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TOWARDS THE ENERGY TRANSITION IN UKRAINE

Finding pathways to energy independence and carbon-neutral power sector

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About the Publisher

The Michael Succow Foundation was established in 1999 as the first charitable conservation foundation under the Civil Code in the new federal states of Germany. The prize money from the Right Livelihood Award, bestowed upon Prof. Dr. Michael Succow in 1997, was donated as the basis capital for the foundation, which aims to 'Preserve and Sustain' the ecological balance.

The Michael Succow Foundation is an operational foundation on the national and international level. It is engaged in the development and protection of national parks and biosphere reserves in the transformational countries of the former Eastern bloc (Azerbaijan, Turkmenistan, Uzbekistan, Georgia, Russia).

For almost 10 years, the recognition and conservation of Germany's national natural heritage has been the foundation's most important emphasis nationally. Accordingly, the foundation is currently managing 13 Nature Conservation Areas in north-eastern Germany, with other areas soon to follow. The goal is the development of wilderness oases, accompanied by special opportunities to visit and experience nature firsthand, which are meant to foster a deeper understanding for the re-transformation of the Central European cultural landscapes into wilderness.

Professor Michael Succow and his deeply committed team are supported by an honorary foundation board and countless active volunteers. The foundation works in close co-operation with the Institute of Botany and Landscape Ecology of the Ernst-Moritz-Arndt University in Greifswald, as well as with many other national and international research facilities, i.e., the International Institute for Deserts, Flora and Fauna in Ashgabat, Turkmenistan.

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CONTENT

Abstract

This discussion paper focuses on future of Ukraine's electric power sector, investigating existing risks and opportunities for their mitigation. An assessment of renewable energy potential and present status of coal and nuclear power plant installations is performed, outlining projections for future installed capacities. Significant technical, economic and geopolitical risks, associated with continued reliance on unsustainable sources of energy, and vast development opportunities, associated with deployment of renewable energy, are creating prerequisites for energy transition in Ukraine. Strengthening of economic and technical cooperation between Germany, other EU member states and Ukraine in fields of renewable energy, energy efficiency and innovation could facilitate this transition.

KEYWORDS: Ukraine, electric power system, energy efficiency, renewable energy, Energiewende, energy transition, energy security, sustainable energy, nuclear safety.

List of abbreviations and acronyms:

CHP – combined heat and power plant

EIA – Energy Information Administration of United States of America

EU – European Union

GDP – gross domestic product

GHG – greenhouse gases

GIS – geographic information system

GW – gigawatt

IAEA – International Atomic Energy Agency

IEA – International Energy Agency

IRENA – International Renewable Energy Agency

mtce – million tons of coal equivalent

MW – megawatt

NPP – nuclear power plant

PJ – petajoule

TPES – total primary energy supply

TPP – thermal power plant

Executive Summary

Ukraine can make an effective contribution to global efforts to mitigate climate change by utilizing its huge and practically untapped potential for energy efficiency and by restructuring its excessive and obsolete power sector with high share of coal capacities. Now country is faced with multiple threats posed by dependence on imports of energy resources, old and deteriorating energy infrastructure and risks associated with continued operation of nuclear power plants beyond their design lifetime. To meet these challenges Ukraine's energy sector needs to undergo radical changes.

Currently Ukraine generates biggest share of its electricity from nuclear power plants (number of which already operate beyond their designed lifetime) and outdated thermal power plants, with a small share of hydropower and emerging renewables. Bulk of Ukrainian coal capacities were commissioned in 1960-ies and lack even basic pollution control. Under EU regulations, most, if not all of coal plants, would not be permitted to operate due unacceptable levels of pollution. Still, number of them are supplying electricity for exports to the EU *[1]*.

Without comprehensive long-term vision and action strategy, Ukraine is risking to become an outsider in new realities of Europe's energy sector, which is now undergoing radical changes. These changes are driven by paradigm shift towards development of flexible, interconnected, efficient and ultimately renewable-based energy systems. To join this path Ukraine needs to set new priorities and follow a forward-looking and systematic approach to energy policy.

Continuation of business as usual never was a forward-looking strategy. This approach in energy policy along with rampant corruption poses major threat for Ukraine. In the end accumulation of unresolved problems such as dependence on supplies of fossil fuels, nuclear risks, record high-energy intensity of economy, economic stagnancy and overall mounting costs for maintenance of deteriorating centralized infrastructure, can result in severe and irreparable damage to the state and well-being of its citizens, bringing socio-economic destabilization and other negative consequences to the region.

Ukraine's imperiled economy does not need patching; it needs the transition to a new energy basis. This basis is renewable energy and self-reinforcing circle of energy saving. Similarly, in late 1940-ies, along with technical and financial support from United States provided by the Marshall Plan, strong fiscal and anti-monopoly policies laid down the foundations for German "Wirtschaftwunder" and economic recovery throughout Western Europe, enabling creation of highly productive oil-based economy.

Continued reliance on imports of gas and nuclear fuel is detrimental for energy security and creates political leverages for Russia, who currently supplies not only gas, but also dominant share of nuclear fuel to Ukraine and accepts spent fuel for re-processing. In addition to gas and nuclear fuel dependences, Ukraine is forced to import anthracite coal from occupied territories. Since 2014, Ukraine has lost a large part of its coal reserves, which were mined in the now militarized Donbas region. While gas and nuclear dependences were weakened by enabling of reverse gas flows from Europe and new supplies of nuclear fuel from Westinghouse Corporation, coal dependence is only aggravating and yet needs to be addressed.

A strategic approach to Ukraine's energy policy is more urgent than ever before. Focusing on renewable energy sources and energy efficiency measures is the only way to increase the country's independence from politically constrained fuel imports, alleviate energy poverty and reduce GHG emissions.

To achieve socio-economic recovery, maintain nuclear safety in the region, contribute to climate change mitigation and preserve the environment, Ukraine needs a just transition to renewable energy. While the era of oil is starting to decline, renewable energy is destined to be a new dominant source of power in 21st century, both technically and politically.

It's time to grasp lessons of XX century and move on to sustainable future, creating lasting solutions for future generations rather than burdensome legacies.

Abandoned propaganda station in Pripyat, the contaminated ghost city near Chornobyl NPP
Photo: Oleg Savitsky

1. Introduction and problem statement

The soviet industrialization has left Ukraine with legacy of two tragic cases: the aftermath Chornobyl nuclear accident and environmentally and socially imperiled Donbass region, which became a zone of ongoing conflict since 2014.

Massive energy complex, inherited by independent Ukraine from Soviet times, became excessive and underutilized in realities of economic breakdown following the collapse of Soviet Union. The structure of the energy sector in Ukraine has seen no changes for the last 25 years, as little to no effort made to modernize the energy sector and define new priorities, which would enable a shift to alternative development pathways. Every succeeding government of independent Ukraine have failed to address structural crisis in coal mining sector, resulting in its progressive deterioration, which tragically concluded in socio-economic meltdown of Donbass region.

Due to political reasons, there was no motive to strategically develop renewable energy sources and implement energy efficiency policies. Currently the amount of energy spent in Ukraine to produce one dollar of gross domestic product (GDP) is three times higher than the EU-average, while carbon dioxide emissions per unit of GDP are the highest in Europe *[2]*.

Currently Ukraine generates more than 50% of its electricity from nuclear power plants (number of which already operate beyond their designed lifetime and represent a threat for the entire continent) and outdated coal power plants, with a small share of hydropower and emerging renewables. Bulk of Ukrainian coal capacities were commissioned in 1960-ies and lack even basic pollution control. Under pollution control regulations, most, if not all of coal plants, would not be permitted to operate in any of EU member states due to high emissions of SO2, NOx and toxic particulate matter.

Country's energy sector faces unprecedented challenges, from a reliance on expensive fossil-fuel imports to inefficient infrastructure and monopolized markets. However, the main challenges are of political nature. The ongoing conflict with Russia, continued presence of politicians engaged in corrupting the energy sector, weak anti-corruption enforcement and lack of political will to implement long-overdue reforms are posing an existential threat for future of the country.

Ukraine now needs a new model for development of energy sector, which is essential both for reduction of GHG emissions and for overcoming the country's dependence on imported fossil fuels and enriched uranium. Furthermore, country's dependence on these resource flows is feeding domestic corruption and Russian authoritarian regime. Transition away from coal and nuclear is a major challenge, which Ukraine is currently incapable to address on its own. To solve this crisis Ukraine needs a carefully elaborated major economic program, comparable to restoration of post-war Europe and the Marshal Plan. Without such effort, socio-economic crisis coupled with nuclear and environmental threats in Eastern Europe will continue to exacerbate.

However, present day situation should be considered as a major development opportunity, while renovation of infrastructure and large-scale deployment of renewable energy in Ukraine can create hundreds of thousands of green jobs and become a basis for new economic miracle in Eastern Europe.

In realities of emerging global energy transition, which is vitally necessary to meet Paris Agreement commitments to limit global warming well below 2 degrees, Ukraine also needs to step on the energy transition pathway as soon as possible and join global efforts to mitigate climate change.

50 year-old 2.3 GW Burshtyn thermal power plant. Photo: Oleg Savitsky

2. Status of Ukraine's power sector

2.1 Overview

Ukraine's power system is at risk today because of ageing of outdated, inefficient and environmentally hazardous centralized infrastructure, inherited from Soviet times. Due to its origin, Ukraine's power system is also highly vulnerable in energy security terms. Moreover, even putting short-term political matters aside, Ukraine faces a strategic challenge to renovate its electric infrastructure to maintain stable power supply in the long run, while existing centralized generation capacities are declining due to ageing. The ultimate challenge comes from deep discrepancy between volume and structure of modern demand for energy services in Ukraine and centralized supply, which is based on relics of soviet age.

As of December 2015 Ukraine's total installed power capacity was 50 883 MW. Thermal power plants account for 48,7%, and nuclear plants for 27,2%. Hydro accounts for 9,2% of the total installed capacity. Most hydro power plants are situated along Ukraine's major river – Dnipro, another one is located at Dniester. Most of coal power plants are in the South-Eastern Ukraine and several others are in the western and central regions. Ukraine has four nuclear power plants with 15 reactors in total. They are located in Rivne, Khmelnitskiy, Mykolayiv and Zaporizhya regions.

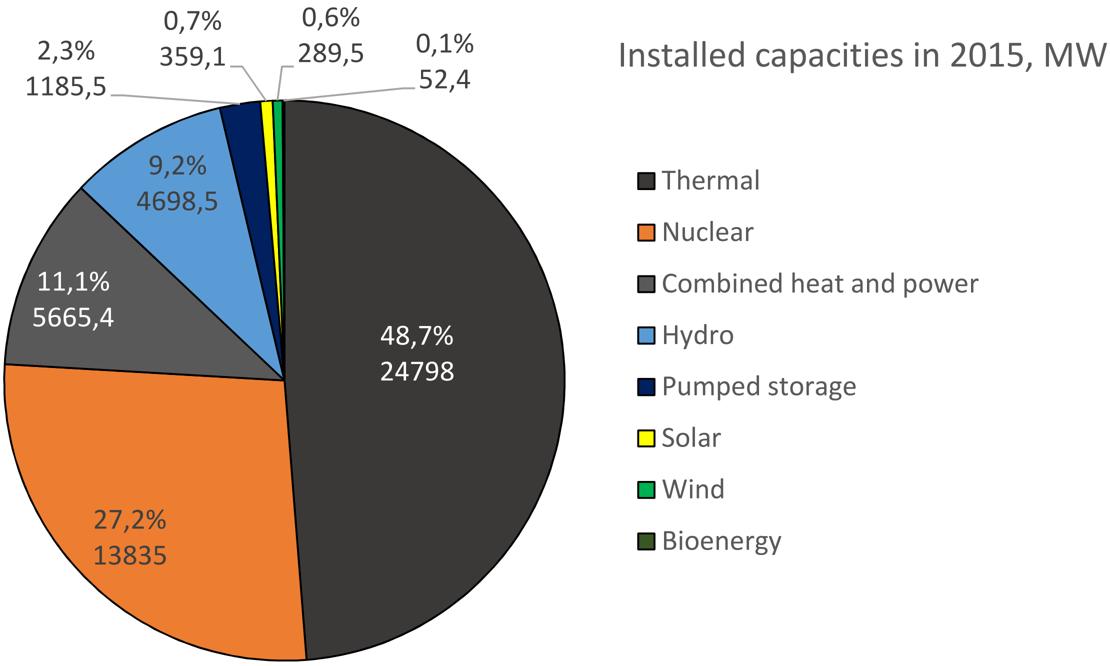

Figure 1: Electric power installed capacities in Ukraine. Data source: National power company "Ukrenergo"

Deployment of renewable energy sources has only started recently. With 701 MW general capacity located in continental Ukraine (not counting capacities in Crimea), most of which was commissioned in last five years, renewables account for only 1,4% of total installed capacity. However, their share in electricity production is much higher is steadily increasing. The share of thermal power plants in electricity output is disproportionally low, because less than third of thermal generation capacity is being utilized continuously and capacity factors continue to decline.

