GREEN ECONOMY OPTIONS FOR UKRAINE:
Opportunities for greening the energy sector

POLICY BRIEF

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FOREWORD

The *Policy Brief on Green Economy options for Ukraine: Opportunities for greening the energy sector* was prepared in 2014-2016. The modelling analysis was developed using the energy sector data and information, national policy documents (including strategies, action plans, etc.) available for that period. Various targets, which were assessed in the modelling study, are from the Ukraine's Energy Strategy 2030.

Since the time of preparation of the modelling analysis, the situation in the energy sector of Ukraine has drastically changed. One of the important changes has been made in the policy framework of the sector: Ukraine adopted a new Energy Strategy through 2035. Other policy, institutional and administrative changes have been occurring. These updates of the policy and administrative progress are summarized and presented on page 4 of this document – "Update since 2016".

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Ukraine's energy sector is subject to a number of competing influences, both positive and negative. On the one hand, the development of the sector has been negatively impacted by an unstable energy supply, the persistence of below-market energy prices, and instability in the eastern region of the country. On the other hand, positive influences stimulate the sector such as the government's long-term sectoral development strategy, an actively engaged and technically strong non-governmental organization sector, and increased cooperation with the EU and international financing bodies.

Despite challenges related to both the structure of the sector and the recent instability, there are a number of opportunities for the greening of Ukraine's energy sector. For example, reforms to subsidies and energy prices can drive efficiency as well as the development of renewable energy resources. Similarly, regulatory reforms can promote the implementation of energy efficiency measures; education and capacity-building can raise public awareness and drive changes on the demand side; and access to public and private financing channels can support growth in renewable energy. These measures can address energy demand gaps, increase energy security and assist in meeting Ukraine's renewable energy and greenhouse gas (GHG) reduction targets, presented in Ukraine's Intended Nationally Determined Contribution (INDC).

Going forward, Ukraine will have to make sure that its policies and plans reflect the changing dynamics in the country, increase ties with regional initiatives and partners that can support energy efficiency and renewable energy, and ensure a workforce that can support a green transition.

THE ROLE OF THE ENERGY SECTOR IN PROMOTING THE GREEN ECONOMY TRANSITION

UPDATE SINCE 2016

The *Policy Brief on opportunities for greening the energy sector of Ukraine* was prepared during 2014-2016 and was based on national statistical data up to 2015. The simulation analysis, its main conclusions and recommendations were prepared while taking into account national targets and plans set in Ukraine's Energy Strategy for 2030.

Since the time of preparation of the initial document and the simulation analysis, the situation in Ukraine has changed dramatically. The ongoing conflict in the Donbas area, which started in 2014, has been affecting the whole energy system, infrastructure and policy in Ukraine. Domestically produced coal supply is cut, and coal is imported from abroad. National energy companies look for alternatives to coal for energy production. The government develops policy on energy independence, including increasing its own natural gas production and diversifying its energy resources.

Many positive changes have happened, too. Ukraine adopted a new Energy Strategy through 2035 – a much more ambitious strategy than the previous one. The energy sector, among other sectors, has been reforming: between 2014 and 2016 gas prices for the population were increased in three stages, aiming at a reduction of energy use and the promotion of energy-efficiency practices. Renewable energy, energy efficiency and savings became the priority issues for the modernization of the energy sector. A new electricity market is under discussion by experts. New policy documents on low-carbon development and greenhouse gas (GHG) emissions reduction were adopted.

In 2017 Ukraine joined the International Renewable Energy Agency (IRENA), which provides access to new funds from the Abu Dhabi Fund for Development and to the IRENA database, opportunities for improvement of legislation and new investments, and a platform for cooperation with countries that are leaders in the field of renewable energy.

In 2017, the State Agency on Energy Efficiency and Energy Savings of Ukraine developed and presented a draft of a new mechanism for promoting energy efficiency to energy-intensive enterprises in the form of carbon tax funds that will be accumulated and directed exclusively to finance energy efficiency measures and a shift to renewable energy sources (a new mechanism is under discussion now). A special Energy Efficiency Fund was launched in December 2017, is intended to work on implementation of the mechanism (State Agency on Energy Efficiency and Energy Savings of Ukraine, 2018). The carbon tax system works well in many developed countries.

Under the National Action Plan on Energy Efficiency, an energy services company (ESCO) module was launched for the purchase of energy for public buildings. As of end of 2017 about 180 ESCO tenders for public buildings in 19 cities of Ukraine were issued via the online public procurement system, where the main criterion of energy efficiency of the final product was applied. Ukraine expects to issue another 250 public tenders in 2018. Initiatives on energy management and monitoring of public buildings in 93 cities and nine administrative units (oblasts) were supported, and four technical regulations on energy labelling were adopted.

Ukraine's Energy Strategy through 2035

The Strategy will be implemented in three main stages:

- Energy sector reform by 2020 – the main priorities are reform of national energy companies; increase of natural gas extraction; creation of a coal market; a decrease in energy intensity of GDP; adherence to high ecological standards of energy production, transportation and consumption; an 11 per cent increase in the share of renewable energy resources; implementation of the National Plan on GHG emissions reduction from large combustion plants; and integration of Ukraine into the European Networks of Transmission System Operators for Electricity and Gas (ENTSO-G and ENTSO-E);
- Optimization and innovation development of energy infrastructure by 2025 – the main priorities are to increase domestic natural gas extraction to a level that fully covers needs; to develop smart grids; to create local systems of energy supply; to install and improve accounting systems and self-management of consumer demand for energy resources; to develop infrastructure for electric transport; and to implement investment projects;
- Sustainable development of the energy sector by 2035 – the main priorities are to increase natural gas extraction, including from shale; to reduce GHG emissions; to have 25 per cent of energy come from renewable resources; to apply "passive house" technology.

The state programme on "warm" credits aims to support modernization of energy devices and to promote energy efficiency and saving activities.

The system of subsidies for people with low and insufficient income enables the population to pay the energy bills.

Ukraine's Energy Strategy foresees that by 2035 the share of fossil resources will be 75 per cent and the share of renewable resources will be significantly increased and will reach 25 per cent of the energy supply (biomass can contribute as much as 11.5 per cent by 2035). (See Table 1)

Table 1. The structure of total primary energy supply in Ukraine, %.

Source of primary energy supply	2015	2020*	2025*	2030*	2035*
Coal	30.4	22.0	16.1	14.3	12.5
Natural gas	28.9	29.3	31	30.8	30.2
Oil products	11.6	11.5	9.2	8.2	7.3
Nuclear	25.5	29.3	32.2	29.7	25.0
Biomass, biofuel and energy from waste	2.3	4.9	6.9	8.8	11.5
Wind and solar	0.1	1.2	2.4	5.5	10.4
Hydro	0.5	1.2	1.1	1.1	1.0
Thermal	0.6	0.6	1.1	1.6	2.1
Total primary energy supply	**100**	**100**	**100**	**100**	**100**
Fossil resources	96	92	88	83	75
Renewable resources	4	8	12	17	25

** Forecast*

Source: Ukraine's Energy Strategy through 2035 (2018).

New electricity market

In June 2017 a new law on the electricity market entered into force. The law applies a new approach to the generation and distribution of electricity, and introduces new market participants and a new procedure for setting tariffs. The new electricity market law provides for the introduction of a new electricity market structure, which is being redesigned in order to dissolve old monopolies.

The model introduced by the law focuses on the free formation of market prices, and comprises five new segments: a market for bilateral sale contracts with market participants (commercial consumers); a day-ahead market; an intraday market; a balancing market; and a market of ancillary services.

National plan on emissions reductions from large combustion plants by 2033

The aim of the Plan is to reduce emissions (SO_2, NO_x and suspended solids particles) from existing large combustion plants with thermal capacity of 50 MW and more. The plan also provides a list of the combustion plants that will be closed by 2023, and identifies activities to improve the natural absorption of pollutants. This national plan is a solid background document for international financial institutions and potential investors in the energy sector of Ukraine.

Draft low-carbon development strategy

The draft strategy was presented to meet Ukraine's commitment to reduce GHG emissions by 60 per cent compared to the 1990 level under the Paris climate agreement. It aims to enable the transition to an energy system that uses low-carbon energy sources; to develop clean electricity and heat sources; to promote energy efficiency and energy saving in all sectors of the economy and in housing and communal infrastructure; to encourage the use of alternative petroleum products for transport and the use of environmentally friendly modes of transport; to increase absorption by applying best climate change adaptation practices in farming and forestry; and to reduce GHG emissions. In addition, on 7 December 2016, the Cabinet of Ministers of Ukraine approved the concept for realization of the state policy in climate change for the period up to 2030.

SECTORAL OVERVIEW [1]

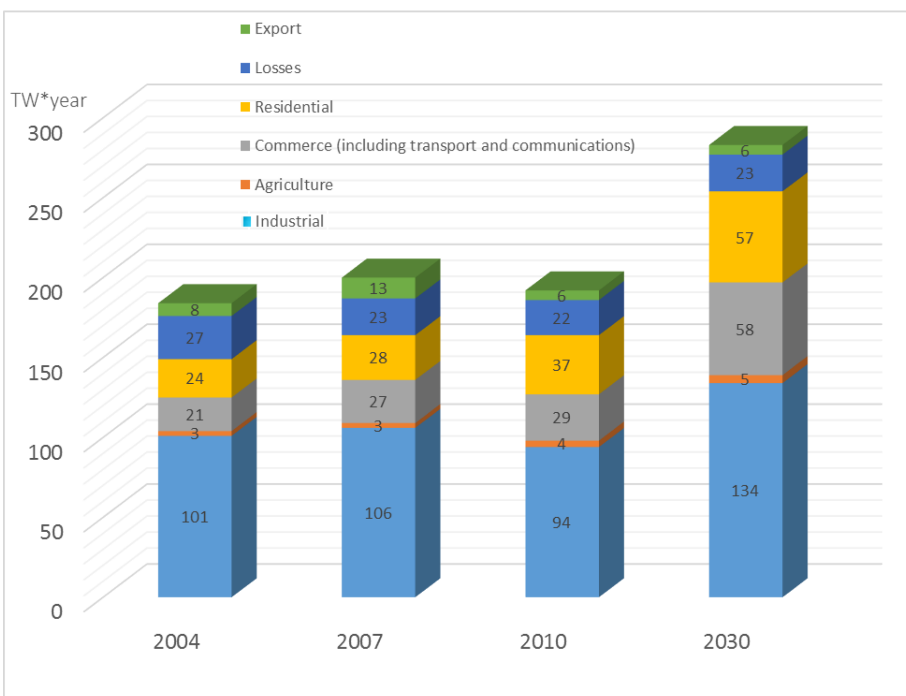
After a sharp decline of 47 per cent in the 1990s, Ukraine's total primary energy supply was relatively stable over the 2000s. According to the State Statistics Service of Ukraine, in 2014 the country's total primary energy supply amounted to 105,683,000 tonnes of oil equivalent, while total energy consumption came to 61,460,000 tonnes of oil equivalent. The country's primary energy mix indicates a highly emissions-intensive energy sector, where fossil fuels (coal, oil and gas) account for roughly 75 per cent, while 21 per cent derive from nuclear power and less than 1 per cent from renewable energy sources (hydropower, wind and solar energy). The country depends on significant imports of oil and gas (IEA, 2012). Before the conflict in Eastern Ukraine in 2014, most of the coal used for energy in Ukraine was domestically produced. Ukraine ranked sixteenth in global coal production in 2014 (British Petroleum, 2012). Per capita use was roughly 2,334 kg of oil equivalent, while per capita greenhouse gas emissions were 6.26 metric tonnes in 2014 (World Bank, 2016).

