# System transformation for an optimised integration of renewable energies in Ukraine – AS-IS Report

**Client: Ukrenergo**

**Country: Ukraine**

Berlin, 11th October 2019

# System transformation for an optimised integration of renewable energies in Ukraine – AS-IS Report

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|---|---|
| **Summary** | This report presents the AS-IS situation of the Ukrainian power system based on facts regarding the entire supply chain. Further, the AS-IS situation is mapped to key challenges regarding the vRES integration into the system. |
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## Approval

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## Previous versions

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## Related documents

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| Document ID | Document title |
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| Document ID | Document title |

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# List of Abbreviations

| | |
|---|---|
| ACER | Agency for the Cooperation of Energy Regulators |
| ASP | Ancillary Service Providers |
| BNetzA | Bundesnetzagentur (German Regulation Agency) |
| BRP/BSP | Balance Responsible Party / Balancing Service Providers |
| CAPEX | Capital Expenditure |
| CBA | Cost-Benefit-Analysis |
| CEP | Clean Energy Package |
| CHP | Combined Heat and Power |
| CIS | Commonwealth of Independent States |
| DAM | Day-Ahead Market |
| DLR | Dynamic Line Rating |
| DSM | Demand Side Management |
| DSO | Distribution System Operators |
| EBRD | European Bank for Reconstruction and Development |
| ENTSO-e | European Network of Transmission System Operators for Electricity |
| EU | European Union |
| FACTS | Flexible Alternate Current Transmission Systems |
| FiT | Feed-in tariff |
| HR | Human Resources |
| HVDC | High Voltage Direct Current |
| IDM | Intraday Market |
| IPS | Integrated Power Systems |
| IT | Information Technology |
| NEURC | National Energy and Utilities Regulatory Commission |
| NPP | Nuclear Power Plant |
| NREAP | National Renewable Energy Action Plan |
| PSO | Power System Operator |
| PV | Photovoltaic |
| RES | Renewable Energy Sources |
| TPP | Thermal Power Plant |
| TSO | Transmission System Operator |
| TYNDP | Ten Year Network Development Plan |
| vRES | Variable Renewable Energy Sources |

# 1 Introduction

Ukraine is shifting its energy strategy towards the inclusion of higher shares of variable renewable energy sources (vRES), namely wind and solar photovoltaic (PV) power, in its power mix. Naturally, vRES have the characteristic of non-controllability and intermittency. Cost-effective and reliable integration of vRES requires a substantial transformation of the electricity sector, encompassing technical, legal and regulatory fields of action. Given the complexity of the task, a multi-layered approach involving all actors is required. Experiences from all around the world show that the role of transmission system operators is central in the successful implementation of such a transition.

This project aims to support the Ukrainian Transmission System Operator (TSO) Ukrenergo by analysing the challenges of the Ukrainian power sector towards the needed system transformation. The project orientation is organised in 3 areas:

1. **Analysis of the As-Is situation in Ukraine** with regards to the vRES integration preparedness and mapping of key challenges.
2. **Presentation of the experiences and lessons learnt** from the integration of vRES in the electricity grid in Germany in the last 2 decades from the TSO's perspective.
3. **Identification of gaps and proposal of recommendations** to increase the readiness of Ukrenergo to implement the energy transition targets.

In order to cover all dimensions of the complex system transformation, the project structure is oriented on five key areas with regards to the integration of vRES: **1) System Transformation & Planning, 2) Grid & System Operation, 3) Market Design & Flexibility, 4) TSO Positioning & Strategy and 5)** framework conditions with regards to **Regulation & Finance**, as shown in the figure below.