In general, Ukrainian electricity system is highly inefficient and its grid infrastructure requires major renovation and de-centralization to encompass emerging renewable sources of electricity production. Most of grid infrastructure was built 40-50 years ago and in last 25 years not many investments were made to modernize even critical equipment (such as high-voltage transformers and switching gear), not talking about innovations and optimization of system performance.

Prohibitively large share of country's electricity output is wasted. Losses in distribution networks are nearly 2 times higher than those in Poland. In 2013, they accounted for 20.7 TWh, or more than 50% of electricity consumption by Ukrainian households, which totaled 41 TWh that year *[3]*.

Most recent maximum load occurred on 5 January 2016. It was 23 898 MW (including energy that is lost in transmission and distribution, but excluding exports) at 6 PM with ambient temperature -10 °C. At that time, power output from NPPs was 11 976 MW, while TPPs were running only at 8 557 MW.

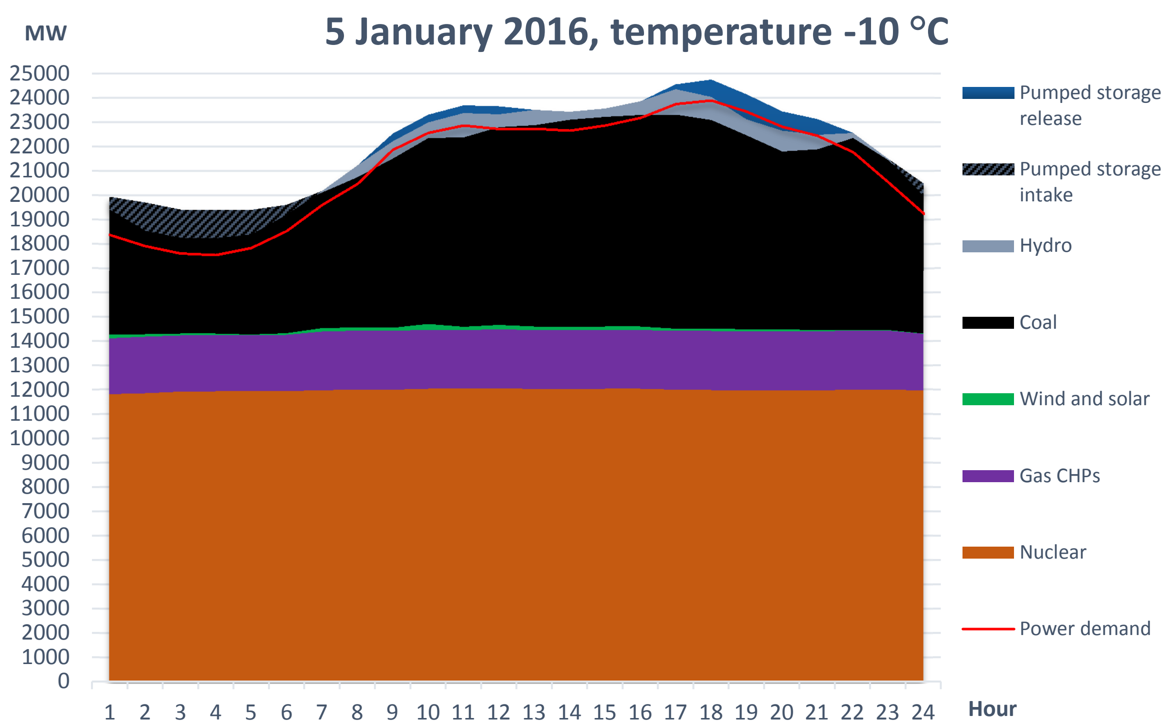

Figure 2: Structure of power supply during the day of maximum winter load in January 2016

In summer time, power consumption and overall load are significantly lower. On 29 June 2015 power load didn't exceed 17 GW with minimal load at 11,4 GW at 6 AM. Nuclear power plants operated 11 of 15 units at 9,5 GW, while baseload coal power output shrinked to 3,3 GW. Additional 1,6 GW of coal power was switched on during the peak demand hours. During that day only 4,9 GW of thermal power plant capacity was used, bringing average capacity factor for coal to as low as 22,5%.

Two power plants in western Ukraine (Burstyn and Dobrotvir) are still exporting electricity to EU member countries including Hungary, Slovakia, Romania and Poland, while these countries would not be allowed to host plants with such levels of hazardous emissions *[4]*.

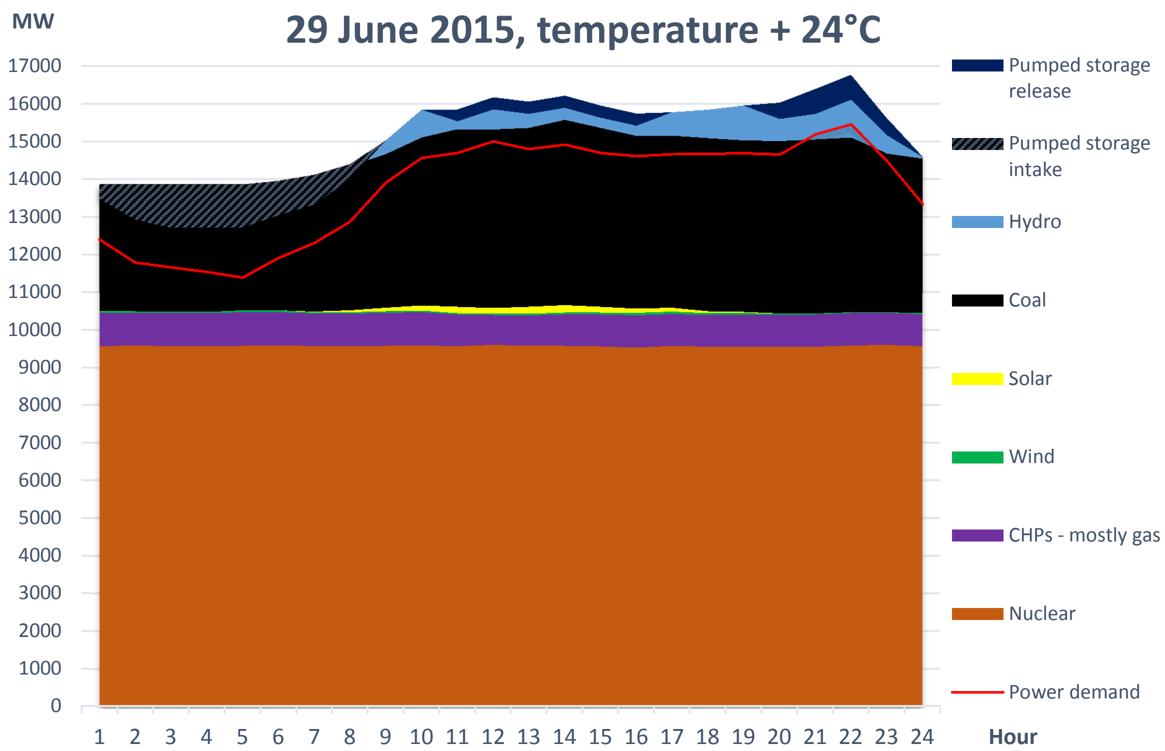

Figure 3: Structure of power supply during the day of minimum annual load in June 2015

1.8 GW Ladyzyn thermal power plant at dusk. Photo: NECU archive

2.2 Coal power

Ukraine has significant overcapacity of outdated and highly polluting thermal power plants. At peak power demand in January 2016 only 8,5 GW (or 1/3 of installed capacity, see figure 2) of thermal power generation capacities were running. The average annual capacity factor for thermal plants is only about 27%. In total there are 14 large coal-fired power plants with nominal 21,8 GW. These power plants account for major share of thermal generating capacities.

Most of power units of at these plants were built in 1960-ies and 1970-ies, which means that they are approaching the end of their technical life expectancy, half of them are likely to retire before 2030. None of 14 major thermal power plants has sufficient pollution control to meet emission limit values for hazardous substances set by Large Combustion Plants Directive. These thermal power plants now demonstrate the lowest levels of technical, economic and environmental performance in Europe.

Coal power sector is responsible for 80% of total emissions of sulfur dioxide in Ukraine and 25% of nitrogen oxides. Levels of hazardous emissions from Ukrainian TPPs exceed the EU standards in 5-30 times, and often breech even national emission limit values. At many TPPs emissions of dust are higher than EU emission limit values up to 45 times *[4]*. Purification of flue gases from sulfur and nitrogen oxides is practically absent at Ukrainian TPPs *[5]*. Economic damage related to increased mortality and morbidity attributed to air pollution was estimated at about 4 percent of GDP. In total, air pollution related mortality represents about 6 percent of total mortality in Ukraine. The range of pollution-attributed deaths in Ukraine was estimated to be in the range of 22,000 to 27,000 annually *[6]*.

Along with severe impacts on health status and increased mortality, air pollution in Ukraine also causes loses in agriculture and forestry through acidification of soils. In general, patterns of air pollution from sulfur dioxide and nitrous oxides emissions in Ukraine and their implications for ecosystems are not sufficiently studied. According to data collected by Coal Energy Technology Institute, in Ukraine annual emissions of sulfur dioxide from coal-fired plants exceed 1 million tones *[7]*.

Reducing emissions to acceptable levels will require restructuring of the whole sector and closure of number of power plants. Total cost of retrofits necessary for existing thermal power plants to meet requirements of Industrial Emissions Directive is estimated at 2,6 billion Euro. In many cases such retrofits would be economically unfeasible, as most of TPPs will be forced out of operation by technical and economic factors well before they can provide return on investments. Investments in pollution control do not make economic sense without first replacing the major equipment, as existing plants would not be able to operate long enough to pay back the money invested to reduce emissions. Replacement of boilers and other primary equipment is even more costly and is practically equal to construction of new power units, which would enchain energy sector to continued CO2 emissions for several decades and is not acceptable from climate change mitigation perspective.

