grid constraints and grid stability will be important to help determine the best construction strategies for renewable energy plants. More should also be done to assess affordability and define the fuel mix for power generation (for both renewables and non-renewables), to keep power prices from uncontrolled growth. Finally, availability of incentives for small and medium-size projects will be important in view of the estimated potential in the residential sector as well as for Ukraine's industry sector, with many small and medium-scale plants.

Ukraine should also develop systems for standardisation and certification of solid and liquid biofuels. Local-content requirements combined with the lack of domestic production of modern renewable energy equipment limits the availability of affordable and reliable equipment. Domestic biomass boilers are expensive per unit of capacity, and also not available in large capacities. Biogas plants are expensive and generally produced with foreign expertise, even though such plants could be locally produced at much lower cost.

Biomass will clearly be the main source of renewables in Ukraine in the future, however there are no regulations to mandate the use of bioenergy where an exploitable resource exists. One example that could be implemented is the compulsory inclusion of a biogas plant in major new projects by agro-food companies. In addition to demand-side policies to accelerate capacity deployment, policy support will be necessary to create a sustainable and affordable biomass supply market. There is a significant supply potential, but how it will be utilized needs to be carefully planned when meeting the future demand growth. Ukraine has a large territory and the biomass resource potential is dispersed across the country. While locating processing and conversion plants close to supply areas will be priority, utilising the biomass supply potential will still require transport infrastructure to ensure supply meets demand in heating, power generation and biofuel production plants that are mainly in central and eastern parts of Ukraine. This is a major barrier to exploit Ukraine's forestry for the heating and power generation sectors. For cost-effective supply of biomass, existing road and rail infrastructure will require improvements.

The use of straw is hindered by significant collection cost, and the fact that most agricultural enterprises lack the ability to collect, bundle and adequately store straw. There is no wholesale market for biomass products and the practice of agreeing to long-term biomass supply contracts between producers and consumers is not yet established. Pre-commercialization costs are high which limits reaching economies of scale. There is also an untapped potential to improve agricultural yields. Wheat yields in Ukraine are 2.7 tonnes per hectare today, compared to the world average of 2.86 tonnes and Western Europe average of 8 tonnes per hectare. Thus far, limited improvement has been observed in Ukraine's agricultural yields. Closing this yield gap will be important to make land available for energy crop production (van der Hilst *et al*. 2013).

Another important issue is land use and land ownership. During the land reform, land was distributed to the workers of the collective and state farms. Today, most landowners lease their land. This has led to the rise of agriculture holdings which are increasingly accounting for a larger share of land ownership, and potentially having more power in controlling and decision making for Ukraine's land use and agriculture sector (Plank, 2013). New policies to increase energy crop and agricultural residues supply would need to be formulated carefully to ensure sustainability by considering the specific characteristics of the Ukrainian land ownership.

Based on the NREAP and Ukraine's Energy Strategy, this study assumes that the total final energy demand will grow at moderate rates of about 1.3% per year as opposed to today's trends where total demand decreases. If the future demand follows today's developments, there could be two implications on the total renewable energy use and shares. The first implication could be that the total renewable energy use may also grow at slower rates by following the total demand. This because the need for new capacity is lower, which may reduce the future renewable energy shares. The second implication is when the absolute renewable energy use grows identical to what is envisioned by Ukraine's government plans. Compared to lower total final energy demand, this would cover a higher share and would raise the total renewable energy share as opposed to what has been estimated in this study.

Today, the global renewable energy sector is facing a number of risks in utilizing its potential. Ukraine may also face similar risks in realizing the REmap 2030 potential. The first is related to the high costs of capital for renewable energy investments. Capital costs are usually influenced by local economics when plants are built, such as conditions for financing, depreciation, and potentially also by the type of investor or financier. These can be local companies, foreign ones, or the state, either directly or through government-owned mechanisms. Today the cost of financing in Ukraine is high. In 2014, interest rates for Hryvnia-denominated loans exceeded 25%. High cost of financing acts as a barrier for investment. Furthermore, most industrial ventures in Ukraine have narrow profit margins and have limited ability to invest in modernisation and the high interest rates, lowers access to funds. In the first half of 2014 the total loan portfolio of the Ukrainian banking system decreased by 8% due to high interest rates and banks' reluctancy to lend. Removing the key risk factors will help accelerate lending in Ukraine. Until that is achieved, measures such as injecting banks with more capital, providing liquidity and exploiting international sources of funds and expertise could be important. The second most important risk is the changing renewable energy policy that creates lack of confidence investors. Predictable and stable policies that can be maintained over long periods will be important for the continuity of investments in renewable energy technologies. Finally, a significant share of the current renewable energy capacity as well as the resource potential that needs to be utilized in reaching both the NREAP 2020 targets and the REmap 2030 estimates lies in the Eastern parts of Ukraine.