Ukraine has historically been one of the larger CO_2 emitters per unit of GDP in Europe (E5P, n.d.). Currently GHG emissions are substantially lower than historical highs, decreasing from roughly 953.1 million metric tonnes of carbon dioxide equivalent (Mt CO_2e) in 1990 to 404.9 Mt CO_2e in 2012 (Government of Ukraine, 2015). There is also evidence of continued emission reductions as a result of the economic downturn and infrastructure damage caused by the current conflict in the east of the country. It should be noted that despite this decrease, Ukraine's energy sector remains a strong driver of emissions, given its heavy reliance on fossil fuels.

Overall energy efficiency is low and below that of many EU countries. An International Energy Agency (IEA) report from 2012 identifies significant untapped potential in Ukraine's energy sector with respect to modernization and renewables. For instance, the percentage of the country's residential buildings that are equipped with heat metering devices remains small (UNDP, n.d.). For the immediate term, however, a heavy focus remains on the use of fossil fuels, in particular natural gas and coal.

According to Ukraine's Energy Strategy for 2030, the demand for electricity is expected to grow by nearly 50 per cent in 2030, driven primarily by increases in electricity demand in the manufacturing, commerce and residential sectors (Figure 1). Similarly, the Ukrainian government acknowledges that significant reconstruction will be necessary in the country's manufacturing facilities, gas and oil pipelines, and other infrastructure (Government of Ukraine, 2015). This will require substantial capital investment and could have a major impact on future energy demand. Coupled with efficiency challenges and the current political instability, Ukraine is faced with an imminent energy demand gap that needs to be addressed.

Figure 1: Demand for electricity



Source: Energy Strategy of Ukraine for the period until 2030 .

[1] Also see the information on "Update since 2016" text box (p.4).

POLICY LANDSCAPE[2]

Among the legislation and policies guiding the development of Ukraine's energy sector are the National Action Plan on Energy Efficiency, the Ukraine Energy Strategy for 2030, the National Plan on Renewable Energy, and the Intended Nationally Determined Contribution submitted in 2015.

Additional supporting legislation includes the Economic Programme for Development of Industry, the Transport Strategy of Ukraine, and the Development Strategy for Agriculture, the Low-carbon Strategy and others.

National Action Plan on Energy Efficiency

Ukraine's National Action Plan on Energy Efficiency for the period until 2020 sets an intermediate goal of reducing energy consumption by 5 per cent by 2017 (SAEE, 2015). With energy tied closely to fossil fuel use, this action plan can be a significant contributor to the country's emission reduction efforts. Some specific actions outlined in the plan include:

- Encouraging investment in thermo-modernization of residential buildings (up to 25 per cent to be refurbished by 2020), in construction of buildings with near-zero energy consumption (target of 3 per cent of newly built construction per year), and in energy efficiency measures in industry;
- Improving fuel standards and technologies to European levels;
- Introducing energy efficiency certification and labels and setting minimum energy efficiency requirements for buildings and household appliances;
- Reviewing construction norms and standards, and introducing energy audits and energy management systems in buildings;
- Ensuring that 100 per cent of gas, heat and water usage is metered, introducing a billing system for consumed energy, and providing analytical information on the dynamics of energy consumption and on other utilities.

Ukrainian Energy Strategy for 2030

Efficiency is also a prominent issue in the Ukrainian Energy Strategy for 2030, which includes a 50 per cent energy intensity reduction target (UNDP, n.d.). The projection for the 2030 strategy includes an estimated annual electricity consumption of 282 TW. Without the actions included in the strategy, as well as those specifically included in the energy efficiency action plan (see above), consumption would climb to as much as 331 TW per year. In order to meet the 282 TW target, the commercial building and transport sectors have to meet an energy savings goal of 30 per cent, and distribution and transmission losses have to drop by 57 per cent.

Ukraine's Energy Strategy for 2030 also lays out a goal for reducing consumption of natural gas. Reaching the target of 49 billion cubic metres of consumption by 2030 calls for major reductions in industry consumption (53 per cent), residential consumption (33 per cent), and heat and electricity generation (27 per cent).

The 2030 strategy also indicates significant potential for continued expansion of renewables in the country, and identifies the capacity of small hydropower, solar and wind power to each reach about 3-4 GW.

[2] Also see the information on "Update since 2016" text box (p.4).

National Plan on Renewable Energy

The National Plan on Renewable Energy is linked to the 2030 Energy Strategy (see above) and notes that Ukraine's energy intensity exceeds developed country averages by a factor of three to four. The development of renewables is a key priority in lowering both the country's energy intensity and its reliance on imported fossil fuels.

At the beginning of 2014, Ukraine's renewable energy capacity was 1,419 MW – consisting of roughly 35 per cent wind power, 58 per cent solar power, 5 per cent small hydropower and 2 per cent biomass/biogas (Government of Ukraine, 2014).

The plan sets out 2020 capacity targets for specific renewable energy sources, and foresees the aggregate capacity of renewables to reach 12.6 per cent by 2030 (excluding large hydropower). The 2020 targets for the expansion of hydropower include micro (55 MW), small (95 MW) and large (5,200 MW) installations. Solar power generation capacity is also projected to grow to 2,300 MW, wind capacity to 2,280 MW, and bioenergy capacity to 950 MW. Geothermal power is also included in the national plan, projected to grow to 20 MW by 2020 (Government of Ukraine, 2014).

Energy Independence Policy

Ukraine's Energy Independence Policy calls for diversification of energy sources and routes of energy supplies (Government of Ukraine, 2014) based on:

- Increased domestic production of hydrocarbons for energy security;
- Modernization of electricity generating capacity;
- Elimination of cross-subsidies and transition to market rates for gas and electricity;
- Introduction of compensation mechanisms for the economically vulnerable;
- Construction of housing to new energy standards;
- Alternative energy projects with a focus on efficiency.

Tools to help modernize the energy sector include adopting legislative reforms in the management of gas transportation, and making efforts to attract greater investment. Major investments in construction of new energy infrastructure over the next several years are also identified as a major need, including significant investment in electricity transmission.

With regard to financing this transition, the elimination of cross-subsidies is a key part of increasing revenues from energy companies. Transparent and fair competition rules for the development of resources also go hand in hand with the transition to market rates for energy.

CHALLENGES[3]

The current conflict in the east of the country and its impact on energy infrastructure are without question the most significant challenges for Ukraine's energy sector. Since the 2014 cut in the supply of coal for energy production, the country has faced challenges on purchasing coal from abroad. Furthermore, there is a substantial need for reconstruction of the energy infrastructure that has been damaged during the armed conflict.

The IEA estimated that the cost of the modernization of the energy sector between 2012 and 2030 would be EUR 170 billion (IEA, 2012). With the current instability and ongoing conflict, however, it is likely that this figure will rise. Real GDP has declined and a recession has also taken hold as a result of the unsettled security situation. The east of Ukraine accounts for a large share of the country's industrial output and export revenue and as a result of the conflict, overall production has been down (by 10 per cent in the first half of 2014), while exports have also fallen (Prentice & Burmistrova, 2014). Estimates for 2015 have shown an overall economic contraction in the range of 5.5-7.5 per cent, coupled with the 6.8 per cent decline observed in 2014 (Vojevoda, 2015). The ongoing conflict has also led to escalation of gas prices and interruptions of service (IMF, 2014). These interruptions further contribute to declines in industrial production, reaching 4.7 per cent year-over-year decline in the period from January to June 2014 (IMF, 2014).

Even before the current security issues, however, the IEA identified challenges with Ukraine's energy and carbon intensity, oil and gas transportation routes, declining production of energy resources, and investment climate (IEA, 2012). Other significant challenges include inefficiencies in the housing and communal sectors, which account for 44 per cent of all energy consumption. Production, transportation and distribution of natural gas are also subject to significant energy losses. During the production process, losses come to 22 per cent of the production total. Then, during transportation, 25 per cent of what was available from the production stage is lost. Finally, of the amount left, 30 per cent is lost during distribution. These losses include illegal trading of natural gas, and altogether the losses represent almost 60 per cent of the original production (UNDP, n.d.).

The government sees energy dependence on Russia as one of the major challenges for energy security, economic development and the country's independence (Government of Ukraine, 2014). The dispute between the Ukrainian gas company Naftogaz and Russia's Gazprom escalated in 2014 to the point of interruption of service, and in 2018 the cooperation was suspended. The future of gas transit through Ukrainian territory is uncertain, especially in light of the latest decision of the Stockholm arbitration court (Reuters, 2018). While actions have been taken to address these interruptions, including seeking energy from EU sources (a more costly solution for the country), the current deficit of Naftogaz is a further challenge. The World Bank has classified Naftogaz's situation as a major financial risk (World Bank, 2014). Urgent energy sector reform and modernization are critical to enhancing the country's energy efficiency and supporting the recovery of the whole area of the ongoing conflict (IMF, 2014; IEA, 2014). Energy diversification and increases in domestic natural gas production are the country's priority areas.

Finally, Ukraine intensified reforms in all sectors and in combatting climate change. To implement a number of action plans, strategies and policy documents in climate change and energy security, a stable political, economic and administrative apparatus should be in place and be capable of leading the necessary reforms and modernization.

[3] Also see the information on "Update since 2016" text box (p.4).

OPPORTUNITIES FOR GREENING THE ENERGY SECTOR[4]

Ukraine has huge opportunities for green reform within the energy sector, given its largely untapped potential for energy efficiency, subsidy reform and renewable energy development, as well as its access to a network of potential domestic and international partners.

The World Economic Forum identifies significant potential in wind, solar and biomass energy in the country (World Economic Forum, 2014). The IEA noted the potential to develop biomass energy sources (IEA, 2012), which would further contribute to greening the country's energy sector. Post-conflict reconstruction and modernization of industrial facilities and infrastructure will also present opportunities to increase energy and material efficiency to European standards, while reducing industrial pollution and creating new job opportunities.