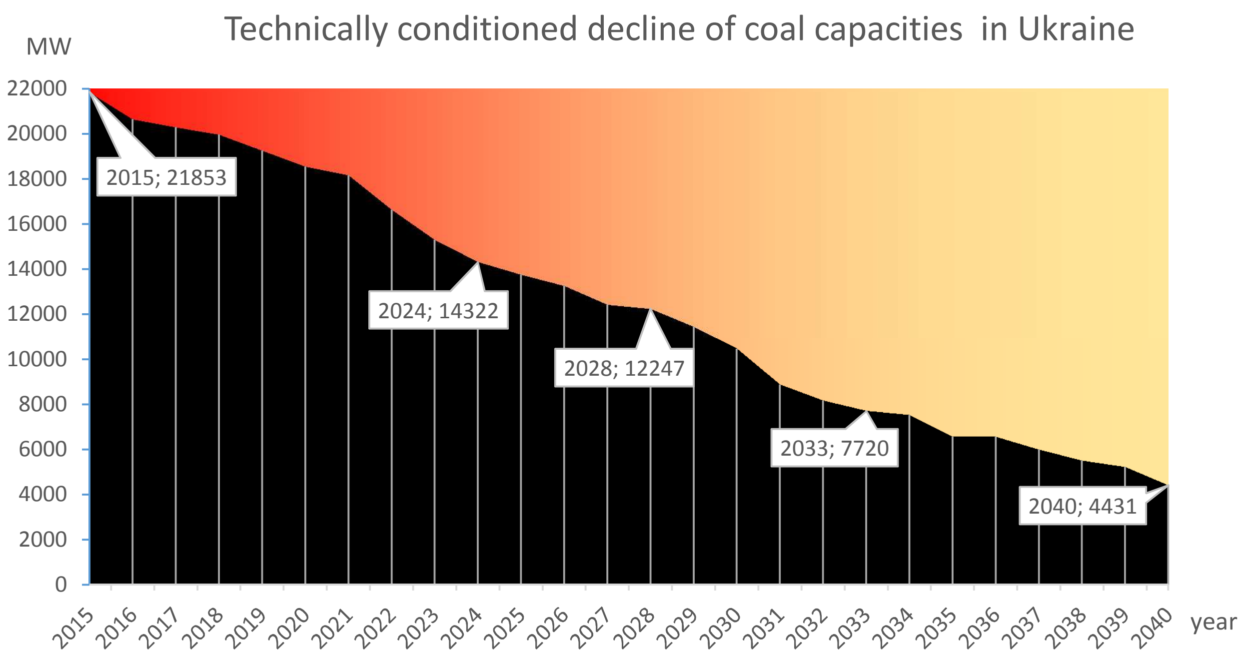

Figure 4: Projection for coal-fired capacities. Author's own analysis, based on data from Coal Energy Technology Institute.[1]

[1] Assuming marginal limit for boiler metal at 320 000 operational hours and extrapolating annual loads for individual units at present levels

Construction of new confinement for unit 4 at the site of Chornobyl nuclear power plant. Photo: NECU archive

2.3 Nuclear power

Ukraine has 4 operating nuclear power plants with 15 VVER-type reactors. Zaporizhya NPP and South Ukraine NPP are testing fuel assemblies provided by Westinghouse Corporation in course of program for diversification of nuclear fuel supplies. But generally the industry is still running on nuclear fuel imported from Russia. Ukraine's nuclear industry doesn't have full technological cycle and is dependent on Russia in the critical middle chain – enrichment of uranium. Ukraine lacks facilities for spent nuclear fuel and it is being shipped to Russia for re-processing and interim storage. Uranium mining is still active in Ukraine.

EU citizens themselves are at risk of being exposed to possible negative impacts, that may arise from prolonged operation of nuclear industry in Ukraine. Most significant, of course, is the risk of new nuclear accidents, which is being exacerbated by military and security threats in conditions of ongoing conflict with Russia.

Twelve out of fifteen nuclear units will reach the end of their project lifespan by 2020. Four of them already operate beyond original 30-year project lifespan. Continued operation of these facilities without modernization and security improvements represents a threat for the entire continent, as no one can guarantee nuclear safety in such conditions. Furthermore, to ensure a safe future and protect present and future generations from nuclear hazards, long-term decommissioning program needs to be developed with a chronologic line-up of closure date for each unit. To allow safe and timely decommissioning sufficient amount of money must be accumulated.

To manage the financial burden, technical and organizational challenges associated with nuclear decommissioning, Ukraine would have to apply step-by-step approach to spread the task over adequate time period and distribute annual expenses. As the first step, 2 VVER-440 units at Rivne NPP and 2 non-serial (trial technology) VVER-1000 units at South Ukraine NPP should be closed down and enter decommissioning process by 2025. Next step – decommissioning of another five units by 2030 with line-up of closures according to expiration of their project lifespan. The final third step – decommissioning of remaining six units by 2040. This scenario is realistic and includes 10-year lifetime extension for most of the units.

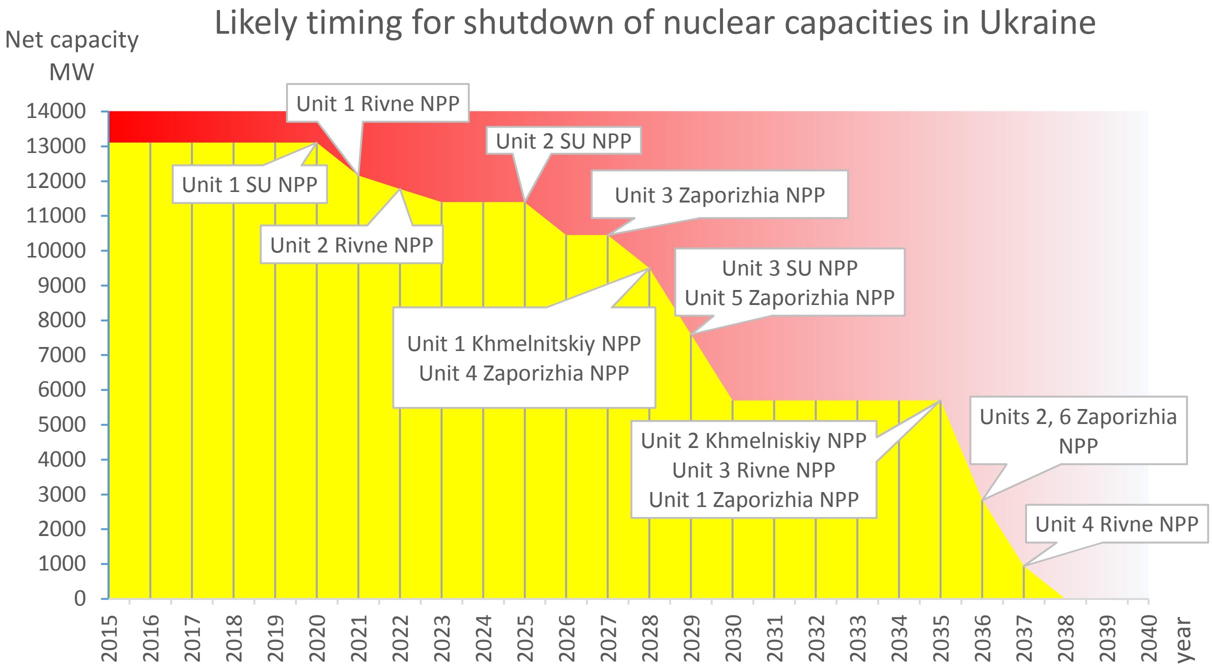

Figure 5: Projection for nuclear capacities, considering present limited investments in maintenance and assuming decommissioning decisions taken after 30 or 40 years in operation.

The licensing process for lifetime extension of all nuclear generating capacities in Ukraine for 15-20 years is underway since 2010 and is being supported by current governmental policies. Unfortunately licensing for lifetime extension is being issued without full and comprehensive technical examination of critical equipment (such as reactor pressure vessels and vulnerability of their materials to thermal shock in case of emergency coolant injection). Moreover, licenses for lifetime extension are being issued without completed and verified safety upgrades.

The most indicative case is lifetime extension of two reactors at Rivne NPP, which is located in Kuznetsovsk, Rivne Oblast. This NPP has four units: two VVER-440/213 type and two VVER-1000/320. The first two nuclear units are the oldest in Ukraine, having been put into operation in 1980 and 1981. In 2010 and 2011 these two reactors were licensed for lifetime extension.

Reactor facilities of the same design (VVER-440/213) as in units 1 and 2 at Rivne NPP were installed at Greifswald NPP in eastern Germany (units 5 and 6). During operation of this power plant in 1974-1989 two near-meltdown accidents have occurred in December 1975 and November 1989 *[8, 9]*. After re-unification of Germany all six units (four VVER-440/230 and two VVER-440/213) were found to be non-compliant with German national nuclear safety standards and recognized as too risky to operate. In 1991 operation of all reactors at Greifswald NPP seized permanently, in 1995 started their decommissioning.

Results of safety analysis published by International Atomic Energy Agency in 2009 show multiple problems and inherent risks for VVER-440/213 type reactors *[10]*. IAEA report concludes that without timely manual operator action, malfunctions of equipment can result in the release of substantial amount of radioactive materials into the environment. Control and protection systems at VVER-440 reactors were not designed to deal with malfunctions in reactor cooling circuits automatically. Successful control over such accidents and prevention of severe consequences critically depends on early and appropriate operator actions. In case of major leak and without proper manual control, coolant tanks can become depleted and core heat-up may take place, posing a risk of reactor meltdown. Due to absence of intelligent control and safety systems, technical malfunctions and operator mistakes can result in severe accidents. In this context continued operation of units 1 and 2 at Rivne NPP represents a significant risk to nuclear safety in the region.

In 2013 Ukraine was found to be in non-compliance with Espoo Convention requirements by not preparing environmental impact assessment (EIA) in the case of lifetime extensions for nuclear units at Rivne NPP and not consulting about it with neighboring states. Assessment of the environmental component of the EU-Ukraine bilateral cooperation also revealed multiple other problems, which lead to non-compliance of Ukraine with Aarhus and Espoo Conventions *[11]*.

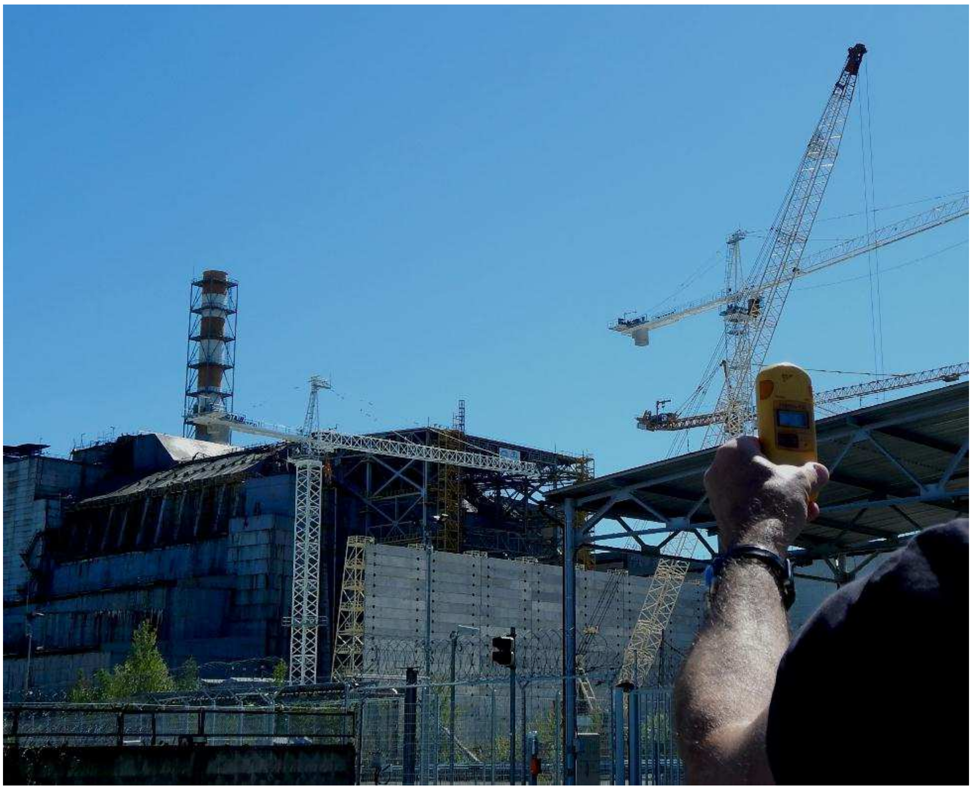

Photo: NECU archive

2.4 Untapped potential of energy efficiency

Ukraine has vast underutilized potential in energy efficiency and energy savings. Energy efficiency can significantly reduce the total investment requirements in the energy sector and support decoupling of economic growth from the increase in greenhouse gas emissions. However, actual regulatory policies continue to undermine necessary action.