Based on the findings of this analysis, and the above discussion of barriers to renewable energy deployment in Ukraine, these suggestions are proposed to accelerate the uptake of renewable energy in Ukraine:

- Modernise and improve the efficiency of the existing power generation and heating capacities with new investments for energy efficiency and renewables
- Complement and improve energy efficiency and security by diversifying natural gas imports and increasing production of indigenous natural gas
- Increase investments both domestic and foreign in new capacity by easing the procedure to qualify for green tariffs, by developing incentives for small-scale investors, and by creating financing through affordable loan products such as loan guarantees
- Add knowledge on resource potential and the cost and benefits of renewables, and develop norms, rules, standards and definitions
- Utilise local manufacturing capacity to create an affordable market for renewable energy equipment
- Develop a national transmission and distribution grid plan that considers more than a 15% share of generation from wind and solar, and consider flexibility in newly constructed thermal power plants
- Develop collection systems for agricultural residues and invest in infrastructure for the sustainable recovery of forest biomass

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LIST OF ABBREVIATIONS

CHP	combined heat and power
CO_2	carbon dioxide
CoM	Cabinet of Ministers
EC	European Commission
EJ	exajoule
EnC	Energy Community
EC	European Commission
EU	European Union
EUR	Euro
FiT	feed-in-tariff
FSU	Former Soviet Union
Gcal	gigacalories
GDP	gross domestic product
GFEC	gross final energy consumption
GHG	greenhouse gas
GJ	gigajoule
GT	green tariff
GW	gigawatt
ha	hectare
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
kt	kilotonne
kWh	kilowatt-hour
LFG	landfill gas
LNG	liquefied natural gas
m^2	square meter
m^3	cubic meter
MSW	municipal solid waste
Mt	megatonne
MW	gigawatt
NCSEPUR	National Commission for State Energy and Public Utilities Regulation
NERC	National Electricity Regulatory Commission
NO_x	mono-nitrogen oxide
NREAP	National Renewable Energy Action Plan
PJ	Petajoule
PJ	petajoule
$PM_{2.5}$	particulate matter of less than 2.5 micrometres
PV	photovoltaic
SAEE	State Agency on Energy Efficiency and Energy Savings of Ukraine
SE4ALL	Sustainable Energy for All
SHP	small hydro
SSGCC	State Service of Geodesy, Cartography and Cadaster
SSSU	State Statistics Service of Ukraine
SO_2	sulphur dioxide
t	tonne
TFEC	total final energy consumption
toe	tonne of oil equivalent
TWh	terawatt-hour
UAH	Ukrainian Hryvinia
USD	US Dollars

ANNEX A:

Technology cost assumptions for 2030

	Overnight capital cost (USD/kW)	Capacity factor (%)	LCOH / LCOE (USD/GJ)
Industry			
Solar thermal	800	10	25
Geothermal	1 500	55	11
Biomass boiler (harvesting/processing residue)	500	85	7
Solid biomass industrial CHP (wood residue/waste)	See below in power sector	50	20
Natural gas boiler (industry)	100	50	18
Buildings			
Biomass water heater (fuelwood, wood pellets)	600	30	20
Biomass pellet burner	770	30	26
Biogas heating (biogas)	800	50	11
Solar water heater	700	10	25
Natural gas heating (households)	160	80	16
Power			
Wind onshore	1 500	31	21
Solar PV (utility-scale)	1 400	15	40
Solid biomass industrial CHP (wood residue/waste)	3 000	50	20
Coal	1 300	40	21
Natural gas (power generation)	1 000	30	38
District heat			
Biomass (harvesting/processing residue)	750	85	9
Natural gas (district heating)	300	85	9

LCOH: levelised cost of heat; LCOE: levelised cost of electricity

ANNEX B:

Energy price assumptions for 2030

	(USD/GJ)	Comments and sources
Coal	3.0	Steam coal prices for 2010 was assumed as USD 2.7 per GJ in Ukraine in 2010 (EPA/GMI, 2013). According to IEA (2011), coal prices are projected to increase by about 10% between 2010 and 2030.
Natural gas (household)	4.6	According to the IEA (2012b), household natural gas prices were USD 2-3 per GJ, industry natural gas prices were USD 9 per GJ, and district heating natural prices were USD 4-5 per GJ (all including value added tax). Import prices of natural gas were slightly lower than the industry natural gas prices, but there is an overall relationship between the natural gas price developments for all sectors and import prices. Based on the European natural gas import price growth estimates according to the IEA (2011) of 55% between 2010 and 2030, the 2030 prices are estimated.
Natural gas (industry)	13.8	
Natural gas (district heating)	6.9	
Gasoline	47	According to the GIZ (2012), gasoline price in Ukraine was USD 1.01 per liter.
Ethanol	45-48	Assessments for bioethanol projection cost based on IRENA analysis. Conventional bioethanol is assume to have the same price increase as gasoline. Advanced bioethanol is assumed to have a 20% reduction in production price over current best practice assumptions. Normal fuel taxes in line with those for gasoline are assumed.
Diesel	39	According to the GIZ (2012), diesel price in Ukraine was USD 0.92 per liter.
Biodiesel	39	Same as biodiesel
Energy crops	8.9	These data refer to supply costs and are based on IRENA (2014b)
Harvesting residue	4.9	
Processing residue	2.7	
Biogas	2.7	
Fuel wood	7.9	
Wood residue/waste	11.5	

ANNEX C:

Country meeting minutes

SAEE and IRENA organized the REmap Ukraine final country meeting in Kiev on March 12, 2015. The meeting took place at the premises of the Institute for Renewable Energy, National Academy of Sciences. The meeting was attended by about 25 participants representing the following organizations:

1. International Renewable Energy Agency (IRENA)
2. Ministry for Regional Development, Building and Housing of Ukraine
3. Ministry of Energy and Coal Industry of Ukraine
4. Ministry of Agrarian Policy and Food
5. State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE)
6. Ukrainian Wind Energy Association
7. Bioenergy Association of Ukraine
8. Association of Renewable Electricity
9. Association of Alternative Fuels and Renewable Energy of Ukraine
10. Institute for Renewable Energy, National Academy of Sciences
11. UNIDO/GEF
12. GIZ Ukraine

The aim of this official meeting was to present the final version REmap Ukraine background paper to Ukraine policy makers and the renewable energy industry associations. The final version of the report was released for feedback and comments to participants one week in advance, in order to take any final feedback into account.

The meeting started with the introduction of the SAEE and the National Academy of Sciences (hosting the meeting and closely working the SAEE in energy issues). The introduction was followed by two IRENA presentations. IRENA presented its overall structure, and the various thematic areas of work, including the REmap project. The second IRENA presentation focused on the detailed results of REmap Ukraine. Several participants provided feedback to the analysis during the meeting.

Summary of the feedback received

- Clarify whether there is a pessimistic and an optimistic scenario of renewable energy use in Ukraine in REmap 2030;
- Discuss the results by elaborating on the risks that are being faced today in Ukraine today. Three main risks to renewable energy were mentioned: i) investment risks related to the current political situation in Ukraine, which result in high interest rates, ii) territory issues where a large share of Ukraine's renewable resource potential exists, 3) instability in Ukraine's renewable energy policies;
- This is the first study where biomass use is assessed at the level of all sectors, which also shows that biomass can contribute to large share of Ukraine's total final energy consumption;
- The growth in total final energy consumption between 2010 and 2030 may not be realistic in view of the historical trends. No growth in TFEC between 2013 and 2030 is more realistic;
- By 2030, a 20% share of biomass use in the heating sector is realistic, which is slightly lower than the estimates of REmap 2030 of approximately 25%;
- At least 60% share of biomass supply is expected to be from energy crops and agricultural residues, which is in line with REmap estimates (70-90%);
- There is a potential to cover 6 GW of variable renewables with dispatch capacity. It may not be possible, for the 20 GW capacity estimated in REmap;
- National Academy of Sciences has estimated the potential of renewables for the power and heating sectors for the years 2030 and 2035. According to these estimates, wind power capacity reaches 10 GW by 2030, and 16 GW by 2035 (in both years 3000 full load hours per years). For solar PV, total installed capacity reaches 4 GW by 2030, and 8 GW by 2035. Renewable energy

share in power generation reaches 22% in 2030 and 28% in 2035. Biomass heat reaches 10 Mtoe per year, and a total of 1.6 GW biomass power generation capacity can be installed by 2030;

- There is a working group established for the development of the power industry and the transmission and grids with a ten year focus. The aim is to identify how much renewable power can be added to the grid;
- In such analysis, it is necessary to cover all types of renewable energy sources, not only biomass or wind, so REmap approach makes an important step forward;
- With the support of IRENA, action is needed in Ukraine for renewable energy deployment at both national and international levels. National and international efforts need to be done in parallel. REmap Ukraine study is a good basis for action for communication with the government as well as the fossil fuel and nuclear power lobbies.

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