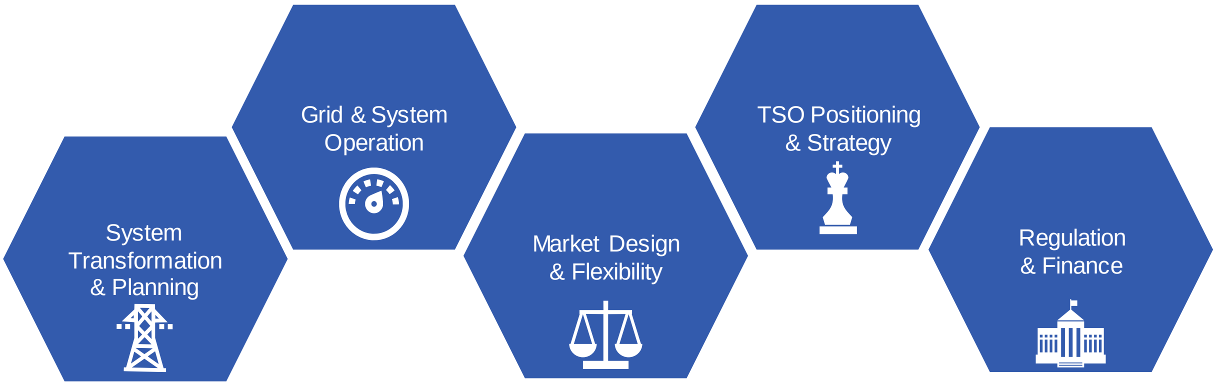



**Figure 1 – Workshop overview**

This report covers the first area as presented above. The report is structured in two main parts. In Chapter 2, the As-Is situation of the Ukrainian power system is presented, based on facts regarding the entire supply chain. In Chapter 3, the As-Is situation is mapped to key challenges regarding the vRES integration into the system. Chapter 4 presents the key conclusions.

# 2 As-Is situation of the Ukrainian electricity sector

## 2.1 Overview of the Ukrainian power sector

**Ukraine's power sector is set for a major transition.** Ukraine expressed its desire to follow European standards by signing the Agreement on the Conditions for the Future Interconnection of the Power System of Ukraine with the Power System of Continental Europe and adopting its new energy strategy in 2017.

Currently, the power system of Ukraine consists of two parts (see Figure 2) – the main part synchronised to the power systems of Commonwealth of Independent States (CIS) and Baltic States (96% of the Integrated Power System of Ukraine - IPS) and a small part (4% – Burshtynska Island) as a part of the European Network of Transmission System Operators for Electricity (ENTSO-e).

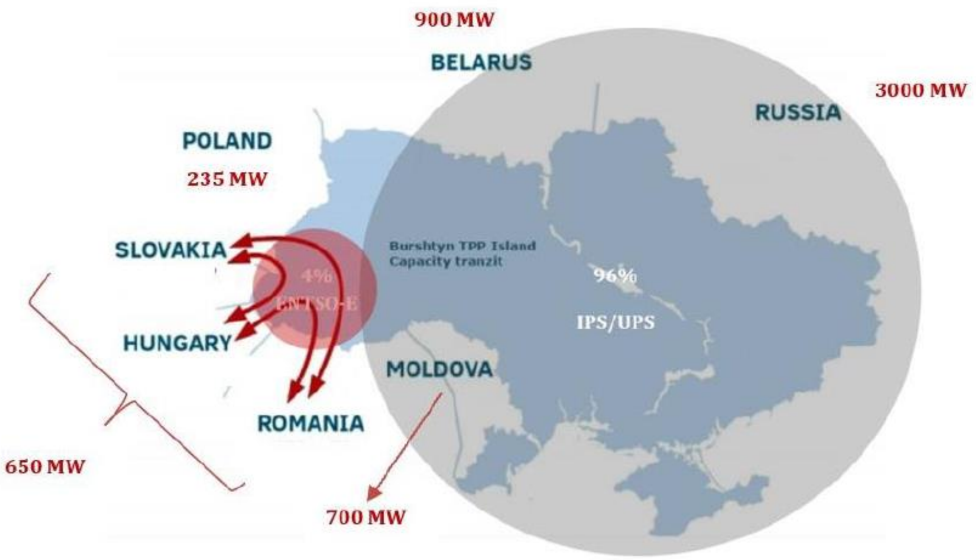



Figure 2 - Two parts of the Ukrainian power system (Ukrinterenergo, 2019)

**Electricity transmission** is carried out by Ukrenergo with a grid area covering more than 600 thousand km$^2$ which consists of 8 regional control centres. A short comparison of key facts between Ukrenergo, Elia (Belgian TSO) and 50Hertz (one of the four German TSOs) for the year 2018 is presented in Figure 3. As can be seen, the Ukrainian system includes higher voltage levels (750kV and 500kV). A lower grid and load density is observed: although the grid area is 5,5 times larger than the 50Hertz area and almost 20 times larger than the one of Elia, the grid length with respect to both countries is just 2-3 times longer and the load 1,5-2 times higher (peak and energy consumption). One elementary difference is given by the lower Renewable Energy Sources (RES) shares in Ukraine being in the initial phase of the RES integration (1,7%).