According to expert estimates, Ukraine's energy-saving potential could be as much as 50% of its current energy consumption *[12]*. Until recently, introduction of energy saving and energy efficiency measures had been effectively blocked by lobbies of domestic energy intensive industries and fossil fuel suppliers.

Currently energy efficiency measures are included in the concept paper for energy strategy until 2035 *[13]*, but not in a significant way. Unclear policy and regulatory framework leads to absence of significant business, community, and political support for energy efficiency measures and does not allow creating a momentum to fully utilize this potential. Moreover, new drafts of Ukraine's energy strategy continue to ignore the potential of harnessing the full spectrum of renewable energy technologies, which are not limited to electricity production. Major share of primary energy demand can be met with solar thermal technologies, air-heating and cooling systems, heat pumps, waste heat recovery, biomass and biogas for space heating and co-generation, sustainable biofuels for transportation, development of modern renewable-based district heating systems, etc.

Improving energy efficiency and reducing primary energy consumption should be one of the key priorities of Ukraine's energy policy. Improvement of energy efficiency is extremely important for the country, which imports up to 60% of its energy and is in dire need to decouple economic output from primary energy consumption. Setting energy efficiency as priority is critical to re-launch country's socio-economic development on a new, sustainable basis.

Photo: Oleg Savitsky

2.5 Political and regulatory environment

Monopolization and lack of transparency remain the biggest obstacles for sustainable change in Ukraine's energy sector. To solve these problems Ukraine needs to re-structure and split its vertically integrated companies, both private and state-owned, and ensure free and equal access for new players and fair competitive environment.

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 and implement number of packages of EU Directives nationally.

These directives set mandatory national goals, offer investment guarantees and encourage innovation and development of advanced technologies. Under Energy Community Treaty Ukraine has an obligation to produce 11% of electric power supply from renewable sources by 2020.

Ukraine has great potential for deployment of established renewable energy technologies (wind, solar, biomass), which is evidenced by successful kick-start of this sector in 2010-2013. Renewable energy is one of the few areas where implementation EU Directives under Energy Community was fairly effective. One of the deterrent factors was obligatory "local content" in renewable energy projects, which was forcing developers to purchase during construction fixed share of components and services in Ukraine. After adoption of Law "On amendments to some laws of Ukraine to ensure competitive conditions for the production of electricity from alternative energy sources" on 12 June 2015, these distortions were rectified. The new law introduced stimulating factor for investors: an increase to the "green tariff", if renewable power generation facility is commissioned with use of components manufactured in Ukraine and/or with involvement of local contractors. However, due to current turbulent political and economic environment, investments in the renewable energy sector have shrinked dramatically in last two years and need to be re-launched.

As a point of major concern, Ukraine is falling short to meet obligations in the field of energy efficiency under the Energy Community treaty. The national legislation does not comply with 2006/32/EC Directive on energy end-use efficiency and energy services and the 2010/31/EU Directive on the energy performance of buildings and implementation deadlines are long overdue.

Another Ukraine’s obligation under Energy Community Treaty is to reduce hazardous emissions (SO2, NOx, toxic dust) from thermal power plants and implement provisions of Large Combustion Plants Directive 2001/80/EC. With the partial entry into force of the Association Agreement with the EU on 1 November 2014 and number of country-specific decisions adopted by Energy Community Ministerial Council, Ukraine is also obliged to implement certain provisions of Industrial Emissions Directive 2010/75/EC, which imposes stricter pollution control requirements for thermal power plants. In order to meet pollution control standards set by Industrial Emissions Directive at Ukrainian coal fired TPPs major reconstruction and long-lasting investment programs would be needed, which is hardly realistic in current conditions.

In the next 10-15 years, Ukraine will have to close down half of currently existing coal capacities because of technical and economic reasons as mentioned in section 2.2. Operators of coal power plants are hardly planning any investments in desulphurization and denitrification equipment – the only way existing plants might conceivably be allowed to continue functioning after 2028. It simply does not make economic sense to invest in such equipment at most of Ukraine’s obsolete coal plants.

Given the current dire economic situation in Ukraine, there is only one economically feasible way to meet the EU pollution control requirements: reduce the share of coal-based generation and develop a coal-phase strategy, starting with the decommissioning of the most polluting and outdated plants. To avoid possible shocks from simultaneous decline of nuclear and coal capacities in the future, Ukraine’s power sector needs rapid deployment of renewable energy for substitution.

In coming years Ukraine’s energy sector needs to be fundamentally reorganized. This can be achieved by de-monopolization of energy services, re-structuring of coal mining and thermal power generation, liquation of cross-subsidies and introduction of transparent energy pricing, ensuring priority grid access for renewables and introduction of incentives for energy conservation (such as White Certificates for utilities and time-bound pricing for consumers). Along with structural reform, a politically independent and professional energy regulatory authority must be established.

For this to be achieved Ukraine needs to build its energy policy on the rule of law, transparency and sustainable development goals instead of service for private interests. These changes can be facilitated by adoption and effective enforcement of new national legislation package for implementation of Energy Community acquis communautaire. Energy Community treaty and Association agreement now are seen by many actors (both national and international) as major drivers of reform process in Ukrainian energy policy. Still, major long-term efforts are needed to bring energy, environmental and climate policies in Ukraine in line with the EU's framework.

Photo: Oleg Savitsky

3. The excellence of soft energy path and risks of hard energy

The "soft energy path" is a concept for long-term sustainable energy strategy, elaborated by US energy policy analyst Amory Lovins back in 1976, who now is one of the leading energy experts in the world. Now, 40 years after his landmark publication in Foreign Affairs magazine *[14]*, his ideas are becoming mainstream in Europe *[15]*. His argument that energy efficiency and appropriate use of renewable energy sources can steadily replace centralized energy systems based on fossil and nuclear fuels is becoming a reality in Germany and other parts of the world, where governments and societies chose to build their energy future on sustainable basis.

The first step towards the soft energy path for Ukraine would be to withdraw any commitments to creating inflexible infrastructure, that locks economy to unsustainable (both geopolitically and environmentally) supply patterns for decades and wastes financial and social capital. In parallel, Ukraine should develop a transition strategy away from reliance on declining centralized infrastructure, which bounds us to hazardous technologies (such as fossil fuels and nuclear fission) and aggressive and unscrupulous fuel suppliers, namely Russia.

Transitional strategy for Ukraine should focus on four key principles:

1. Energy efficiency as a priority
2. Decentralization of energy infrastructure
3. Strong anti-monopoly enforcement to guarantee free and even access to energy markets for new players
4. Removing institutional and regulatory barriers for deployment of renewable energy technologies and energy innovations

As have been recently shown by number of studies, *[16, 17]* a renewable-based economy can be created in Ukraine with straightforward solutions that have been demonstrated and prove to be economic globally. A strategic approach to rebuilding its energy infrastructure is necessary in Ukraine. The country is at important cross-roads right now and decisions of present day will have significant and long-lasting consequences. If new strategy will be based on four abovementioned principles, its successful implementation can have revitalizing effect for the whole economy and create hundreds of thousands of new jobs in construction, manufacturing and services, needed for deployment of renewable energy sources.

In contrast, the so called “hard energy path”, defined by Lovins as reliance on over-centralized, inefficient and environmentally hazardous energy infrastructure, proves to be a wrong way to go, yet many countries still follow this path due to inertia, vested interests and political barriers. However, Ukraine’s economy seems to have almost exhausted its ability to follow the troublesome road of hard energy path further. Without a major shift in energy policy, this can result in a grave situation of long-lasting overall socio-economic decline and disintegration of basic infrastructure.

In the last 40 years, Ukraine has hit some very painful potholes on the hard energy path, permanently losing significant area of livable space due to radioactive contamination following the Chornobyl nuclear disaster and encountering ongoing political and socio-economic collapse in Donbas region. Donbas crisis represents a clear case of resource conflict, caused by race for power and control over fossil fuel reserves between groups of oligarchs and corrupt officials in Ukraine and Russia *[18]*.

Continued over-reliance on the fleet of ageing nuclear reactors, which lack independent and thorough oversight, for the next 20 years (which currently positioned as the default option for Ukraine) poses a number of threats to the whole region: from proliferation of radioactive materials to another major accident. This threat recently has been aggravated by security concerns, provoked by statements from Russian parliament obscenely delivered at the 30th anniversary of Chornobyl disaster *[19]*.

On the parallel side of the hard energy path, Ukraine has excessive and obsolete fleet of extremely polluting coal power plants, which are approaching the end of their lifespan. In 2013 the health costs caused by unabated air pollution from large combustion plants in Ukraine were estimated to be 9,1 Euro annually, according to study commissioned by Energy Community Secretariat *[5]*. The average age of coal power units is already 47 years, while their capacity utilization rate is well below 30%. It is obvious that major re-structuring and phase out of the oldest and most polluting plants is necessary just to keep the industry afloat *[20].*

However, decrepit centralized fossil-fuel capacities should not be replaced with new ones. Such investment would be a major mistake, resulting not only in waste of capital and creation of stranded assets in climate-constrained world, but also in increased energy poverty and low quality of energy services. Gradual phase out of coal power plants can bring tremendous environmental and public health benefits by reducing effects of currently rampant air pollution. As mentioned above in section 2.2, the number of deaths attributed to air pollution in Ukraine is estimated to be in the range of 22,000 to 27,000 annually *[6]*.

To minimize mounting of acute and chronic risks, posed by nuclear and coal-fired power plants, Ukraine needs to kick-start transition to the soft energy path as soon as possible.

4. Dual phase out of coal and nuclear – mission possible

4.1 Technical feasibility of capacity replacement

To cover its current needs at peak demand Ukraine needs less than 17 GW of electric power supply in summer and less than 25 GW in wintertime *[21]* (see figures 2 and 3). Considering that levels of economic activity are unusually low due to ongoing crisis and acknowledging the future need for electrification of transport, in mid-term we can expect a slight increase in electricity consumption which will stabilize at a certain point on the new level. Moderate growth of supply from present level would be needed to power the recovering economy. In any case it is highly unlikely that this new load levels will reach those observed in 2013 (28 GW max in winter), which was before the territorial losses and power cut-off for Crimea (which had average net consumption of around 1 GW). Another major factor is ongoing decline of obsolete energy intensive industries in eastern Ukraine, which has structural nature and was catalyzed by hostilities in Donbass region. Taking into account these considerations, it would be fair to assume that future electricity consumption will never exceed 28 GW at peak demand during wintertime in the most pessimistic scenario for energy efficiency (dis)improvements.

Successful implementation of energy efficiency programs in residential and commercial sectors can reduce temperature sensitivity of electric power consumption. Demand-side management can significantly decrease peak demand, making costly gas-fired maneuverable capacities or massive energy storage unnecessary. In this scenario peak demand can be reduced at least by 10%, limiting maximum load in the future to present 25 GW, reducing need for expensive peak-load capacities and reducing overall system costs. In such case consumption in GWh per year will be higher than present, yet with more even demand patterns. Currently, compared to peak demand of less than 25 GW, Ukraine has 50,9 GW of installed capacities, which vividly represents the fact of overcapacity. Such overcapacity coupled with cross-subsidies creates an economic deadlock in the power sector.

If centralized nuclear and coal power plants would disappear altogether from Ukraine's electric power grid in winter time at peak demand hours, the system would have deficit of around 20 GW of guaranteed power supply, as existing large hydro and renewables combined already can provide more than 5 GW of power supply. Is it possible to provide these 20 GW with more renewables?