The potential for subsidy reform to address efficiency is also unrealized. The low energy efficiency in Ukraine provides an opportunity to reduce dependence on imported fossil fuels, while also opening up domestic fiscal sources for a green transition and driving energy efficiency through higher energy prices. At the same time, a targeted social assistance scheme has been introduced to shield low-income residents from energy price increases (IMF, 2014). This social protection is an essential component of any subsidy reform programme, demonstrating how efficiency can be addressed in an inclusive manner.

There is also an opportunity for Ukraine to work with wider coalitions for reform. Ukraine has a highly mobilized non-governmental organization (NGO) sector that can support government initiatives given its strong technical, economic and regulatory expertise (IEA, 2014).

Ukraine has also shown success in working with regional partners, including via the Eastern Europe Energy Efficiency and Environment Partnership (E5P), which as of 2013 has initiated nine projects that will result in saving 772,000 MWh of energy and will reduce CO_2 emissions by more than 272,000 tonnes per year, over a 15-year period (E5P, n.d.). This group alone includes links to prominent international donors for Ukraine, including the European Bank for Reconstruction and Development, the European Investment Bank, the International Finance Corporation, the Nordic Environment Finance Corporation, the Nordic Investment Bank, and the World Bank.

[4] Also see the information on "Update since 2016" text box (p.4).

SIMULATION ANALYSIS AND KEY RESULTS

SCENARIOS

The analysis presented in this study is based on the creation of customized simulation models based on existing national and international statistics. Data collection was carried out across sectors for the models.

Because of the lack of data at the national level for certain sectors and selected indicators, the models are based on the available information, and generate projections that could be directly compared with existing databases, whether national, regional or global. Assumptions from the literature, even if they do not reflect the specifics of Ukraine, were used in certain instances to simulate the scenarios. The methodology applied is System Dynamics (Forrester, 1961; Sterman, 2000). It uses causal relations, feedback loops, delays and non-linearity to represent complexity. It allows the generation of projections that are not as reliant on historical data as optimization or econometrics studies. Validation was carried out using behavioral and structural validation tests (Barlas, 1996). The simulations start in the year 2000 and run to 2030 in order to enable historical behavioral validation over a period of approximately 10 years for most variables, depending on data availability.[5] The comparative analysis of green economy interventions, however, is shown only for future years and certain calculations, as there is no historically comparable data.

Two main scenarios are simulated and analyzed in this study, as presented below.

- A Business as Usual (BAU) case that assumes the continuation of historic trends and includes all policies and interventions currently active and enforced, but excludes policies planned but not yet implemented.
- A set of Green Economy (GE) scenarios that simulate additional interventions that reduce energy intensity and increase the use of renewable energy.

The specific interventions and assumptions simulated in the GE scenario are listed below and in Table 7.

Assumption: GDP growth: 0.13 per cent average annual growth between 2015 and 2018, constant at 4 per cent after 2018

Table 2. Assumed GDP growth under all scenarios

2015	2016	2017	2018
-9%	2%	3.5%	4%

Sources: National projections and IMF, World Economic Outlook, October 2015.

Assumption: Population growth: -0.61 per cent annual growth from 2020 to 2030

Table 3. Assumed population growth under all scenarios

2020	2025	2030
-0.52%	-0.61%	-0.71%

Sources: UN, World Population Prospects: The 2015 Revision.

5 All the data used for the customization and calibration of the model include Crimea and Sevastopol. In order to avoid inaccuracies in scaling the data to exclude Crimea and Sevastopol the model considers per cent changes, rather than absolute values for the selected key variables (e.g. population and GDP, see Table 2 and Table 3).

Assumption: Energy Prices: 2 per cent annual growth rate as of 2014 for coal prices and 4 per cent annual growth rate as of 2014 for petroleum and natural gas prices (assumption based on the 10-year historical trends observed for fossil fuel prices in the international market)

Table 4. Assumed increase in energy prices

Energy source	Price change (2014 – 2030)
Oil	+4%
Natural Gas	+4%
Coal	+2%

Assumption: Energy efficiency improvement: 0.5 per cent from 2014 to 2030 under the BAU scenario; 1.7 per cent from 2016 until 2020 and 1.1 per cent from 2021 until 2030 estimated under the GE scenario, based on the INDC target

The improvement would be performed equally across key sectors, including residential, industrial, transport and others. This leads to a 9 per cent increase in energy efficiency by 2020 and 18 per cent by 2030, as indicated in the INDC pledge and in Ukraine's National Action Plan on energy efficiency until 2020. [6]

Table 5. Assumed annual energy efficiency improvement

Scenario	Annual energy efficiency improvement		
	2014	2016 - 2020	2021-2030
BAU		0.5%	
GE	0.5%	1.7%	1.1

Assumption: Renewable energy expansion: annual construction of renewable energy capacity is projected to accumulate to a production capacity of 11 GW by 2020, 17 GW by 2030 and 23.5 GW by 2040

This level of electricity generation capacity from renewable energy is consistent with the National Plan on Renewable Energy until 2020 and the 2030 Energy Strategy.

Table 6. Assumed renewable energy capacity

	2020	2025	2030
Renewable energy capacity	11 GW	17 GW	23.5 GW

[6] These energy efficiency improvements will be achieved through the implementation of several interventions, as indicated in the National EE Action Plan for 2020. These include thermo-modernization of buildings; promotion of EE certification of buildings; promotion of energy-audits and energy management practices; investment in near-zero-energy buildings; investment in EE measures in industry; adaptation of fuel and fuel use standards to European standards; encouraging freight operators to purchase more energy-efficient transport means; accounting for 100% of commercial energy consumption in low cost and communal housing; and review of construction norms and standards.

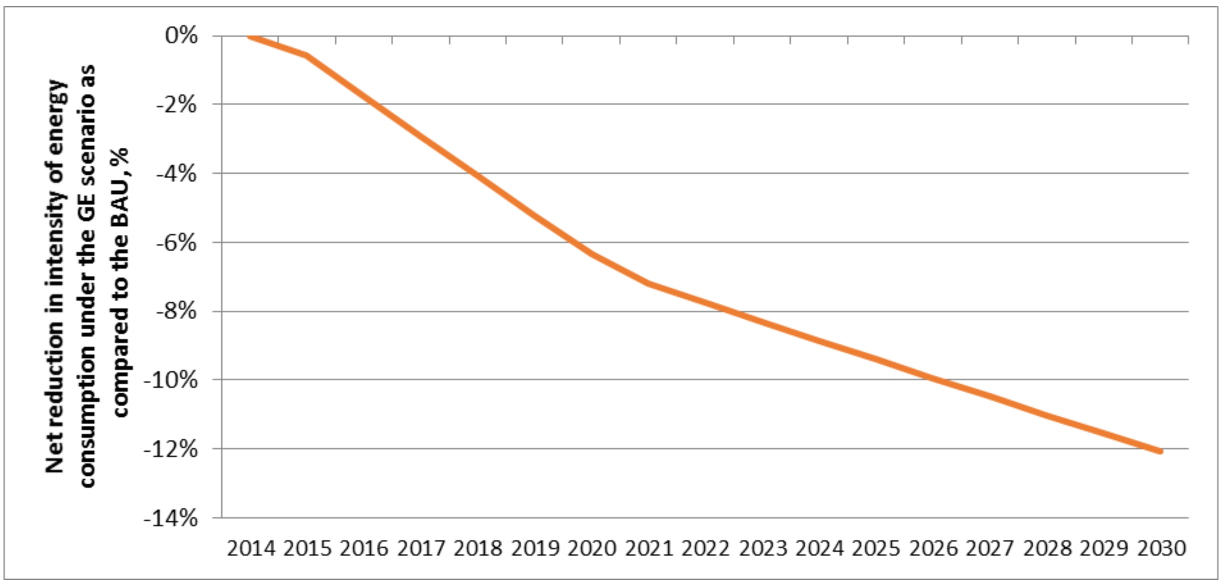
Table 7. Main assumptions used for model development and scenario simulation

Energy efficiency employment	Method 1: Job years per GWh: 0.59 (source: Kammen, 2004)
Renewables construction cost	US $1.79 m per MW (IEA, 2014)
Renewables maintenance cost	US $46,000 per MW (IEA, 2014)
Hydro construction cost	US $2.27 m per MW (IEA, 2014)
Hydro maintenance cost	US $53,000 per MW (IEA, 2014)
Fossil fuels construction cost	US$ 2.00 m per MW (IEA, 2014)
Fossil fuels maintenance cost	US $60,000 per MW (IEA, 2014)
Nuclear construction cost	US $6.60 m per MW (IEA, 2014)
Nuclear maintenance cost	US $198,000 per MW (IEA, 2014)
Energy efficiency investment	US $50 per avoided tonne of CO_2 emissions from electricity generation (IEA, 2014)
Average emissions from fossil fuel electricity generation	Based on power source and technology used. Highly influenced by the commissioning of nuclear power and fossil fuel thermal generation. Starting from 136 tonne/TJ in 2014.

ENERGY DEMAND

In the GE scenario, energy efficiency improvements lead to a reduction in total energy consumption of 6.3 per cent, 9.4 per cent, and 12.1 per cent relative to the BAU case in 2020, 2025, and 2030 respectively. Under the GE scenario, the change in total annual energy demand compared to 2015 is -3.7 per cent in 2020, 0.8 per cent in 2025, and 7.1 per cent in 2030. The improvement in energy efficiency mentioned above corresponds to a reduction in energy intensity (estimated as energy consumption per unit of GDP), compared to 2015 levels, of 13.4 per cent in 2020, 25.7 per cent in 2025 and 25.4 per cent in 2030 for the GE scenario. The projected energy intensity of the GE scenario against business as usual (Figure 2) attains a net reduction through energy efficiency interventions of 6 per cent in 2020, 9 per cent in 2025 and 12 per cent in 2030.

Figure 2: Dynamics of the net reduction in intensity of energy consumption under the GE scenario as compared to the BAU, %



Investment
The assumed annual investment required to reach the energy efficiency targets for electricity for the GE scenario amounts to US $261.1 million per year on average in the period 2015-2020, US $500.7 million per year on average in the period 2015-2025, and US $770 million per year on average in the period 2015-2030. The total (cumulative) investment in energy efficiency in the electricity sector would amount to US $1.6 billion for the period 2015-2020, US $5.5 billion for the period 2015-2025, and US $12.3 billion for the period 2015-2030.

The total investment for energy efficiency, as a share of GDP, reaches 0.20 per cent in 2020, 0.34 per cent in 2025, and 0.47 per cent in 2030.