| | 50hertz 2018 | 2018 (Belgium) | 2018 (Ukraine) |
|---|---|---|---|
| **Grid area** | 109.619 km² (~31 %) | 30.688 km² | 603.628 km² |
| **Length of lines** | 10.390 km (~30 %) | 8505 km | 21.800 km |
| **Voltage levels** | 380/220/150* kV | 380/220/150/ 110/70/36/30 kV* | 750/500/400/ 330/220/110 |
| **Max. Load** | ca. 16 GW (~20%) | ca. 13,5 GW | ca. 23,9 GW |
| **Power consumption** | ca. 97 TWh (~20 %) | ca. 77 TWh | ca. 153,1 TWh |
| **Installed capacity:**<br>- of which Renewables*<br>of which Wind<br>- Thermal<br>- Nuclear<br>- Hydro | 55.244 MW (~26%)<br>32.355 MW (~30%)<br>19.414 MW (~33%)<br>22.892 MW (~29%)<br>0 MW<br>279 MW (~3%) | ca. 22.600 MW<br>7.941 MW<br>3.247 MW<br>7.378 MW<br>5.919 MW<br>1.433 MW | 49.730MW<br>1.713 MW<br>389 MW<br>21.842 MW<br>13.835 MW<br>6.241 MW |
| **RES share in power consumption*** | 56,5% | ca. 9,1%** | 1,7% |

*Source: Elia Group 2018*

*(%) share of total Germany*
**150kV AC Offshore connection*

**DC Nemo Link operated at 400kV*
***2017 Value*

*Source: Ukrenergo*

**Figure 3 – Power System comparison between 50Hertz, Elia and Ukrenergo**

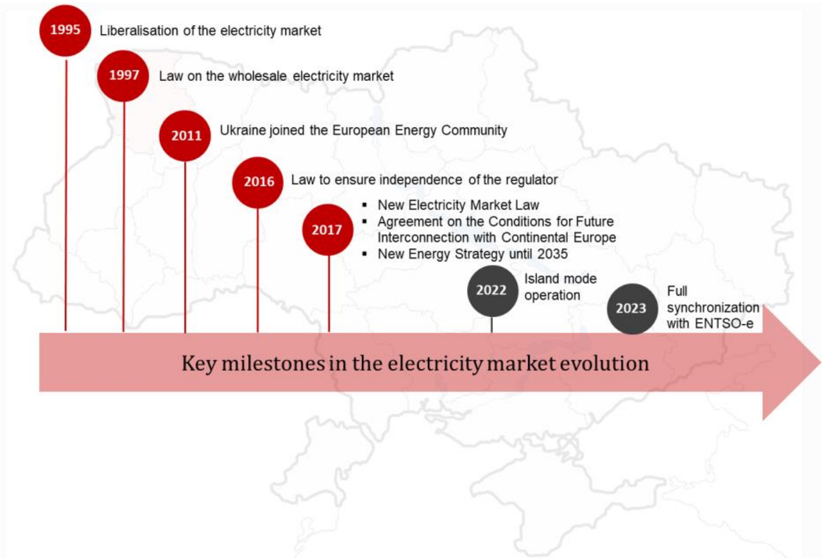



**Figure 4 - Evolution of the Ukrainian electricity market (EGI)**

**The Electricity market** of Ukraine is liberalised after the unbundling between generation, transmission and distribution activities. After liberalization the country opted for a single-buyer market model where power generators compete to sell power to the single-buyer company (Energorynok) under long-term power purchase agreement. This model was used since establishment of the power market in 1995 and until 2019. The **1st of July 2019** became a milestone for the country's power sector, as Ukraine adopted **a new competitive market model**. The single-buyer model is remaining only for renewable energy generators at the moment. The new market model consists of the following elements: a) Retail electricity market, b) The market of bilateral agreements, c) Day-ahead and Intraday market, d) Balancing market and e) Ancillary services market.