To find out, lets look at the German electric power system. In July 2014 Germany had 83,8 GW of renewable capacities, bulk of which were commissioned in last 15 years *[22]*. In 2015 alone Germany added to that more than 3,5 GW of wind *[23]* and 1,3 GW of solar PV *[24]*. Average capacity factor for wind farms in Germany is 35% and 17% for solar PV. In Germany (as of December 2015) wind with 41 GW and solar with 36 GW of installed capacities provided on average more than 20 GW of continuous electric power supply. Biogas plants, which operate 24/7 and not depending on weather, have very high capacity factors, provided another 6 GW.

Germany has deployed 26 GW of baseload power supply provided by renewable energy sources from nearly zero in less than 20 years, pioneering the energy transition and bearing all the research, development and system integration costs. Currently Germany is producing more electric power from renewables than Ukraine's total demand. Thanking to German early investments, and following global advances in renewable energy technology, these costs are by far lower than they were 20 years ago and periods of project implementation (development + construction) have reduced dramatically.

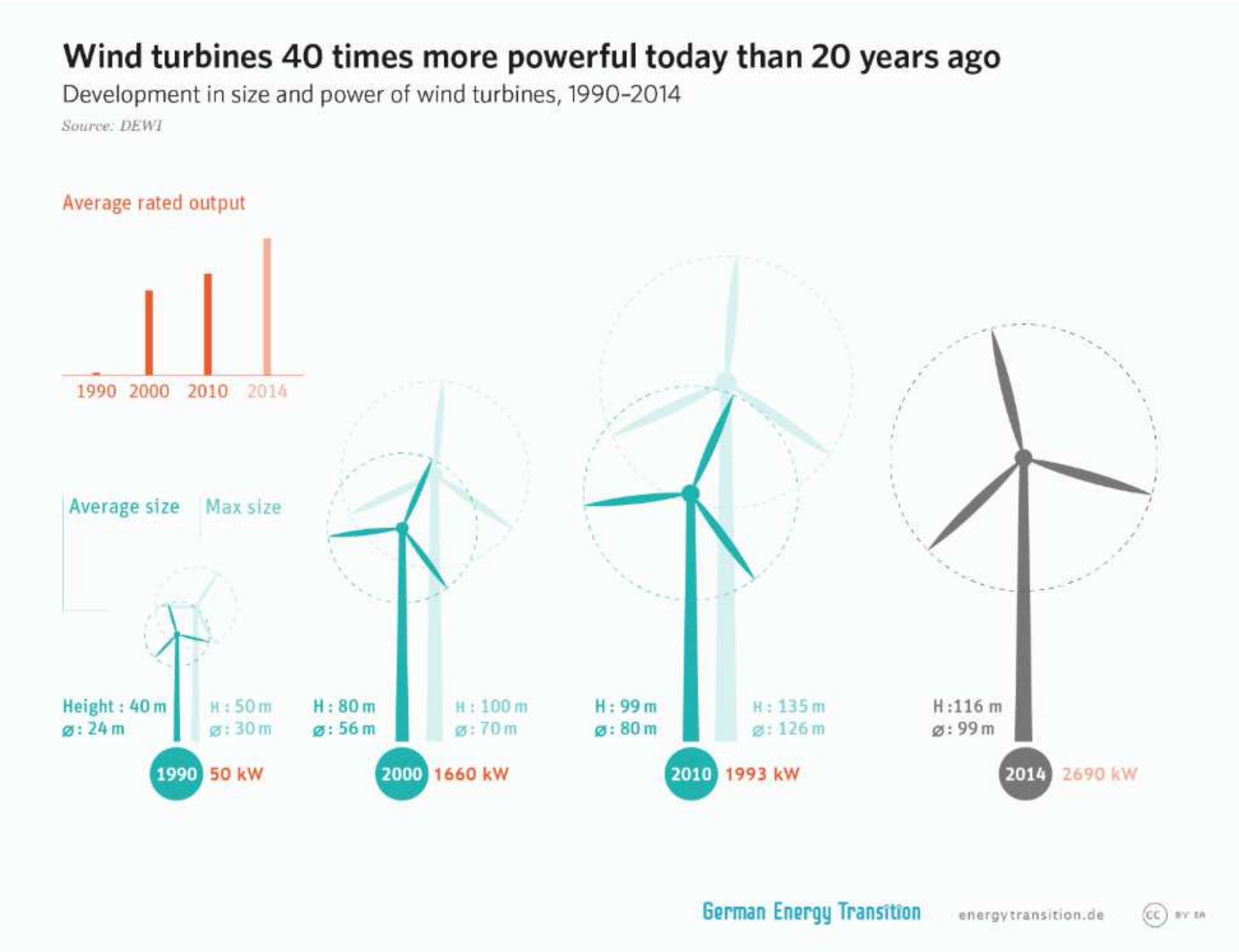

Figure 6: Progress of wind power technology. Source: German Energy Transition http://energytransition.de/2014/12/infographs/

Potential of solar PV and onshore wind in Ukraine, being recently investigated with GIS tools by numerous private and public actors (see maps in annexes A and B), was found to be one of the highest in Europe.

In general, three factors are playing to Ukraine's benefit in terms of potential for energy transition. Firstly, due to its geography, Ukraine has significantly better insolation conditions for solar PV, especially in southern regions, which results in higher capacity factors and increased net output for the same type of installations. Secondly, due to much bigger territory, lower population density and long coastlines, Ukraine has relatively more space for deployment of onshore and offshore wind than Germany. Thirdly, Ukraine is a major agricultural producer with the potential to become biggest in Europe, yet the rate of utilization of agricultural biomass by-products (which is a huge and largely untapped resource) is very low. Biogas production from agricultural waste and manure is still in the stage of pilot projects in Ukraine. Biomass resources are more abundant in Ukraine than in Germany, but still their potential is limited by the same environmental and economic factors as in Germany and they should be utilized sustainably.

Ukraine also has pumped hydro storage with total capacity of 1 185 MW. Currently pumped storage is being utilized to fill in the drop in power consumption at night and to provide maneuverable peak-load generation in the afternoon. These capacities are operating in cyclical mode with daily charges and discharges. But with significant share of renewables in the energy system, pumped storage can have other function – to tap over-production of electricity in periods of generous sunshine and strong winds, preventing negative electricity prices, which occur in Germany increasingly often. In this scenario pumped storage will become an important flexibility reserve on the supply side, accumulating energy in periods of high production from renewables, which will mostly occur on daytime due to contribution of solar capacities, and produce energy in periods when output from renewables is limited. Pumped storage constitutes a valuable energy storage resource, which is readily available in Ukraine.

Last, but not least, significant geothermal potential is available in many regions of Ukraine. Large reserves of thermal waters found and in Chernihiv, Poltava, Kharkiv, Luhansk and Sumy regions. Hundreds of exploration wells with thermal waters are in conservation and can be recovered for further use in geothermal heat extraction systems *[25]*.

With annual capacity additions of 1 GW guaranteed power supply (considering load factors for modern technologies, that would be around 3 GW of physical capacity), Ukraine can replace coal and nuclear entirely in less than 20 years. If we start in 2018, by 2038 Ukraine can be powered by 100% renewable electricity. This is more than realistic from technical and economical standpoints, actually it is conservative, as it does not factor in the exponential trends in development of renewable energy technologies and possible emergence of new technical breakthroughs. Additions of 1 GW of guaranteed power supply can be achieved in multiple ways by different combinations of renewables. The only barriers for such desirable course of events are of political and institutional nature. Even with all these barriers, further complicated by economic crisis and hostilities in Donbas, Ukraine added 181,5 MW of renewables to the grid in the troublesome 2014 year.

Table 1:
Scenarios for commissioning of new capacities to deliver 1 GW of guaranteed power supply in year 2027.

Energy source	Solar		Onshore wind		Bioenergy		Offshore wind (OW), geothermal (GT) and other*	
Load factor	20% (for PV)		32%		90%		20-95%	
Capacity	MW	factored share	MW	factored share	MW	factored share	MW	factored share
Scenario 1: Wind	1 200	24%	1 750	56%	100	9%	OW: 350	11%
Scenario 2: Local resources	1 200	24%	1250	40%	200	18%	GT: 160 SH: 50	18%
Scenario 3: Solar boom	2 750	55%	1 000	32%	100	9%	GT: 50	4%
Scenario 4: Innovation	1 500	30%	1 000	32%	45	4%	OW: 325 GT: 200 WE: 50	34%
Scenario 5: Balanced	1 525	30,5%	1500	48%	112	10%	OW: 100 SH: 20 GT: 80	11,5%
Capacities built in 2014	18,6		137		25,9			

* SH – small hydro, WE – wave, tidal and currents energy

What was seen as pure fantasy twenty years ago has now become an applied science. In modern world, you can deploy renewables much faster and cheaper. China is now breaking every record by adding 30,5 GW of wind an 18,4 GW of solar capacities in sole 2015 *[26, 27]*. That would be enough to replace bulk of Ukraine's electric power supply entirely, and China commissioned these capacities just in a single year.

China's territory, which includes unhospitable areas like deserts and mountains, is nearly 16 times of Ukraine. Based on its territory, natural and industrial potential the rate of renewable generation capacity deployment of 3 to 4 GW per year is well achievable in Ukraine in the near future. To make this a reality all regulatory and institutional barriers need to be removed and deployment renewable energy should be set as a political and economic priority.

4.2 Economic and geopolitical incentives

Ukraine's people have already made their political choice – accession with EU and improving cooperation in all spheres up to full integration. For this to be achieved policy frameworks, including energy policy, should be fundamentally reshaped to reflect the common goals and values of European Union. Europe is already heading full steam toward integration of national energy systems in a single super-grid and transition to renewable sources of energy, as the historical project of European Energy Union advances. Further reliance on declining centralized fossil-based infrastructure is not sustainable from three key perspectives:

- environmental,
- economic,
- geopolitical.

This is already clear for European policymakers.

Current Ukraine's positions in environmental, economic and geopolitical areas are very weak. For decades, environmental problems was being largely ignored or systematically downplayed in Ukraine, despite adverse health impacts and aggravated degradation of environment. Long-term socio-economic impacts of policies and infrastructure projects were not evaluated, undermining consistency and legitimacy of decision-making process. Geopolitical risks associated with dependence on fossil fuel imports and reliance on Russian nuclear technologies have materialized and now pose a threat for the sole sovereignty and political integrity of Ukraine. To start moving steadily towards European integration and meet major challenges, created by decades of misrule, energy policy in Ukraine needs a new course. Ukraine can no longer rely on energy infrastructure commissioned in soviet times.

Continued reliance on nuclear energy and fossil fuel imports is detrimental for energy security and creates political advantages for Russia, which currently supplies dominant share of nuclear fuel to Ukraine and accepts spent fuel for re-processing. In addition to gas and nuclear fuel dependences, Ukraine is forced to import anthracite coal from Russia or occupied territories. During the conflict, Ukraine has lost control over large part of its coal supplies since Donbas region has turned into two self-proclaimed "people's" republics – internationally outlawed militarized zones. While gas and nuclear dependences were weakened by reverse gas flows from Europe and new supplies of nuclear fuel from Westinghouse Corporation, coal dependence is only aggravating and needs to be addressed as soon as possible. Every ton of coal supplies from non-controllable territories is feeding corruption in Ukraine and handing cash to terrorist regimes in non-controlled territories, motivating them to use forced labor in make-shift coal mines and aggravating perilous situation with human rights in Donbass region even further.

Another big issue is mass energy poverty – 70% of Ukraine's households are paying unsustainably high share of their incomes for energy bills. Rising energy prices are affecting increasingly big part of general population. As more people spend a higher portion of their income on energy needs, the least likely they will be able to afford investments in energy efficiency such as renovations and thermal insulation of buildings, replacement of windows, installation of more efficient heating appliances. Energy subsides, lack of incentives for energy efficiency improvements and abuse of consumer rights and liberties creates a vicious circle of exacerbating socio-economic crisis. The only effective way to combat energy poverty is to set energy efficiency and transition to decentralized energy production as policy priorities.