Avoided cost
Average electricity savings for the period 2015-2020 amount to US $540.8 million, US $954 million for the period 2015-2025, and US $1.3 billion for the period 2015-2030. The total (cumulative) electricity savings for the period 2015-2020 amount to US $3.2 billion, US $10.5 billion for the period 2015-2025, and US $21.5 billion for the period 2015-2030.

Employment
The attainment of the national 2030 Energy Efficiency strategy to increase energy efficiency for electricity and fuels is also projected to increase employment in the energy sector. Job creation from energy efficiency in electricity amounts to 4,710 full-time direct jobs for the period 2015-2020, 7,996 full-time direct jobs for the period 2015-2025, and 11,753 full-time direct jobs for the period 2015-2030. On average, annual job creation in the electricity area amounts to 785 full-time direct jobs per year for the period 2015-2020, 724 full-time direct jobs per year for the period 2015-2025, and 735 full-time direct jobs per year for the period 2015-2030.

ELECTRICITY SUPPLY[7]

Under the GE scenario, the renewable energy sources share of the national power capacity mix will be 10.2 per cent in 2020, 11.5 per cent in 2025, and 12.2 per cent in 2030, against the target of 12.6 per cent included in the 2030 Energy Strategy. The nuclear power share of the national power capacity mix will be 47.1 per cent in 2020, 44.1 per cent in 2025, and 39.9 per cent in 2030. In addition, the hydropower share of the national power capacity mix will be 6.9 per cent in 2020, 6.7 per cent in 2025 and 6.2 per cent in 2030, which is also consistent with the 2030 Energy Strategy, which calls for 50 per cent of power capacity to be represented by large hydropower plants by 2030. (See Figures 3 and 4 for BAU and GE projections.)

Figure 3: Electricity generation by energy source (Million MWh/year). Historical trends and future projections, BAU scenario

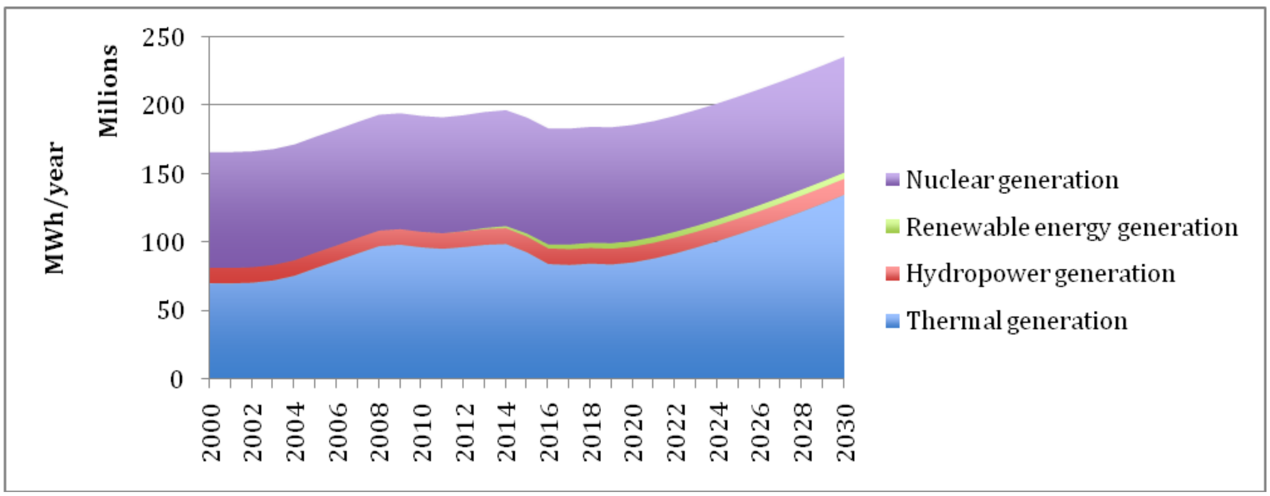
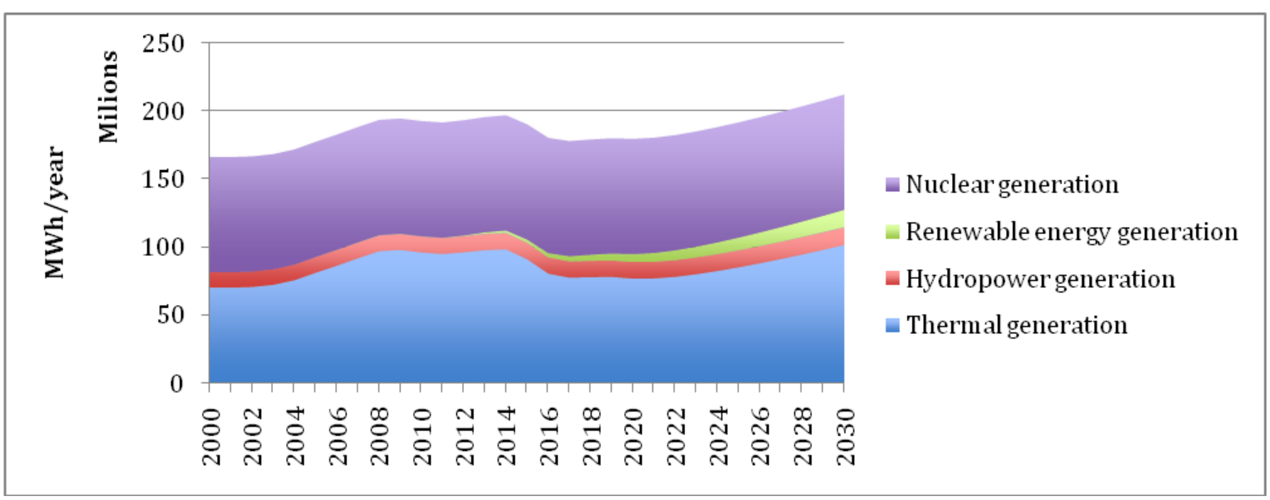


Figure 4: Electricity generation by energy source (Million MWh/year). Historical trends and future projections, GE scenario



[7] Data are taken from old Ukraine's Energy Strategy for 2030.

The change in the electricity mix – expansion of renewable energy and the decline of thermal generation – leads to changes in electricity prices. This occurs because increased energy efficiency lowers the need to expand power generation capacity and allows for the retirement of less efficient (obsolete) capacity. In addition, the expansion of hydropower and other renewables allows for the generation of electricity at a stable and foreseeable cost, thus reducing exposure to the volatility of fossil fuel import prices. According to IEA data used in the preparation of the World Energy Outlook[8], despite the high upfront cost, new renewable capacity can compete with conventional (and certainly older) thermal capacity. In the GE scenario the improvement of energy efficiency and the reduction in electricity consumption leads to a reduction in electricity expenditure compared to BAU of 6.4 per cent in 2020, 9.4 per cent in 2025, and 12.1 per cent in 2030.

Investment

Under the GE scenario, renewable energy investments amount to US $1.77 billion for the period 2015-2020, US $1.86 billion for the period 2015-2025, and US $1.95 billion for the period 2015-2030. This represents renewable energy investments that are higher than renewable energy investments under BAU by 59.8 per cent for the period 2015 -2020, 102.4 per cent for the period 2015-2025, and 122.4 per cent for the period 2015-2030. Of the total power generation capacity investment, renewable energy investments represent 23 per cent for the period 2015-2020, 20 per cent for the period 2015-2025, and 18 per cent for the period 2015-2030.

Average annual investment in electricity demand management (efficiency) and supply (renewables) amounts to US $7.39 billion in the period 2015-2020, US $9.16 billion in the period 2015-2025, and US $10.61 billion in the period 2015-2030. In addition, the total (cumulative) electricity investment amounts to US $44.33 billion in the period 2015-2020, US $100.73 billion in the period 2015-2025, and US $169.73 billion in the period 2015-2030.

Avoided cost

Under the GE scenario, investments in electricity demand management (efficiency) and supply (renewables) are lower than under the BAU scenario. This is due to the improvement in energy efficiency, which lowers energy consumption and as a result the electricity generation capacity required to satisfy the (lower) electricity demand. In other words, investments in energy efficiency and renewable energy are less than the avoided fuel and capital costs. Investments in energy supply are higher until 2017 and turn negative (into savings) from 2018 onwards. (See Figure 5.) Cumulative savings start being accrued from 2020. Specifically, the reduction of investments in the GE scenario reaches 5.1 per cent in 2020, 8.8 per cent in 2025, and 10.4 per cent in 2030 relative to the BAU scenario. Total net investment, accounting for the cost of energy efficiency and renewable energy as well as for capital cost savings (e.g. from avoided power capacity), amounts to savings reaching 1 billion in 2020, 536.8 million in 2025, and 639.4 million in 2030. (See Figure 6.)

In addition, under the GE scenario, avoided electricity consumption costs amount to 1 billion in 2020, 1.7 billion in 2025, and 2.5 billion in 2030, further increasing the attractiveness of investments in energy efficiency and renewable energy.

[8] See Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015, available at https://www.eia.gov/forecasts/aeo/electricity_generation.cfm

Figure 5: Avoided costs and investments by intervention option (US $/year). Future projections, GE scenario

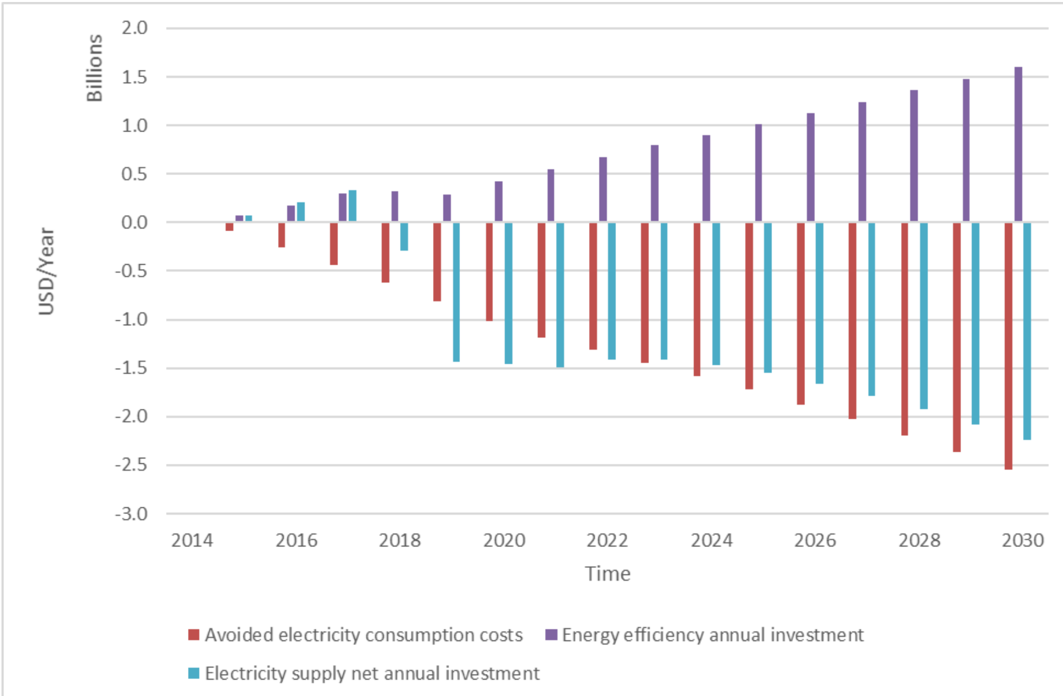


Figure 6: Total avoided costs and investments (US $/year). Future projections, GE scenario