## 2.2 Generation and consumption

### 2.2.1 Generation mix and consumption structure

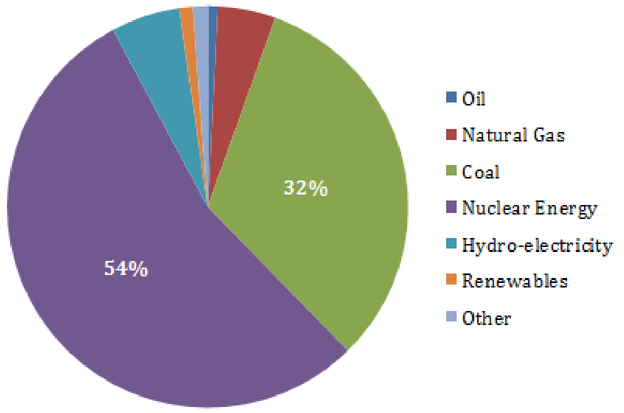


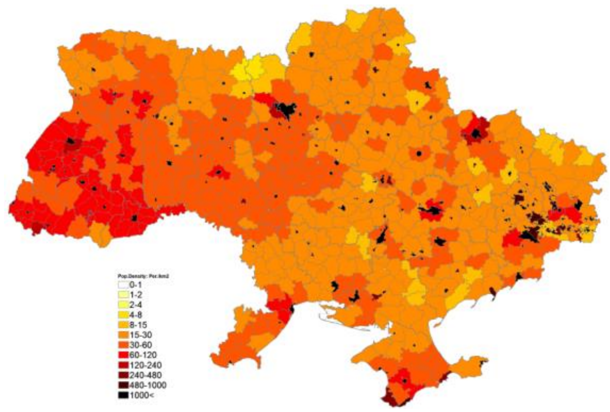

Figure 5 - Electricity generation by fuel, 2017 (BP, 2018)

The generation mix is dominated by nuclear fuel with more than 50% of generated power, followed by coal with over 30%.(Figure 5). Anthracite coal is predominant in power generation from coal. Natural gas is mainly used in Combined Heat and Power (CHP) plants for district heating purposes.

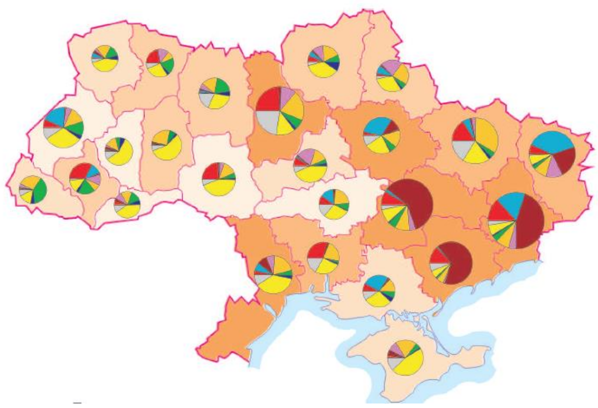
The total share of renewable energy sources (hydro, solar, wind, biomass) in the power generation mix accounted for 8,65% in 2017 (SAEE, 2017). Hydropower is the most significant renewable energy contributor amounting for 6-7% of generated electricity (Ukrinform, 2018b). The share of vRES is about 2%, but is expected to be increased in the near future due to the increasing number of planned new installations.

The Ukrainian power system has achieved a 100% electricity access rate (World Bank, 2016f). Based on the full access rate and the quite constant development of the consumption over the last years (Ukrenergo NFR 2018), the future development of consumption is expected to be stable or even decreasing due to newly introduced energy efficiency regulations (Berlin Economics, 2019). Until now, Ukraine has high electricity consumption per capita due to low efficiency of industrial and household consumers and subsidised electricity prices.

Industry is the major electricity consumer with 42%, followed by residential consumers with around 30% of consumption and public utilities with 12,7%. As can be seen in the figure below, the North – North West region has a higher population density while most of the large industrial electricity consumers are located in the South-East region (metallurgy, steel production).



Population density



Industry density (Hryzak, 2005)

Figure 6 – Population and industry density of Ukraine.

### 2.2.2 Installed capacity

Ukraine power generation sector has more than 49,7 GW of total installed capacity (without the temporary occupied territories, 59 GW in total), almost 60% of which are thermal power plants (coal and CHP), followed by nuclear power plants (NPPs) with more than a quarter share (13,8 GW). All NPPs are owned and operated by a state company Energoatom. Hydroelectric stations with around 4,7 GW installed capacity are owned by a state company Ukrhydroenergo (Ukrhydroproject, 2019). Herein, NPPs are contribute with the highest utilization among all generation technologies. Most of nuclear and thermal generation plants have reached or are approaching the end of their lifetime (EnergyPost.EU, 2014), (IAEA, 2016). Due to old fossil fuel power generation facilities, high import fuel prices and disruption of fuel supply (gas and coal), thermal power plants exhibit relatively low capacity factors[1] (Table 1) compared to the world average.