Multiple treats in Ukraine are readily providing compulsive incentives for energy transition, but they should not be regarded as defining ones in energy policy arena. In the carrot and stick motivation complex, carrot plays much bigger role. Renewable energy, smart transportation systems and efficiency gains in all economic sectors (private, industry and commerce) are the major drivers of growth in the 21st century. These positive incentives are not being fully recognized in Ukraine, their true potential yet needs to be uncovered and investigated.

One of the most important aspects of the energy transition is social justice. Energy efficiency, in particular, not only helps promote domestic added value and increases capital investments, but also reduces energy poverty. Over the long run, the price of renewable energy will remain stable or even decrease, as there are no fuel costs for wind or solar, and equipment costs will continue to drop. The real cost of fossil fuels and nuclear will continue to increase, especially with introduction of carbon pricing, decommissioning and waste treatment surcharges, so the energy transition itself is a way of keeping energy prices in check and avoiding energy poverty. Moreover, energy efficiency and renewables can give way for more equal and just society.

Same as in many other countries, in Ukraine the energy sector has long been in the hands of large corporations (owned by individual oligarchs in Ukraine's case) and electricity is being supplied from huge central power stations. Renewables offer an opportunity, however, to switch to a large number of small generation capacities, and this distributed approach offers an opportunity for citizens and communities to get involved. Local ownership of renewables can provide great economic payback for the investing communities and reshape the energy market.

Unbundling of energy production from transmission and distribution utilities, together with effective anti-monopoly enforcement can provide incentives for major private investments in energy sector, which can boost the deployment of renewable energy modernization of energy infrastructure. Rapid deployment of renewable energy can create thousands of well-paid jobs and deliver reliable, open and generally accessible energy services effectively eliminating energy poverty. Energy efficiency measures and building renovations will also create many jobs in the construction sector.

Locally developed renewable energy, coupled with systematic and municipally governed approach to renovation of building stock will help to address all of the three investigated areas of incentives:

1. From environmental prospective this will allow to achieve high pace of GHG-emission reductions by fossil fuel displacement and make a decent contribution

to climate change mitigation efforts. This will also bring huge benefits for public health by reduction of air pollution. In the face of severe climate crisis maximum effort from every country in the world is necessary to prevent abrupt changes in Earth's life support systems – oceans and the atmosphere.

2. From economic prospective this will create thousands of new jobs and launch self-reinforcing investment cycles: increased investments in energy saving and renewables will retrieve capital spent on fossil fuel supplies and mitigation of large, but unaccounted externalities of their use, strengthening local economies and regional cooperation, which in turn will allow to direct even more capital into new investments.
3. From energy security prospective, this will allow to decrease imports of energy carriers from Russia and eventually eliminate them. Transition to renewable energy and integration to pan-European energy market will guarantee long-term energy security regardless of availability of fuel supplies (both fossil and fission) and geopolitical developments outside Europe.

Ukraine's imperiled economy does not need patching; it needs the transition to a new conceptual basis. This basis is renewable energy, technological innovation and self-reinforcing circle of energy saving. Similarly, in late 1940-ies, along with technical and financial support from US provided by the Marshall Plan, strong fiscal and anti-monopoly policies laid down the foundations for German "Wirtschaftwunder" and economic recovery throughout Western Europe. The Marshall Plan helped to rebuild Europe's new economy using new dominant source of energy – oil. Oil was diving industrial development in Europe for the next 30 years and allowed to build highly mobile and interconnected market economy. In the XXI century decentralized renewable energy is becoming a dominant resource and a basis for ultra-modern economic development.

Ukraine's progress in transition to sustainable energy economy is vitally important for success of EU's effort to create pan-European energy market. Integrity, security and sustainability of energy supply cannot be achieved in Europe without major improvements in energy sector of Ukraine.

European Commission and EU's individual member states, especially Germany, should closely cooperate with Ukraine's civil society groups and develop an ambitious economic program based on rapid rollout of energy transition in Ukraine. A carefully elaborated and transparent plan presented in Ukraine can inspire and mobilize public and facilitate profound economic and political changes.

Transition to renewable energy provides the opportunity to solve the current geopolitical crisis in Eastern Europe, avoid further armed conflicts over fossil fuel extraction and supply, and build cooperative security mechanisms. By harnessing local renewable energy sources, Ukraine can increase its political and energy independency. The degree of international cooperation needed for this transition can act as a catalyst for cooperation in tackling other regional challenges. Finally, phasing out nuclear power would prevent potential threats of nuclear accidents and spread of radioactive materials in the region.

5. The case for energy transition in Ukraine

5.1 100% renewables as global energy destination

As recent Intergovernmental Panel on Climate Change (IPCC) reports highlight, in order to ensure planetary habitability for today's and future generations, we urgently need to build societies powered by safe, affordable, and sustainable energy – worldwide.

More than 2/3 of global GHG emissions originate from combustion of fossil resources such as oil, gas and coal. In order to remain well below a 2 degrees Celsius increase compared to pre-industrial temperatures, it will be necessary to move the world towards fully decarbonized energy sector by 2050. The goal of complete transition toward renewable energy sources is no longer an abstract concept: it is now being implemented in numerous places around the world *[28]*. EU as whole is already moving from roadmaps to real decarbonisation in energy sector *[29]*.

The perfect storm is rising globally with diminishing productive soils and rising food insecurity, public health crisis, energy poverty, escalating climate change and threat of nuclear proliferation. This adds urgency to deployment of renewable energy. All of these threats are present in Ukraine. Moreover, they are combined with chronic economic stress, posed by enormous counterproductive subsidies, political vulnerability of fuel supply and ongoing military conflict in hydrocarbon-rich Donbass region. All these challenges have a single common driver – unsustainable energy supply from fossil fuels and nuclear fission. To address them Ukraine needs an ambitious energy transition plan and integrated approach for climate and energy policy.

The close interconnection between Ukraine's current problems in power sector and the profound national crisis demonstrates that dependence on centralized, polluting and vulnerable energy infrastructure is the key problem we need to solve. Gigantic gas pipelines, nuclear reactors and coal power plants represent an unsustainable legacy of soviet authoritarian regime, yet energy and infrastructure policies have seen little change after the collapse of USSR. The ambitious and comprehensive action is needed to break the existing status quo in Ukraine's energy industry and open the gates for radical innovation and emergence of new type of energy infrastructure – intelligent, flexible and decentralized.

Evidence of imminent system-wide change in energy markets are becoming clear since adoption of the Paris Agreement. By signing the Paris Agreement, Ukraine has also pledged to join the global efforts to mitigate climate change and at all costs avoid dangerous levels of global warming. This means that Ukraine will have to decarbonize it's energy sector, sooner or later. Continued protraction can result in enormous losses in all spheres, being damaging geopolitically, economically and environmentally.

5.2 Capacity projections for Ukraine

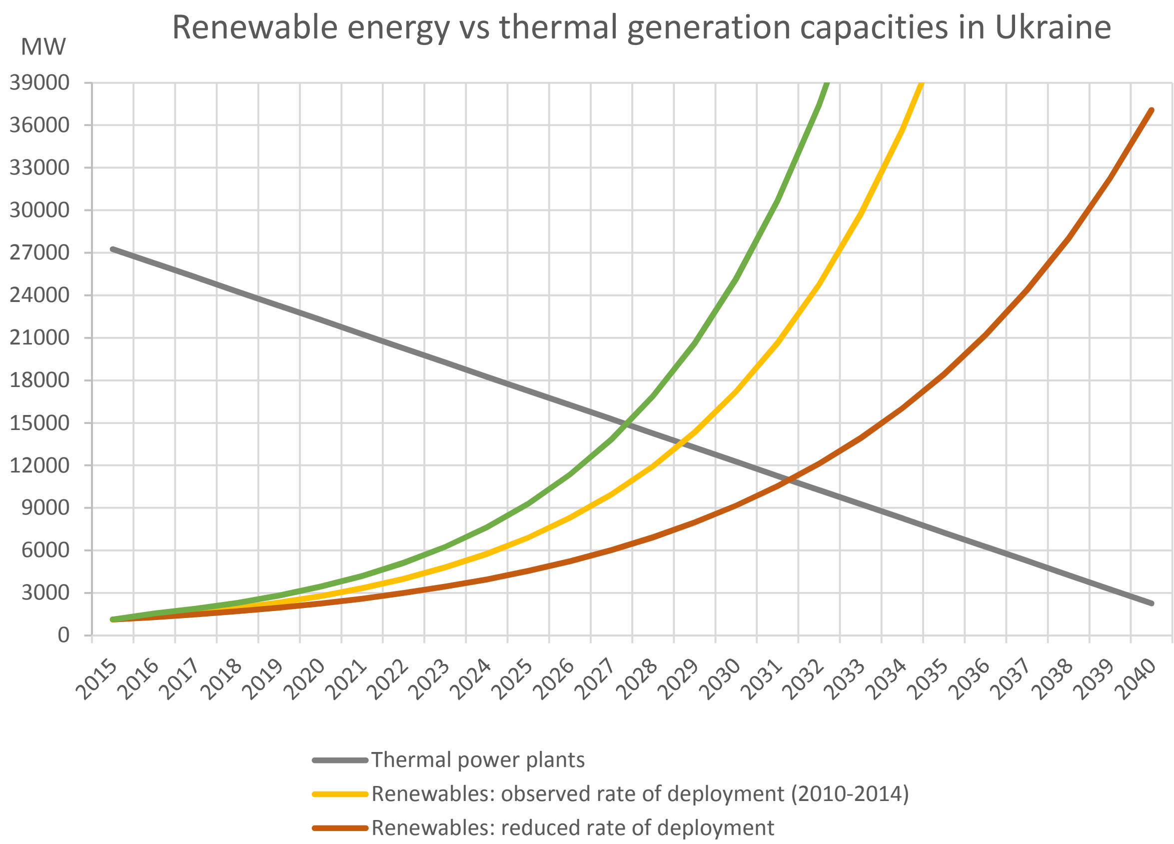

Figure 7: Installed capacity of renewable energy will exceed declining thermal generation capacity by 2031 at latest and before 2028 if REmap options outlined by IRENA for Ukraine are utilized [16].

If development of renewable energy industry in Ukraine will not be artificially suppressed and currently existing incentives maintained, we could expect that by the year 2028 installed capacity of renewables will exceed the capacity of declining thermal power fleet.

After reaching commissioning rates for renewable capacities of 3 GW in 2027 (which is realistic and feasible as illustrated in section 4.1), in 2028 renewables will start to dominate in the structure of power sector and will be providing major share of electricity production, while the role of thermal generation capacities will diminish due to lowering capacity factors.

Based on trends for nuclear and coal capacities (figures 4 and 5) and taking the balanced scenario from table 1 as a reference, we can project on how structure of installed capacities can look like in 2028 in Ukraine. According to this estimate total installed capacity in Ukraine will be 48,5 GW in 2028.