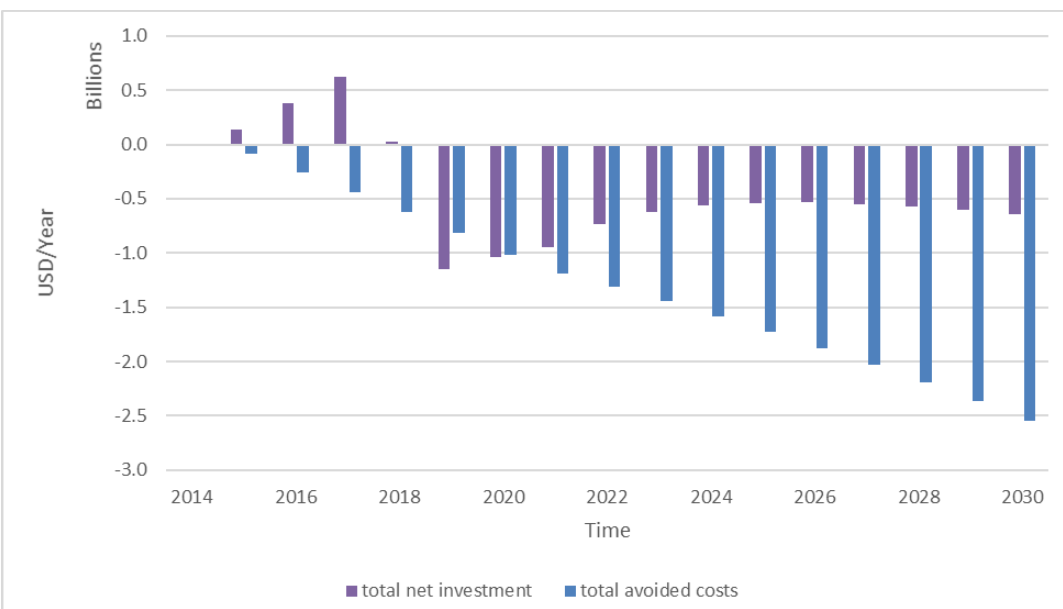
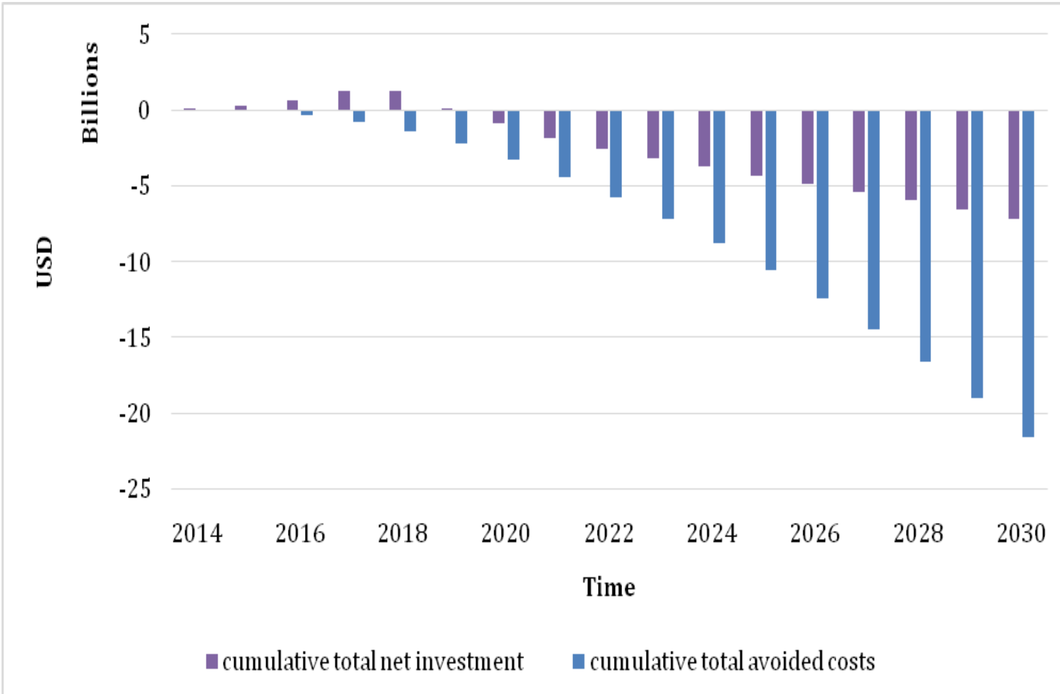


Figure 7: Cumulative total avoided costs and investments (US $).
Future projections, GE scenario



Employment

The expansion of renewable energy capacity is likely to generate employment related to the construction of new plants and to the operation and management of the plants. On average, job creation in the renewable energy sector amounts to 889 full-time direct jobs per year for the period 2015-2030. The share of renewable energy jobs of total electricity employment will be 40.3 per cent in 2020, 36.0 per cent in 2025, and 36.6 per cent in 2030. Of the total jobs in the renewable energy sector the share of jobs in construction amounts to 73.6 per cent in 2020, 66.6 per cent in 2025, and 61.9 per cent in 2030. On average, annual jobs created in the thermal sector amount to -588 full-time direct jobs for the period 2015-2020 (indicating a loss, primarily due to a temporary decline in demand and the growing installations of renewable energy), 879 full-time direct jobs for the period 2015-2025 and 1,022 full-time direct jobs for the period 2015-2030.

The percentage increase of jobs in renewable energy generation under the GE scenario, compared to the BAU scenario, is 1.6 per cent for the period 2015-2020, 6.3 per cent for the period 2015-2025, and 5.9 per cent for the period 2015-2030.

On the negative side, the increasing number of qualified workers who have emigrated in the last few years for economic, political and personal reasons complicates the employment situation.

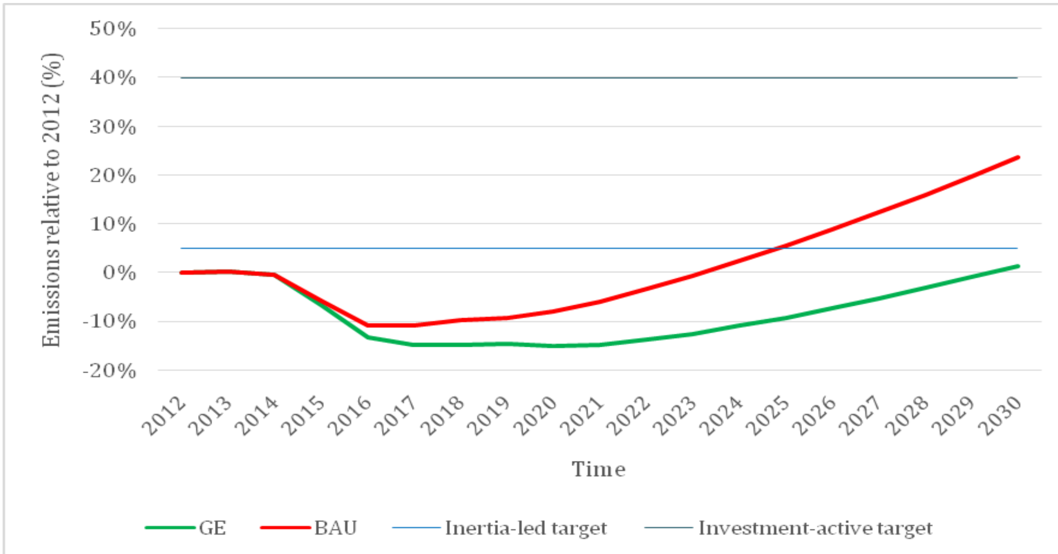
Emissions

Investments in renewable energy and in energy efficiency under the GE scenario lead to a reduction of CO_2 emissions of 7.9 per cent in 2020, of 14 per cent in 2030, and of 18.1 per cent in 2030 compared to the BAU scenario. In the GE scenario the change in CO_2 emissions compared to 2015 is projected as -9.1 per cent in 2020, -2.8 per cent in 2025, and 8.4 per cent in 2030, and in the BAU scenario is projected as -2.3 per cent, 11.9 per cent and 31.1 per cent for those same years.

The reduction of per capita emissions in the GE scenario compared to the BAU scenario amounts to 7.9 per cent in 2020, 14.0 per cent in 2025, and 18.1 per cent in 2030.

These results indicate that the GE scenario can deliver economic growth (e.g. by providing positive returns on investment and net job creation) while reducing CO_2 emissions. Simulations show that investments in energy efficiency and renewable energy can lead to an increasing decoupling of economic growth and energy consumption (and hence emissions). This results in a GE scenario leading to an economic outlook closer to the “investment-active” scenario but with an emission level closer to the “inertia-led” scenario. (See Figure 8.)

Figure 8: Total emissions under the GE and BAU scenarios, compared with INDC targets for the "Inertia-led" and "Investment-active" scenarios



The inertia-led target is 45% of 1990 emission levels by 2030, while the investment-led target is 60% of 1990 emission levels by 2030 – as per the memorandum to the Cabinet of Ministers of Ukraine on the implementation of the INDC (http://climategroup.org.ua/wp-content/uploads/2009/06/2015.08.12-INDC.pdf).

The latter scenario accounts for the desired reconstruction of industrial capacity and infrastructure.

SUMMARY OF MAIN RESULTS

Table 8 presents the main results of the analysis. It provides a general overview of the impacts of investing in green economy interventions on energy demand and on the generation of electricity. It also shows the ensuing effects on CO_2 emissions, and on job creation.