**Table 1 – Capacity factors of generation technologies for 2015**

| Type of power plant | **Capacity Factor Ukraine** (IRENA, 2015) | **Capacity Factor World average** (IRENA, 2019) (WNA, 2016) |
|---|---|---|
| Thermal | 27% | 60-70% |
| Nuclear | 69% | 80% |
| Small Hydro | 29%* | 54% |
| Onshore Wind | 7,9%** | 34% |
| Solar PV | 13,9%** | 18% |
| ** Average 2014-2018*<br>*** Numbers provided by Ukrenergo* | | |

Based on the analysis of the generation mix and the installed capacities, Ukraine has a generation structure based on centralized large-scale power plants. The largest NPP consists of 6 reactors with 950 MW of installed capacity per unit, accounting for total 5700 MW. The largest thermal power plant (TPP) consists of 7 blocks with a total capacity of 3625 MW. The large scale generation units require a high amount of reserve capacity for frequency regulation to cover the instantaneous outage of the largest generation unit. Russia currently provides the secondary reserves for the full CIS synchronous area. In order to disconnect from the CIS system, new secondary regulation reserves should be installed, in order to run the Ukrainian power system on isolated mode. Under the current operating regime, Ukraine is not possible to operate in an isolated mode. After connection with ENTSO-e, Ukraine would be able to share reserves with other countries in ENTSO-e and reduce its reserve needs. The table below presents the reserve requirements in isolated mode and for interconnected operation with ENTSO-e.

**Table 2 – Frequency regulation capacity requirement**

| Regulation | Current Operating Regime | **Isolated mode** (Ukrenergo, 2019) | **Interconnected operation with ENTSO-e** (Ukrenergo, 2019) |
|---|---|---|---|
| Primary | -500, + 100** MW | -500, +1000*MW | -+ 190 MW |
| Secondary | Provided by Russia (CIS) | -500, +1000* MW | -500, +1000* MW |
| Tertiary | -500, +1000* MW | No less (-500, +1000* MW) | -500, +1000* MW |
| **Without disconnection consumers via the automated emergency system*<br>*** Seasonal differences, could reach 170 MW or 90 MW (spring)* | | | |

According to official indicators of installed capacity development published by Cabinet of Ministry, Ukraine aims to increase the total installed capacity to 65,5 GW by 2025. The capacity of nuclear power plants will remain stable, while the installed capacity of thermal power plants (coal) and CHP plants will increase by around 7% and 18% respectively. The capacity of pumped storage and vRES will increase, with additional planned capacity of hydro power plants being around +813 MW (~17% increase).

Combining these projections to stable or even decreasing demand projections, Ukraine may have excess capacity by 2025. In a future system dominated by nuclear, coal, heat-driven (inflexible) CHP and

[1] *Capacity factor – the ratio of actual energy produced to the hypothetical maximum possible energy produced from continuous operation at full rated power.*

vRES, flexibility is expected to become an issue. The development of new flexible gas power plants is challenging due to the limited access to gas after the conflict with Russia (Irena, 2015).

### 2.2.3 vRES Potential and targets

In 2017, Ukraine has adopted a New Energy Strategy focusing on security, energy efficiency and competitiveness, which will be implemented in three stages. A rapid growth of renewable installations will help the country to diversify its generation mix, being independent on fossil fuel sources, to meet renewable energy targets, and empower consumer to become prosumers. According to the New Strategy and the National Renewable Energy Action Plan (NREAP) Ukraine aims to meet 11% of electricity demand by electricity generated from renewable energy sources (incl. Hydro and biomass) by 2020 (IEA, 2014) and 25% by 2035 (Cabinet of Ministry of Ukraine, 2017). It is expected that most of the increase is related to vRES, namely wind and solar PV (see Figure 7).