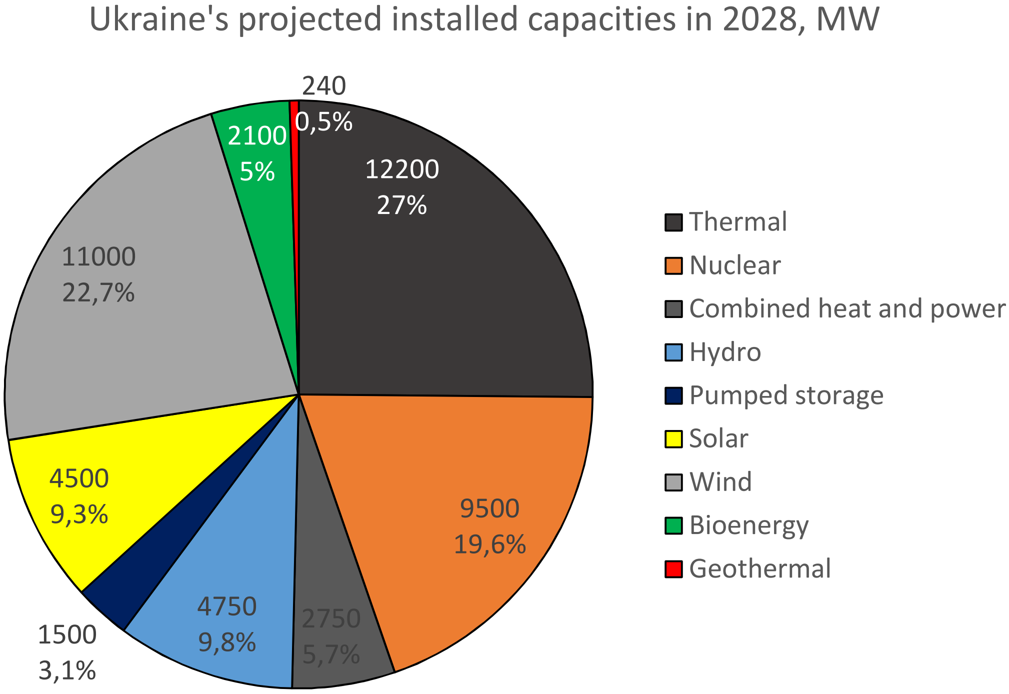

Figure 8: Projected structure of Ukraine's installed electric power capacities in 2028

Models of corresponding electricity supply pattern in winter and summer, based on these projections are presented at Figures 9 and 10.

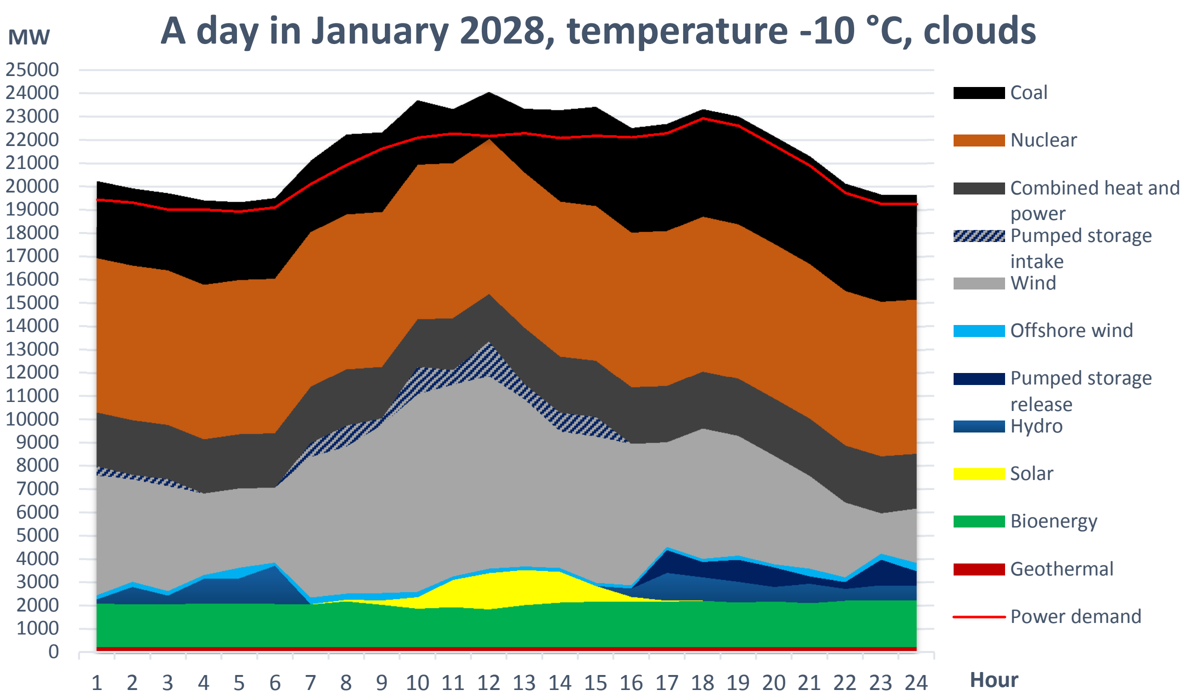

Figure 9: Simulation of Ukraine's electric power supply at the day of potential maximum load in 2028

High-capacity pumped storage is readily available in Ukraine and constitutes a valuable energy storage resource. With significant share of renewables in the energy system, pumped storage will become an important flexibility reserve on the supply side, stabilizing the intermittency of supply from renewables by taping energy in periods of strong winds and producing electricity when output from renewables is limited. Apart from stabilizing function, pumped storage can also provide long-term seasonal storage *[30]*. Using pumped storage to harness excess energy from wind instead of propping up coal-fired TPPs, which currently lack flexibility (see figures 2 and 3), will allow cutting significantly GHG emissions, while maintaining and even reinforcing stability of the power system.

By 2040 most of existing fossil-fuel and nuclear (even if they will be granted with life-time extensions) capacities in Ukraine will retire due to technical reasons. Furthermore, all of them can be fully replaced with renewable energy well before 2040. However, the rate of replacement will largely depend on governmental policies and market structure. The sooner respective policies and new market regulations will be introduced, the better.

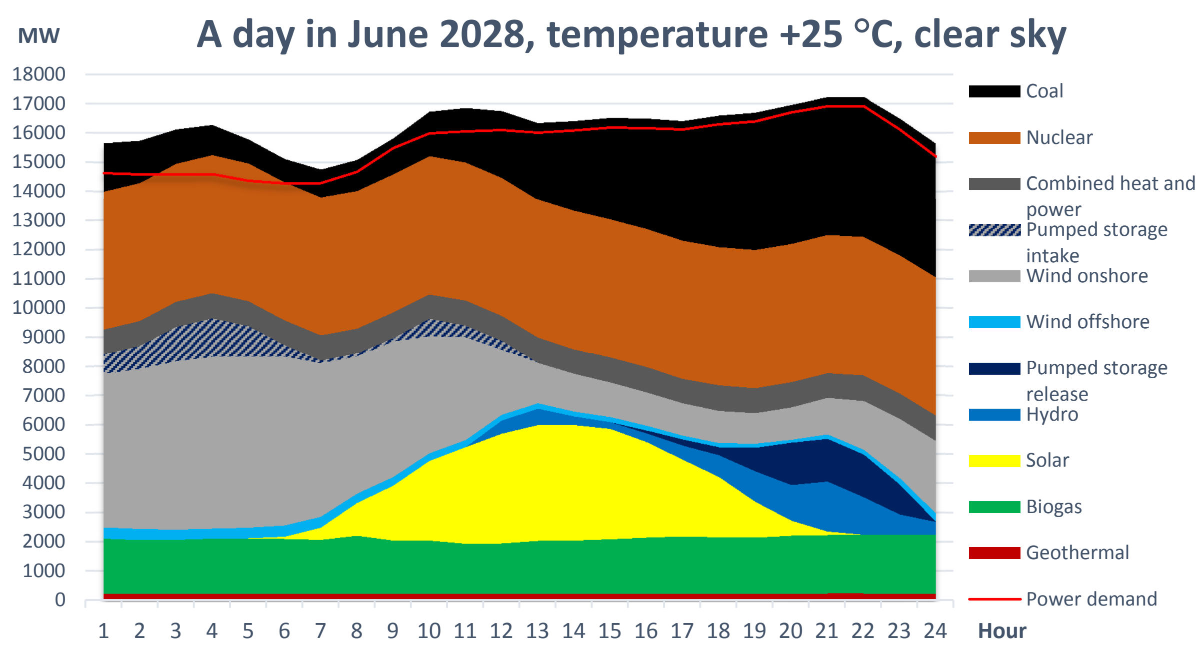

Figure 10: Simulation of Ukraine's electric power supply at the day of maximum solar irradiance in 2028.

At present, wind power has the biggest potential for deployment in Ukraine and soon can start replacing retiring fleet of coal power plants. According to estimates grounded above, by 2028 electricity output from wind power can exceed electricity production from coal. Solar energy will be able to provide more than 12% of electricity supply in summer time and up to 6% in winter time. However, with development of storage technologies and new photovoltaic materials, role of solar energy can dramatically increase in the future and surpass current projections. Bioenergy potential is also significant in Ukraine. Biogas plants and solid biomass for combined heat and power can provide up to 10% of electricity production.

Photo: Oleg Savitsky

5.3 Bioenergy potential

Ukraine has 42.8 million hectares of agricultural 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, containing a high percentage of humus. Depth of organic soil layer in some areas exceed 1 meter. Forests are covering over 10.2 million hectares or around 17,2 % of country's territory. Generally potential for utilization of bioenergy is high in all regions of Ukraine.

In 2013 bioenergy accounted for only 1.6% of total primary energy supply (TPES) in Ukraine, while the renewable energy sector overall accounted for 2.8% of TPES (IEA, 2015). Present rates of utilization of agricultural and forestry waste are low, while many existing practices for bio-waste management are unsustainable. Open burning of straw and other agricultural residues at fields is a common practice, while most agricultural enterprises lack the ability to collect, bundle and adequately store straw and other biomass residues. 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.

According recent study, the economic potential for utilization of agricultural residues per year is estimated at the equivalent of 14-20 mtce per year. Utilization of agricultural biomass waste could potentially cover up to 15-20% of TPES in Ukraine *[31]*. Unsustainable use of firewood for heating in residential sector can be largely replaced with biomass pellets. Solid biomass has also big potential for utilization at small and medium-size combined-heat and power plants. Along with introduction of sustainable forestry practices in Ukraine (taking countries like Sweden and Finland as an example), forestry wastes and by-products woodworking can be converted to wood chips or wood pellets for combustion at such CHPs.

IRENA has been preparing research on bioenergy potential with an outlook to the year 2030 for each of the 26 countries covered by REmap program (IRENA, 2014b). According to IRENA's estimates, achievable bioenergy potential is much higher – between 1115 PJ and 1780 PJ (38-60.7 mtce), which apart from solid biomass also includes production biogas and liquid biofuels from energy crops. According to REmap option for Ukraine, by 2030 bioenergy could provide up to 25% of TPES *[16]*. Separate collection of municipal organic waste along with utilization of agricultural residues for biogas production would mean less landfills (which already cover over 130 thousand hectares), less groundwater pollution and multiple environmental and economic benefits. Even with fraction of this potential biogas capacity in Ukraine can be easily scaled up to 2 GW (which is considered in our models, see figures 9 and 10).

Finally, another promising source of biomass for energy use in Ukraine can be provided by paludiculture – a new approach for agriculture and forestry on wet and rewetted peatlands. Restoration of degraded peatlands and cultivation of reed and other wet fen vegetation for energy use can bring multiple environmental and economical benefits. Drained peatlands are a major source of CO2 emissions within the land use, land use change and forestry sector. Greenhouse gas emissions from oxidation and bacterial decomposition of peat and frequent peat fires are very high in Ukraine, because more than 50% of total peatland area was drained in soviet times. To avoid further land degradation and reduce GHG emissions, rewetting of peatlands is essential. By means of paludicaulture big territories in Volyn, Rivne, Kyiv and Chernihiv regions can be transformed into sites for the production of biomass as an energy source. As demonstrated in number of recent studies, paludiculture-derived biomass can be a sustainable source of energy with significant economic potential *[32, 33]*.

To access the potential of paludiculture-derived biomass in Ukraine further research is needed.

6. Conclusions

The state of play in energy industry is rapidly changing globally. Institutional and private investors around the world are revising their portfolios and divesting from fossil fuels. Investments in renewable energy are starting to dominate over investments in conventional infrastructure. In the EU, where integrated approach to climate and energy policy was adopted, energy transition is accelerating. On this background, Ukraine is not just lagging behind, but seems to be still locked in old authoritarian energy paradigm. Modernization and democratization of energy sector are critically important to overcome corruption, alleviate energy poverty and overall inequality and socio-economic crisis.