Table 8. Summary of outcomes of investing in green economy interventions in the energy sector[9]

Time (Year)	2015	2020	2025	2030
ENERGY DEMAND				
Total country energy demand (%)				
GE vs. BAU	-0.56%	-6.35%	-9.40%	-12.08%
CO_2 EMISSIONS				
Total CO_2 emissions (%)				
GE (RE + EE) vs. BAU	-0.97%	-7.87%	-13.98%	-18.07%
RE vs. BAU	-0.15%	-0.57%	-1.71%	-2.62%
EE vs. BAU	-0.91%	-7.48%	-12.35%	-15.51%
CO_2 reduction relative to 2005 (%)				
GE	-5.90%	-14.40%	-8.50%	2.10%
BAU	-4.90%	-7.10%	6.30%	24.60%
ELECTRICITY GENERATION				
Share of RE electricity generation (%)				
GE	7.70%	10.23%	11.52%	12.16%
BAU	7.49%	8.73%	8.00%	7.14%
EMPLOYMENT				
Energy efficiency employment electricity (person)				
GE vs. BAU	405	4,710	7,966	11,753
Renewable energy employment electricity (person)				
GE vs. BAU	13,709	18,065	22,546	27,027
INVESTMENT AND SAVINGS				
Total cumulative investment (billion US $)				
GE (RE + EE)	7.04	44.34	100.73	169.73
RE only	1.69	10.63	20.48	31.27
EE only	0.07	1.57	5.51	12.32
BAU	6.90	44.96	103.65	173.72
Total annual investment (billion US $/year)				
GE (RE + EE)	7.04	8.76	12.47	14.69
RE only	1.69	1.85	2.05	2.23
EE only	0.07	0.42	1.02	1.60
BAU	6.90	9.67	12.73	14.90
Total avoided costs annual (billion US $/year)				
GE vs. BAU	0.09	1.02	1.72	2.54
Total avoided costs cumulative (billion US $)				
GE vs. BAU	0.09	3.24	10.49	21.50

[9] Notes: the values included in the main text may not coincide with those included in this table. This is because most of the values presented in the text are annual averages (e.g. the average investment in the period 2015–2020), while this table presents annual and cumulative values for selected years. This was done to provide a more complete set of results. Further, the table disaggregates the impacts of EE and RE where relevant. It should be noted though that in certain instances (such as in the case of power supply) the joint implementation of these interventions generates outcomes that are different than the result of their individual implementation.

POLICY CONSIDERATIONS AND ENABLING TOOLS

A number of considerations and suggestions[10] that can help policymakers address challenges and seize opportunities associated with energy efficiency and renewable energy in Ukraine have been identified. These include:

Policy review: Reviewing existing medium and long-term government plans and adapting them to current circumstances is important. Ukraine is currently facing a combination of geopolitical, economic, financial, humanitarian and energy crises (IEA, 2014) that require planning and dynamic responses to properly characterize the emerging challenges. These responses must be assessed for their feasibility and ability to achieve desired outcomes. In light of this, some plans may require revisions of implementation timelines or scales, while others may require more fundamental changes to ensure that they are up to date and effective given the evolving dynamics within the country.

Phasing out subsidies and reforming energy pricing: Studies have shown that a rise in energy prices can lead to greater adoption of energy efficiency measures (Hochman & Timilsina, 2014). The World Bank (2013) noted that while Ukraine has a very high average cost of gas supply, its residential gas and heating tariffs were very low. The analysis shows that subsidies are a major concern in the energy sector as they are underpricing power and generating inefficiencies, while also negatively affecting the economic performance of energy utilities and constraining the national budget (DIW econ GmbH, 2013). Phasing out subsidies for coal and low tariffs for natural gas could address this situation, while also reducing GHG emissions and levelling the playing field for renewable energy technology investment. Reform of fossil fuel energy prices can also have benefits for the competitiveness of renewables.

Regulatory focus on energy efficiency: Both the modelling and the sectoral analysis identify a pressing need to focus on energy efficiency. This has also been underlined in several national strategies of Ukraine. The options to promote energy efficiency include regulatory reforms to building codes, appliance standards, energy management systems, and district heating (IEA, 2012). Efficiency can also be achieved through targeted programming that can take the form of capacity-building, labelling, education, and assistance for low income or vulnerable groups to adapt to rising energy prices or shift to more efficient practices.

Development of local renewable energy resources: Ukraine should focus on renewables and low-carbon sources to promote a green economy transition. As identified in the simulation model of this report, and as indicated in the international literature, renewables are becoming more competitive with fossil fuels (New Climate Economy, 2014). An added benefit for Ukraine is that growth in domestic renewables increases energy security – a particular need in the country. There are significant opportunities for Ukraine in solar, wind and biomass energy, as well as in expanding existing hydroelectric power. Feed-in-tariffs are already driving this shift (IEA, 2015), and as the modelling shows, continued investment in renewable energy will help achieve the national goal for renewable energy for 2030 (12.6% aggregate capacity of renewables in the total national energy supply).

Support for employment: The transformational shift towards energy efficiency and renewable energy development will require government support for employment in related areas and thus will enable the building of a workforce to support the transition. Technological modernization of industry and manufacturing, including efforts targeted at energy efficiency, will require skilled workers. This applies particularly to areas in the eastern regions of the country where significant reconstruction of industrial facilities will be needed. As a result, employment investments and policies should be geared towards building a workforce that is equipped to support the green transition. Targeting workers in traditional energy and fossil fuel sectors can help address potential job losses in these sectors.

Engagement of civil society and building coalitions on efficiency: Ukraine has a strong NGO sector that is willing to engage with the government. Enlisting NGOs to assist with energy efficiency measures can be one way to enact improvements on the demand side. This can include promoting government programmes that support energy efficiency, assisting the socially vulnerable to access supporting mechanisms to adapt to fuel price changes, or running educational and capacity-building campaigns to inform the public on the economic, environmental and social benefits of energy conservation.

[10] For additional recommendations see (UNEP, 2011).

International financing: In 2013 Ukraine was successful in securing over EUR 93 million for energy initiatives under the E5P initiative (E5P, n.d.), the European Bank for Reconstruction and Development (EBRD) and the Green Fund. Ukraine has also actively engaged multilateral banks for support and has been successful at leveraging EBRD support for environmental infrastructure and efficiency projects (EBRD, 2013). Given the significant upfront investments that are required to rebuild energy infrastructure and foster energy efficiency and renewable energy development, it is clear that Ukraine will need to continue and strengthen its engagement with international donors. For instance, the International Monetary Fund has proposed that additional legislative action would be needed to allow foreign direct investment in the gas market (IMF, 2014). If this investment occurs, it can attract fresh capital and help modernize the sector. Developing stronger ties with the EU (under the E5P programme, for example) can further improve Ukraine's access to diversified energy resources, enhance trade and technology transfer, and improve prospects for alignment with EU standards and policies.

Attracting private investment by leveraging domestic and donor investment: International funding streams, along with domestic finance sources can be used to leverage additional private investment. Direct arrangements such as public-private partnerships can be used. Governments can also offer support to private investment through loan guarantees. Indirectly, investments to improve infrastructure or promote energy supply security can also lower risk and raise the attractiveness for private sector investment not just in energy development, but economy-wide. Analysis also shows that moves such as liberalizing utility tariff rates and improving regulation of the electricity sector can make the energy sector more attractive for private finance (DIW econ GmbH, 2013).

CONCLUSIONS AND THE WAY FORWARD

The modelling results suggest that a green economy scenario, which simulates additional investments in efficiency and renewable energy, can significantly reduce energy consumption in Ukraine, and contribute to achieving the 12.6 per cent national target for renewable energy in national supply by 2030. Modelling also reveals that as more domestically produced renewable energy sources become available, energy price volatility from imported energy sources will diminish. A further benefit is the potential to reduce the country's GHG emissions by more than 18 per cent below BAU projections by 2030.

With all of these benefits comes an investment price of roughly US $31.3 billion for renewable energy investments alone, along with an estimated US $12.3 billion required for investment in energy efficiency. This price tag is partially offset, however, by some US $21.5 billion avoided costs expected through electricity savings.

The path for greening the energy sector in Ukraine has both major challenges and significant opportunities. The continuation of the energy pricing reforms, expanded energy efficiency programming with a focus on demand-side management, and continued investment in renewables for energy security and GHG benefits can chart a way forward. The challenges in Ukraine are unique, however, and will require focused attention as they continue to evolve.

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ANNEX 1: MODEL DESCRIPTION – OVERVIEW OF THE APPROACH

Building an integrated model
The model developed for this study includes several variables across sectors and thematic domains. Ensuring data consistency (within and across sectors) allows for the creation of a more comprehensive analysis that in the case of Ukraine includes energy demand, supply and emissions, as well as estimates of the investment required to reach desired emission reduction targets, energy savings and employment creation. In practical terms, "knowledge integration" was performed in a single framework of analysis for low carbon interventions.

Exploring causality
This model is used to assess the outcome of policy interventions. It can introduce targets and estimate the required investment by considering the cost of technology (e.g. depending on the sector and the energy source affected) and the timing of the target (e.g. a learning factor is included in the analysis). Investment changes the demand for energy (e.g. due to an improvement in efficiency) and the energy mix deviates from the baseline scenario (e.g. due to the expansion of renewable energy). A different level of energy consumption and a new energy mix result in a change in the energy bill (e.g. leading to savings on energy expenditure), which, compared to the required investment, gives an indication of the economic performance (or desirability) of the interventions being analysed. The combined effects of changes in energy demand and energy mix lead to a reduction in emissions, which is then compared to the desired target, against a base year (e.g. 2005) and relative to GDP and population.

Since implementation of the investment requires labour (e.g. for the construction, installation and operation and maintenance of power generation capacity), the model also estimates employment creation in two ways: based on the construction, stock and disposal of fixed capital related to energy supply (e.g. coal power plants) and on the investment and resulting energy saving in the case of energy demand management. While job creation (and relative salaries and wages) is generally considered to be a cost in a conventional cost benefit analysis, it is normally considered as added benefit by governments.

Validation
Models can be classified in many different ways and assessed according to different criteria, such as physical versus symbolic; dynamic versus static; deterministic versus stochastic; etc. As it relates to the notion of validity, a crucial distinction must be made between models that are "causal-descriptive" (i.e., theory-like or "white-box") and models that are "correlational" (i.e., purely data-driven or "black-box").

In correlational models, since there is no claim of causality in structure, what matters is the aggregate output behaviour of the model; the model is assessed as valid if its output matches the "real" output within a specified range of accuracy, without any questioning of the validity of the individual relationships that exist in the model. This type of "output" validation can often be cast as a classical statistical testing problem. Models that are built primarily for forecasting purposes (such as time-series or regression models) belong to this category.

On the other hand, causal-descriptive models (such as the one developed for this study) make statements about how real systems actually operate in some aspects. In this case, generating an "accurate" output behaviour is not sufficient for model validity; what is crucial is the validity of the internal structure of the model. A causal-descriptive model, which presents a theory about the real system, must not only reproduce or forecast its behaviour, but also explain how the behaviour is generated, and possibly suggest ways of changing the existing behaviour.