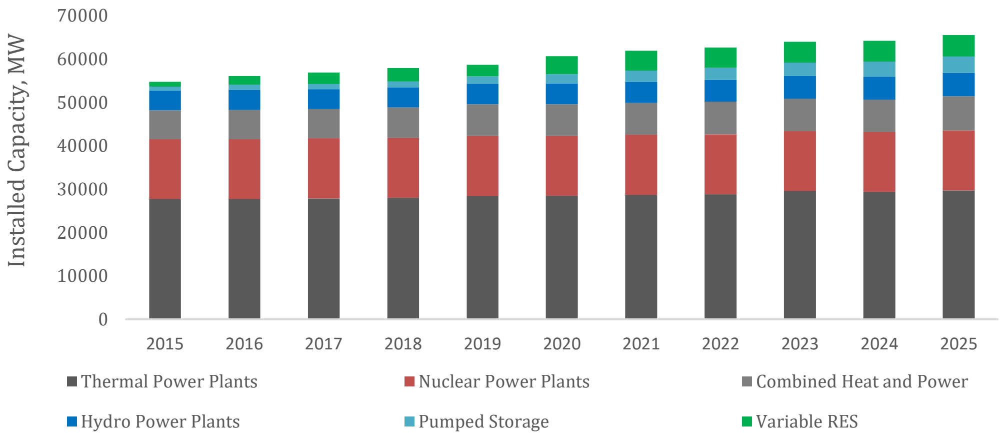



**Figure 7 - Installed Capacities, MW (2015-2025) (Cabinet of Ministry of Ukraine, 2019b)**

However, the market developments point to a more rapid implementation. In particular, the 2025 capacity targets (4500 MW) are expected to be reached by the end of 2019 and the number of connection requests shows that the TSO must prepare for integration of 11 GW. Development of Ukraine's vRES is supported by green feed-in tariffs, which will be replaced by green auctions in 2020. The hotspots of vRES are located in the South-East, where the potential of wind as well as solar PV is quite high.

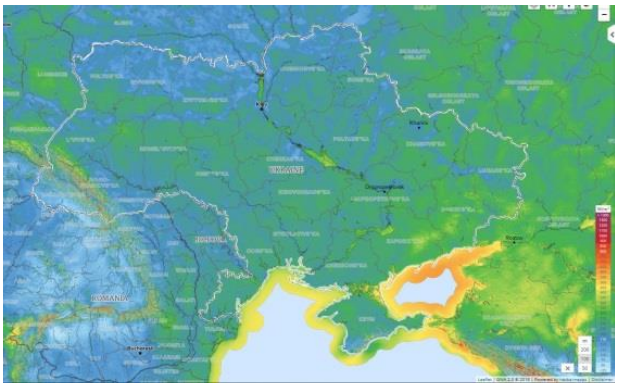


**Figure 8 - Wind energy potential of Ukraine (World Bank and Technical University of Denmark, kein Datum)**

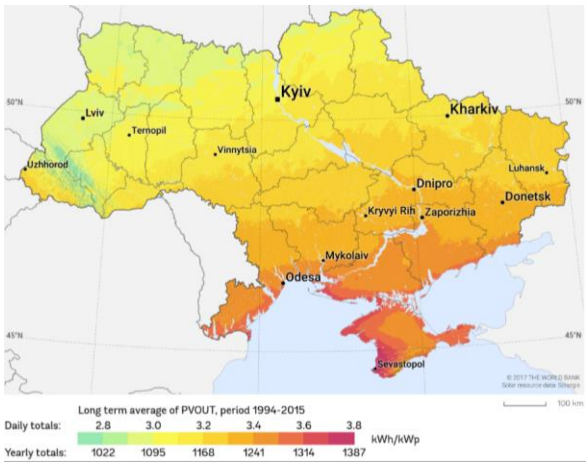



**Figure 9 - Solar energy potential of Ukraine (World Bank Group, 2017)**

## 2.3 Transmission System

Electricity transmission is carried out by a national transmission company Ukrenergo. Ukrenergo, with a total number of 8100 employees, facilitates the synchronous operation with the power systems of Russia, Belarus and Moldova, where Russia plays a key balancing role by ensuring secondary power reserves for frequency regulation. A small part of Ukraine, so-called „Burshtyn Island“, operates in parallel with the ENTSO-e area and is the only one part of Ukraine which is currently synchronized with the power system of Continental Europe. The losses in the transmission system are reported to 2,66%. As can be seen in Figure 10, a strong concentration of the power system in South-East is observed, where most of the large industrial electricity consumers are located (metallurgy, steel production). Until now, they are served by several large-scale NPP and TPP located in the vicinity. A large part of this area is temporally occupied so that no energy supply to the region and – generation from the region to the Ukrenergo’s system is realized.