Ukraine's massive, highly centralized and outdated electric power system needs to be effectively re-structured to create space for deployment of renewable energy sources, smart grids and flexibility options (energy storage, power-to-heat, demand response, etc.). Ukraine's thermal power fleet has already entered a gradual, but terminal decline, due to technical and economic reasons. To guarantee stability of power supply and deliver smooth transition, introduction of integrated approach to climate and energy policy is necessary. The aim of complete phase-out of all existing coal power plants by 2040 is realistic and achievable. As a first step, Ukraine should withdraw any commitments for inflexible centralized infrastructure, that can lock economy to unsustainable (both geopolitically and environmentally) energy supply patterns for decades. Ukraine should avoid wasting capital and creating new risks, associated with capital-intensive projects of new centralized power generation.

Status and performance of nuclear power plants needs to be carefully assessed to develop a comprehensive plan for their decommissioning. With integration to pan-European energy network and rapid deployment of renewable energy sources, coal and nuclear capacities in Ukraine can be fully replaced in upcoming two decades. To manage huge economic and technical challenge of nuclear decommissioning, which is unescapable in the not-so-far future, Ukraine should focus energy innovations, modernization of infrastructure and rapid deployment of renewable energy technologies to create a solid alternative. European Commission and EU's individual member states, especially Germany, should strengthen economic and technical cooperation with Ukraine in fields of renewable energy, energy efficiency and innovation to facilitate energy transition in Ukraine.

After introduction of first priority energy efficiency policies and energy market reform, Ukraine needs to develop well-crafted long term economic development strategy and vision, which would encompass a new energy paradigm based on renewable energy and de-centralized smart grid infrastructure. Integration of electric power sector, heating, cooling and transportation will be increasingly important to allow rapid and cost-effective deployment of renewable sources of energy. These are the fields where international aid is needed at most. Roadmaps for energy transition already exist and already started their implementation in many parts of the world, but most actively in European Union. To recover its economy and take the sustainable "soft" path for development Ukraine needs to catch the EU energy transition train, effectively use policy reform toolbox provided by Energy Community and contribute to continental transformation of energy infrastructure in Europe.

All types of renewable energy – onshore and offshore wind, solar PV, hydro, geothermal and biomass – can and should be widely applied in Ukraine's power sector. Bioenergy has especially big potential for development in Ukraine, but sustainability of its application depends on reforms in many sectors, implementation of new legislation (including Energy Community acquis, but not limiting to it), introduction of new regulations in agriculture and forestry and their adequate enforcement.

Internationally, the next decade will see a dramatic growth in decentralized power generation. Technologies that enhance the ability to coordinate, manage and store locally generated energy, will accelerate moves towards localized generation, distribution and grid management. Community-owned renewable energy generation will be a key part of this,[2] delivering the social endorsement and engagement, need for profound transformation in the energy sector.

Apart from technical side of energy transition, which is quite apprehensible and well-discussed in expert circles, political side still lacks attention and this dialogue in Ukraine is yet to be created.

The pioneering role of NGOs and foundations is to initiate such dialogue on energy transition in Ukraine and international support is much needed in this work. Our notion is that Europe can enter the era of renewables only as a whole, and Ukraine is an inseparable part of Europe. Further involvement of wider public and popular support are necessary to develop a social consensus on new priorities for sustainable socio-economic development on regional and national levels.

[2] Community power refers to multiple individuals pooling resources (such as space, money, and skills) in order to mutually benefit from a shared renewable energy project. Whether the power generated is sold to the grid or used on site to offset electricity usage, community power generation is locally owned and collectively operated, thus creating strong motivation for the public to support energy transition. Positive impacts of such development have already been felt by communities worldwide, especially in Denmark and Germany.

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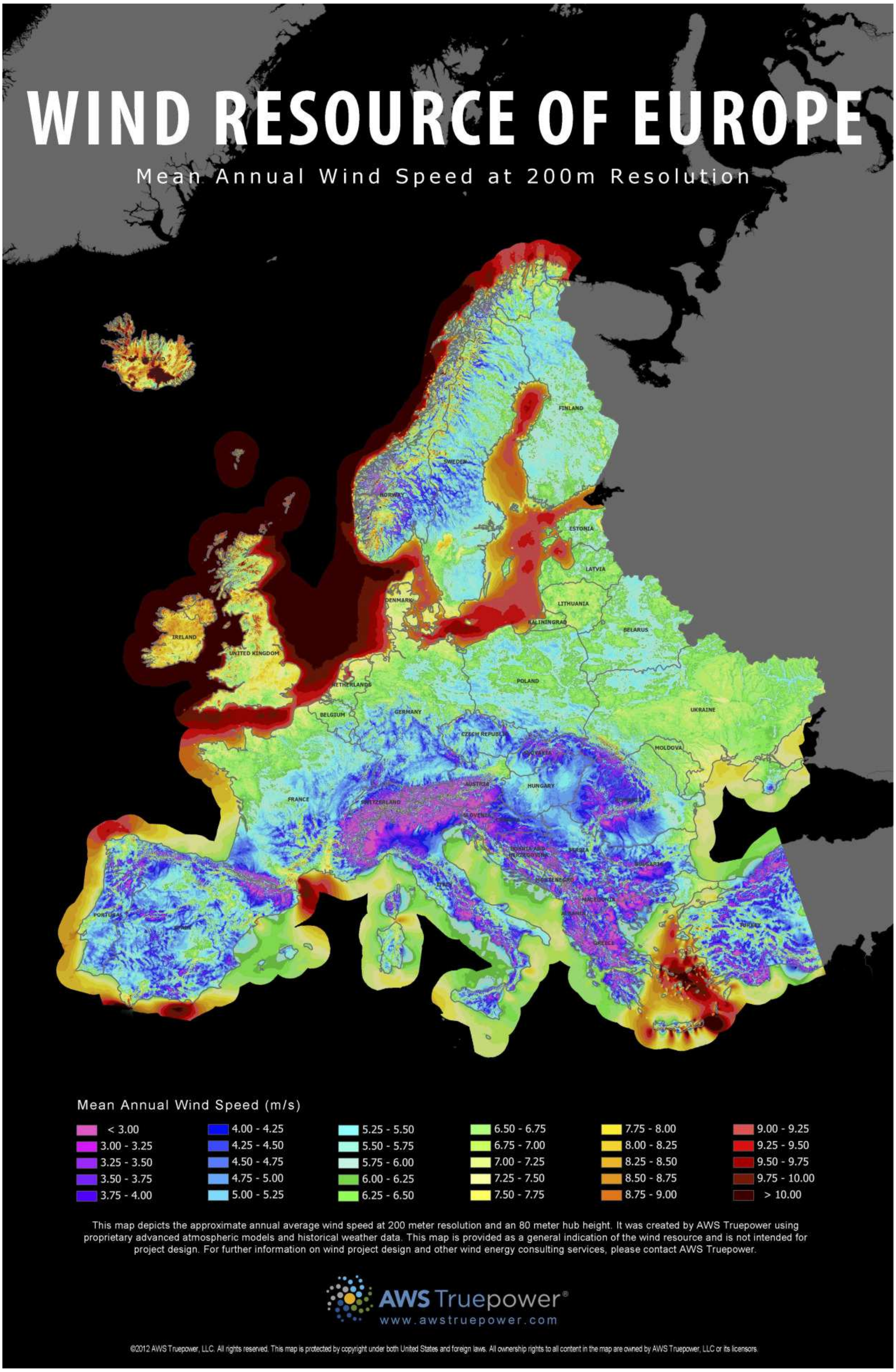
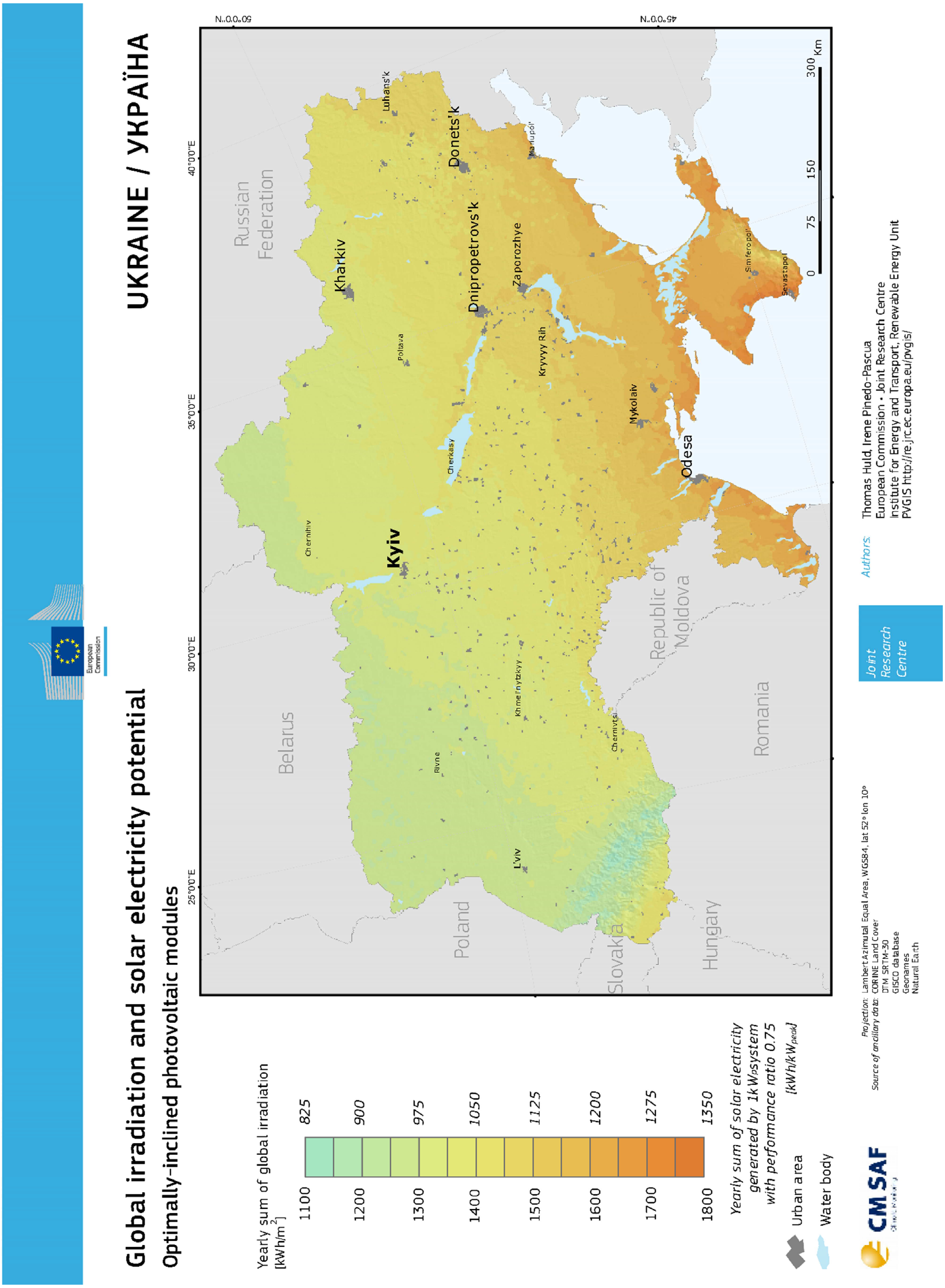


Source: AWS Truepower https://www.awstruepower.com/knowledge-center/maps/



Source: European Comission Joint Research Centre http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm

Marion Dönhoff Working Papers

The “Dönhoff Fellowship Working Papers” is the publishing format for the results of the individual work from the Marion Dönhoff fellows at the Michael Succow Foundation. The fellowship programme is intended to support open and multidisciplinary debates in the areas of environmental journalism, political ecology and sustainable development and to foster a critical East-West dialogue. The target regions are post-soviet countries, including the South Caucasus and Central Asia. As a result of in-depth analyses of specific environmental subjects, including approaches for the solution of environmental problems in the target regions, the Dönhoff Fellowship Working Papers” are a potential basis for further action in environmental protection and sustainable development