The performance of the model presented in this study is checked against historical data (i.e., behavioural validation), while several additional tests are made to validate the variables and equations (i.e., structural validation). The result is a state-of-the-art model that is consistent across sectors (e.g. energy demand and supply) and dimensions (e.g. employment, economic investment and environmental emissions), capable of replicating historical trends and projecting outcomes consistent with the best available research.

Structural Validation
Direct structure tests were performed to assess the validity of the model structure by direct comparison to knowledge about the structure of the real system, equation by equation. Examples of direct structure tests include: structure confirmation tests; parameter confirmation tests; direct extreme-conditions tests; dimensional consistency tests; behaviour sensitivity tests; and phase-relationship tests.
Direct structure tests can be empirical or theoretical. Empirical structure tests involve comparing the model structure with information (quantitative or qualitative) obtained directly from the real system being modelled. Theoretical structure tests involve comparing the model structure with generalized knowledge about the system from the literature.

Behavioural Validation

The model includes 230 variables across sectors. Of these 230 variables 54 are constant, and several others represent conversion factors. In total, 80 to 100 variables were tested against historical data from 2000 to 2014. This indicates that while the model is initialized using historical data for the year 2000, it is not fully driven by data until 2014. As a result, behavioral validation needs to be carried out to assess whether projections (resulting from the simulations of over 200 equations, using a yearly time step) reproduce observed historical trends. The analysis includes pattern prediction (periods, frequencies, trends, phase lags, amplitudes, etc.) as well as point (event) prediction.

Dealing with Uncertainty

While the model has undergone several validation tests to be able to generate solid scenarios, there are several elements of uncertainty that depend not on structural soundness but on the availability of valid model inputs and on the presence of external factors affecting a country's performance.

A sensitivity analysis was carried out for selected parameters. Monte Carlo simulation techniques were utilized to estimate the variability of model outputs to changes in model inputs. This provided a deeper understanding of the potential range of results that could be obtained from the model (e.g. on emissions and payback time) under alternative assumptions (e.g. on the response of energy demand to changes in energy prices).

The following two types of sensitivity analysis were performed:

- Numerical sensitivity exists when a change in assumptions changes the numerical values of the results. Models inherently exhibit numerical sensitivity; testing helps assure that responsiveness is consistent with the functions and feedbacks of the model.
- Behaviour mode sensitivity exists when a change in assumptions changes the patterns of behaviour generated by the model. If plausible alternative assumptions changed the behaviour of a model from smooth adjustment to oscillation, for example, the model would exhibit behaviour mode sensitivity.

Description of the model

The following features characterize the energy model created for Ukraine:

- ***Boundaries:*** The model focuses on energy consumption and does not include emissions from other sectors (e.g. land cover). The model does not include an endogenous estimation of energy supply, apart from electricity.
- ***Granularity:*** The model is customized to represent national energy consumption and is not disaggregated spatially at the sub-national level. On the other hand, the model includes energy consumption from the residential, commercial, industrial and transport sectors, disaggregated into coal, petroleum products, natural gas, biofuels and waste, and electricity.
- ***Time horizon:*** The model is built to analyze medium- to long-term trends. Simulations start in 2000 and extend up to 2030. By starting in 2000, the simulations support both model validation and the correct assessment of long-term trends, including the identification of possible underlying socioeconomic structural changes.
- ***Structure:*** The model is relatively small and uses the following key exogenous drivers: GDP, population, energy efficiency (as an annual per cent increase) and energy prices.

Overview of the model

Major Assumptions

- Exogenous inputs: the future growth of GDP, population, energy prices and baseline energy efficiency, currently projected to improve by 1.5 per cent every year.
- Final energy consumption is estimated considering (1) indicated demand (including the effect of GDP, population and energy efficiency); (2) the price effect; and (3) the substitution effect. Items (1) and (2) are used to estimate *demand for energy services*.
- The potential for fuel substitution is represented by the ratio of an energy price over the national weighted average energy price. This implies that an energy source will become more attractive if its price increase is lower than others when subsidies are removed.
- Price effects require a one-year delay to influence energy consumption.

Constants and Table functions

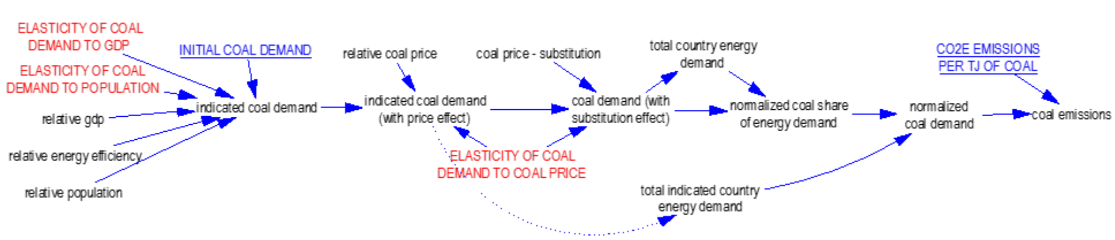
Table 1. Data inputs for the Ukraine Energy Model, estimation of energy consumption and emissions

Variable Name	Type of Variable
Population	Time Series
GDP	Time Series
Electricity Demand [Industrial]	Time Series
Natural Gas Demand [Industrial]	Time Series
Petroleum Demand [Industrial]	Time Series
Coal Demand [Industrial]	Time Series
Biofuels and Waste Demand [Industrial]	Time Series
Electricity Demand [Transport]	Time Series
Natural Gas Demand [Transport]	Time Series
Petroleum Demand [Transport]	Time Series
Coal Demand [Transport]	Time Series
Biofuels and Waste Demand [Transport]	Time Series
Electricity Demand [Residential]	Time Series
Natural Gas Demand [Residential]	Time Series
Petroleum Demand [Residential]	Time Series
Coal Demand [Residential]	Time Series
Biofuels and Waste Demand [Residential]	Time Series
Electricity Demand [Commercial]	Time Series
Natural Gas Demand [Commercial]	Time Series
Petroleum Demand [Commercial]	Time Series
Coal Demand [Commercial]	Time Series
Biofuels and Waste Demand [Commercial]	Time Series
Share of Natural Gas in Electricity Generation	Time Series

Variable Name	Type of Variable
Share of Renewable Energy in Electricity Generation	Time Series
Initial Electricity Price	Time Series
Natural Gas Price	Time Series
Petroleum Price	Time Series
Coal Price	Time Series
Biofuels and Waste Price	Time Series
Emissions Per GWh of Gas Power Generation	Constant
Emissions Per GWh of Coal Power Generation	Constant
CO_2e Emissions Per TJ of Coal	Constant
CO_2e Emissions Per TJ of Petroleum	Constant
CO_2e Emissions Per TJ of Natural Gas	Constant
CO_2e Emissions Per TJ of Biofuels and Waste	Constant
Coal subsidy	Time Series
Petroleum subsidy	Time Series
Natural gas subsidy	Time Series
Electricity subsidy	Time Series
Renewable energy investment per kW	Time Series
Renewable energy capacity factor (%)	Time Series
Energy efficiency investment per TJ	Constant
Elasticity of *Energy* Demand to *Energy* Price	Constant
Elasticity of *Energy* Demand to GDP	Constant
Elasticity of *Energy* Demand to Population	Constant

Functional Explanation

Figure 1. Sketch of the main factors influencing energy consumption (example: coal)



Several variables and equations are used to estimate energy flows (measured in terajoules per year, TJ/year) and emissions (measured in tonnes per year, tonne/year).

To begin with, indicated energy demand (for coal in this example) is calculated using the initial value for 2000, multiplying it by relative GDP and relative population[11] (both indexed to 2000 and raised to the power of a specific elasticity factor obtained from the literature and validated through econometric analysis – trend fitting) and dividing it by relative energy efficiency (also indexed to 2000).

Indicated Coal Demand [RESIDENTIAL] =
(INITIAL COAL DEMAND [RESIDENTIAL]*Relative GDP^ELASTICITY OF COAL DEMAND TO GDP [RESIDENTIAL]*Relative POPULATION^ELASTICITY OF COAL DEMAND TO POPULATION])/Relative Energy Efficiency

The price effect is then calculated by simply taking this indicated demand and multiplying it by the relative energy price (indexed to 2000) and raised to the power of a price elasticity.

"Indicated Coal Demand (With Price Effect)" =
Indicated Coal Demand [Sector]*Relative Coal PRICE^ELASTICITY OF COAL DEMAND TO COAL PRICE [Sector]

The next step considers the substitution effect. The formulation is the same as for incorporating the price effect, but a delay of 1 year is used to represent the lag existing between price changes and demand (or consumption) changes.

"Coal Demand (With Substitution Effect)"[Sector] =
DELAY N (("Indicated Coal Demand (With Price Effect)"[Sector]
*"Coal Price - SUBSTITUTION"^ELASTICITY OF COAL DEMAND TO COAL PRICE [Sector]), TIME TO ADAPT DEMAND TO PRICE CHANGES, ("Indicated Coal Demand (With Price Effect)"[Sector]
*"Coal Price - SUBSTITUTION"^ELASTICITY OF COAL DEMAND TO COAL PRICE [Sector]), 3)

The potential for substitution from one energy source to the other, due to price changes (e.g. as a result to fossil fuel subsidy removal), is incorporated here by using the ratio of *energy source* price (e.g. coal) over the average energy price of the country (estimated as a weighted average of all energy prices). This ratio is also indexed, to ensure consistency with the use of elasticity.

"Coal Price - Substitution" =
DELAY N ((Relative Coal Price/Relative Weighted Average Energy Price), 1,1, 1)

Indicated energy demand (including the price effect) is used to estimate the total indicated energy demand (which is also demand for energy services), which is the total energy that has to be guaranteed at the country level. The potential for substitution is instead used to estimate the actual share of energy consumption by source. As a result, a normalization is performed multiplying total indicated energy demand by the shares obtained from the inclusion of the substitution effect.

Normalized Coal Demand [Sector] =
Total Indicated Country Energy Demand*Normalized Coal Share Of Energy Demand [Sector]

Once normalized demand (which is assumed to be the same as consumption) is estimated, emissions can also be projected. This is done by multiplying normalized demand (in TJ/year) by its specific emission factor (in Tonne CO_2e/TJ).

Coal Emissions [Sector] =
Normalized Coal Demand [Sector]*CO_2E EMISSIONS PER TJ OF COAL

Once energy demand and emissions are estimated, demand is also used to calculate required electricity generation capacity and output. This is done for several technologies, including thermal generation, nuclear and renewable energy options. The capacity is represented as a stock (measured in MW), and changes with expansion (when demand increases, or due to policies such as in the case of renewable energy) and disposal (based on the lifetime of capital). The electricity generation by source is given by the capacity (in MW), the number of hours per year (to obtain MWh/year) and the load (or use) factor of each technology.