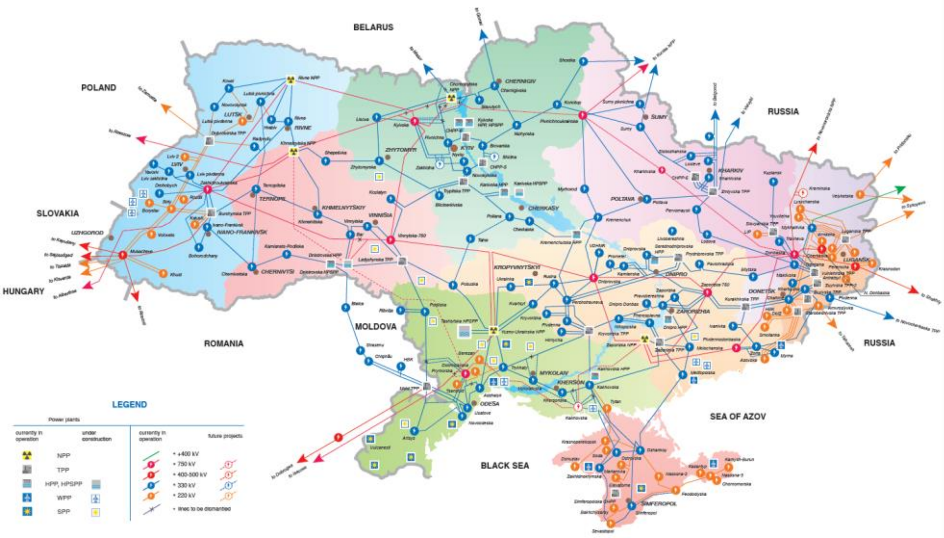



**Figure 10 – Map of the Ukrainian power system (Ukrenergo, 2017a)**

The total interconnection capacity is 5,4 GW, more than half of which is to Russia and around 16% to the European Union (EU). Towards EU, Ukraine is connected to Poland, Slovakia, Hungary and Romania with 3 transmission lines on voltage levels of 750kV, 400 kV and 220 kV. In 2019, Ukraine exported 6,2 TWh to Hungary, Moldova, Poland, Slovakia and Romania (Ukrenergo, 2019a). When connected with the ENTSO-e synchronous system, the country plans to increase its electricity trade with European countries by 4-5 times, raise from 4-5 TWh to 18 TWh and trade volume from $250 mln to $1,5 bln (Ukrenergo, 2017c).

**Table 3 - Maximum cross-border flow capacity, 2019 (Ukrenergo, 2019a)**

| Export direction | Capacity, MW |
|---|---|
| Hungary, Slovakia and Romania | 650 |
| Poland | 235 |
| Moldova | 700 |
| Belarus | 900 |
| Russia | 3000 |

## 2.4 Power market and key players

A new market is scheduled to start working on 1st of July 2019, however European Bank for Reconstruction and Development (EBRD), World Bank, the regulator and Ukrenergo recommended postponing launching a new market due to number of reasons, such as risks for the financial stability of Distribution System Operators (DSOs) (ConcordeCapital, 2019), possible increase of electricity price, risk of market power abuse by some of power suppliers (ConcordeCapital, 2019), low preparation of Information Technology (IT) systems (Ukrinform, 2019c), monopoly in the generation sector, unstable political situation (election of new President, dismissal of government), and regulatory framework not fully ready (Ukrinform, 2019c).