Investments are estimated by multiplying capacity expansion by capital and O&M costs from the International Energy Agency (WEO 2015), and avoided costs are estimated by multiplying energy consumption by energy prices. Similarly, employment in the power sector is estimated by multiplying construction and the stock of capacity by employment multipliers obtained from two main sources – Wei M., S. Patadia, and M. Kammen (2010), "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" *Energy Policy* 38 (2010) 919-931; and Greenpeace International (2009), *Energy Sector Jobs to 2030: A Global Analysis*.

[11] Relative population is only used to estimate residential energy demand.

ANNEX 2: FEEDBACK BY NATIONAL EXPERTS AND ADDRESSED COMMENTS

The Policy Brief on opportunities for greening the energy sector in Ukraine, including the results of the simulation analysis and recommendations, was presented and discussed during national consultations, at which national experts provided their valuable feedback. The EaP GREEN project team addressed comments, and provided clarifications and/or additional information.

The chronology of the addressed comments and clarifications is presented below.

Chapter "Simulation analysis and key Results"

Sub-chapter "Scenarios"

Population growth, p. 12

Comment 1 by Green Economy Institute:
According to Ukrstat, the population in Ukraine on 01.01.2015 was 42,928,900, and the average figure in 2014 was 43,001,000, without accounting for Crimea and Sevastopol. According to the forecasts of the Ministry of Economy/Development, in 2019 the average population size will total 42.2 million.

If we use population dynamics that incorporate Crimea and Sevastopol, then this needs to be referenced in the report, as this may influence the energy efficiency forecasts.

Answer 1 by UN Environment:
To avoid specific figures that may or may not exclude the disputed areas, the report uses % population change instead of absolute values (see footnote 1). This means that, if the population in Crimea and Sevastopol can be expected to grow at the same rate as the rest of the country, our projections are still valid, irrespective of the absolute size of the population. The UN World Population Prospects that we used for the population forecast does not disaggregate population by regions, and if we wanted to exclude Crimea/Sevastopol, we would need to also adjust all other data on energy supply and demand. We have thus adjusted the text to clarify that population dynamics include all regions of the country.

Energy efficiency, p.13

Comment 2 by Green Economy Institute:
Need to add a description of the dynamics of energy efficiency and the approach used for this calculation under the two scenarios. Perhaps a graph showing the calculation and forecasts of this indicator can be incorporated.

Answer 2 by UN Environment:
The trends in energy efficiency are a set assumption and not an output of the model. Energy efficiency assumptions used in the report are in line with the targets laid out in Ukraine's INDC, the 2020 Energy Efficiency Action Plan and other targets communicated to us by GEI (on energy efficiency: 9 per cent increase by 2020 and 18 per cent increase by 2030; and on renewables: 11 per cent increase by 2020, and 18 per cent increase by 2030). We have added three small tables to summarize the different targets and target years.

Comment 3 by Green Economy Institute:
According to our calculations for 2011-2013, the rate of energy efficiency growth is much higher and it is important to explain to experts why we ended up with such slow rates under both scenarios.

Answer 3 by UN Environment:
Your table presents energy intensity (or, better, productivity), not energy efficiency. Intensity (kg of oil eq/$) and productivity ($/kg of oil eq) are affected by GDP and energy demand. The historical data you present consider very low GDP growth. The assumptions used in the model consider a much higher GDP growth. As a result, with higher GDP growth, the improvement in energy intensity is lower (but the improvement in energy efficiency remains high). Summarizing, the reason the model seems to show a lower rate of energy efficiency improvement is because we have used a forecast with higher GDP growth rate than was observed during the period from 2011 to 2013. The model simulates 1.7 per cent annual GDP growth in the short term and 3-4 per cent in the medium and longer term. This is very much in line with the rationale in Ukraine's INDC, which aims for rapid economic recovery that is not constrained by stringent GHG reduction targets. We could use more conservative GDP growth forecasts (which better match the rate from 2011 to 2013), but this would be against current expectations at the national level, and well below IMF projections.

Comment 4 by Green Economy Institute:
It is necessary to mention that calculations include Crimea and Sevastopol. According to the latest estimates of the State energy efficiency agency, by 2020 the capacity of renewable energy installations will reach 7,997 MW. In light of this, the "investments" section on page 5 may require review and elaboration.

Answer 4 by UN Environment:
Can you please provide a link to the official document where the 7,997 MW target is stated? What does this mean for targets beyond 2020? Does the State energy efficiency agency also have updated targets for 2030 and 2040?

Currently, the forecasted capacity of renewable energy used in the model is in line with the 11 GW target listed in Ukraine's 2020 Renewables plan, and also official targets for 2030 and 2040. If we choose to modify the 2020 target as you suggest (to 7.9 GW), we would also need to adjust targets for 2030 and 2040 – otherwise the model will show a spike in investments after 2020, because more capacity (3 additional GW) will need to be installed between 2020 and 2030. Please clarify which is your preferred approach and we can update the model accordingly.

Table 7. Main assumptions used for model development and scenario simulation (on energy efficiency), p. 14

Comment 5 by Green Economy Institute:
This table contains a very short list of assumptions used in the forecasts. Below they added a list of government initiatives, which should also be mentioned in the forecast scenarios. Without these, there will be little credibility as to the results of the models.

Answer 5 by UN Environment:
We will mention that the simulation assumes the implementation of several interventions that will collectively lead to the required energy efficiency improvements – and we have included a footnote listing the measures in the National EE plan. This is also now explained in more detail in the narrative part of the report.

Sub-chapter "Main results"

Energy Demand

Figure 2: Dynamics of the net reduction in intensity of energy consumption under the GE scenario as compared to the BAU, %, p.15

Comment 6 by Green Economy Institute:
Proposed title for the graph: Dynamics of the net reduction in intensity of energy consumption under the GE scenario as compared to the BAU (usual or inertia-led scenario), %.

Proposed axis label: Net reduction in intensity of energy consumption under the GE scenario as compared to the BAU, %

Answer 6 by UN Environment:
The graph does not show total energy consumption, but rather the cumulative improvement of energy efficiency under the GE scenario against BAU. In other words, it is the sum of the annual energy efficiency improvements accrued year after year in the GE case against the BAU. To clarify further, the value does not reach the 18 per cent target by 2030 because there is energy efficiency in the BAU case as well, and this graph only shows the additional improvement brought about by the GE interventions. We have accepted your proposed title for the graph.

Comment 7 by Green Economy Institute:
There is some contradiction here, due to the use of 2 different indicators: efficiency and intensity. This can confuse readers, and thus we suggest selecting just one indicator and explaining its dynamics in more detail.

Answer 7 by UN Environment:
We have adjusted the terminology throughout the report and used energy "efficiency" (in relation to the investment required to reduce consumption) in all cases possible.

Comment 8 by Green Economy Institute:
We suggest outlining all the measures that will be taken under the National EE Action Plan for 2020: thermo-modernization of buildings; promotion of EE certification of buildings; promotion of energy-audits and energy management practices; investment in near-zero-energy buildings; investment in EE measures in industry; adaptation of fuel and fuel use standards to European standards; encouraging freight operators to purchase more energy efficiency transport means; accounting for 100 per cent of commercial energy consumption in low-cost and communal housing; and review of construction norms and standards. [For further information, the only quantitative targets therein are: thermo-modernization (up to 25 per cent of residential housing to be refurbished by 2020); and increasing the share of near-zero-energy buildings in the total number of newly built structures by 3 per cent per year].

Answer 8 by UN Environment:
As previously mentioned, these will feature as a footnote in the results section (see above) and are now explained in more detail in the narrative part of the report.

Investment, p.15

Comment 9 by Green Economy Institute:
We request that you indicate how the numbers on the required investments were obtained, and on what basis the numbers US $261.1 million per year, US $500.7 million и US $770 million are derived.

If we are accounting for the reductions in CO_2 emissions that are the result of EE measures during electricity generation, then we need to indicate what levels of CO_2 per unit of increase in EE we recommend to use, and what sort of relationship between these two factors is incorporated into the model.

Answer 9 by UN Environment:
The values for required investment were obtained through multiplication of the emissions avoided (calculated based on the energy efficiency targets) by the cost to reduce 1 tonne of CO_2. The cost assumption is based on IEA cost estimates. We currently use $50/tonne of CO_2, but we could use different values if needed (e.g. an average for the industrial or transport sectors only). The CO_2 reductions resulting from energy efficiency improvements are estimated by taking into account the reduction in the use of oil, natural gas and coal in the residential, commercial, industrial and transportation sectors. As a result, the average reduction of emissions per unit of investment in energy efficiency is proportional to the use of fossil fuels across sectors and in the country.

Comment 10 by Green Economy Institute:
We do not see how EE investments as a share of GDP reach the 0.12 per cent, 0.24 per cent and 0.31 per cent levels. What numbers did you use for GDP (where are these data from?), were these annual or cumulative amounts over 6, 11 and 16 years? Please explain.

Answer 10 by UN Environment:
Initially the model used real values for GDP and investments. This may be confusing because it builds on information on the exchange rate with the USD and inflation. In this updated version, we used nominal values, making it easier to link up the numbers. The % values have subsequently increased.

Employment, p.15

Comment 11 by Green Economy Institute:
Such an increase in employment as a result of activities related to energy efficiency and renewable energy is not realistic for Ukraine, unless there is active government support/policies to support employment. The greatest increase in employment results from technological modernization of industry/manufacturing and reconstruction of medium and large-sized enterprises – which should also be accompanied by an increase in energy efficiency.
It is particularly important to note that after the reestablishment of peace in the eastern regions of the country, destroyed industrial facilities will be reconstructed, and more modern infrastructure will be built, (including railways, water supply/ canals etc.).

We are also expecting a transition to (at least in part) more modern technologies that reduce industrial pollution and increase energy- and material-efficiency as per European standards. All this combined will lead to increments in employment.
In the calculations of investments required, these processes should also be mentioned.

Answer 11 by UN Environment:
We cannot simulate the effects of industrial reconstruction or modernization in the model, but we have incorporated your explanations into the narrative part of the report. In the case of renewable energy, up to 80 per cent of the job creation is for manufacturing of capacity (e.g. solar panels). It could therefore be mentioned that, if all the MW required are imported (e.g. from China), the actual local employment creation may only be 20 per cent to 30 per cent of what is currently indicated in the text. As a result, the numbers provided should be understood as belonging to a scenario where local employment creation is supported.

Energy efficiency is different, mostly because audits and installations are more typically performed by the local labour force. In addition, even more employment gains could be expected from activities that increase energy efficiency as a by-product (e.g. reconstruction of factories that would employ more efficient capital and technology).

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