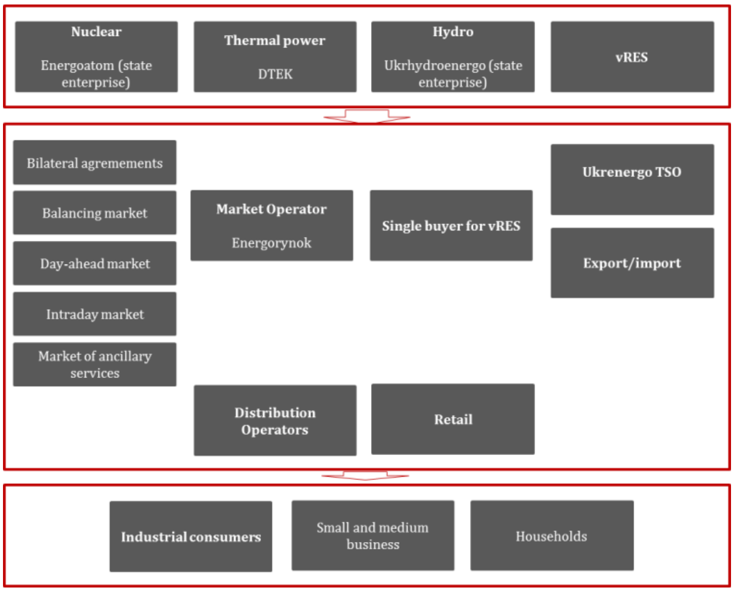



**Figure 11 - New market model (EGI)**

Despite these recommendations, the new competitive market was launched on 1st of July. The structure of the new market is shown in Figure 11. The reform established a new competitive wholesale electricity market with multiple submarkets like bilateral market, Day-Ahead and Intraday exchange market, balancing and ancillary services market. The former single-buyer company Energorynok became the market operator, and remained the single-buyer for vRES (a model of guaranteed single-buyer).

The consumer sector was restructured introducing 3 consumer types: big industrial consumers, small and medium business and households. The industrial customers can directly procure their energy need via the competitive market. Otherwise, customers are supplied by Universal Service Suppliers. In general, the generation sector remains with only two companies generating more than 70% of electricity and limited import, which could lead to abuse of power and price increase. Prices for industrial consumers rose for 20-25% after the launch of new market, while electricity price for households remained regulated and at the same level as before (LIGA, 2018).

According to (Energy Community, 2019), the market introduction in July 2019 happened without any major issues. The strong market regulation with trade volume limitation and price caps, in particular the Public Service Obligations and other regulation from the national regulator National Energy and Utilities Regulatory Commission (NEURC), has ensured that there are no market major disruption. More or less, the Single-Buyer is still in place for the big state-owned generation companies Energoatom and Ukrhydroenergo. Free market mechanisms are only applied to small generators. Table 4 includes the update of the short-term market's development after the first two months of market opening. The limited amount of trade volume and the high decrease between July and August (in the first 20 days 10,8% in Day-ahead Market (DAM) and 19,31% in Intraday Market (IDM)) are indicators for a limited interest for the market participants to trade via the competitive market. The main reason is due to the price caps. The market price calculation shows that the marginal price is close to or even higher than the price cap. The possible justification for the high calculated market price is the concentrated market power in an oligopolistic market. The other justification is that most of the cheap electricity is bought by the Guaranteed Buyer via the long-term bilateral contract as per regulation so that only the generators with the highest prices in the merit order remain in the free market. (Energy Community, 2019) Regarding to the balancing market and ancillary service market, there is a lack of fast reserves for balancing because the market of ancillary services is not launched yet due to the limitation of applied and prequalified service providers (Ukrenergo, 2019).

**Table 4 - Market Structure Update two months after competitive market opening (Energy Community, 2019)**

<table>
<tr><th>Submarket</th><th>Participants</th><th>Trade Product</th><th>Volume</th><th>Current Assessment</th></tr>
<tr><td>Bilateral market</td><td>• State-owned generation companies (mandatory),<br>• Privately-owned generation companies,<br>• Universal Service Company (equal to Power Supply Companies),<br>• Guaranteed Buyer,<br>• System Operators<br>• Industrial customers</td><td>Long-term Electricity for Supply<br>Long-term Electricity for Network losses</td><td>n.a.</td><td>Strong regulation for Energoatom and Ukrhydroenergo due to the Power System Operator (PSO) Act.</td></tr>
<tr><td>Day-Ahead</td><td rowspan="2">Same Participants as Bilateral Market</td><td rowspan="2">Short-term electricity supply</td><td><u>July:</u><br>• 4068,4 GWh in IPS Ukraine<br>• 2793 GWh Burshtyn Island<br><u>August (day 1-20):</u><br>• 2353,9 GWh in IPS<br>• 138,4 GWh in Burstyn Island</td><td rowspan="2">• Lack of liquidity<br>• Application of price caps prevents freely established market price<br>• Calculated market price close to price cap or even higher than price cap<br>• Limited interest from market participants to trade</td></tr>
<tr><td>Intraday</td><td><u>July:</u><br>• 88,4 GWh in IPS<br>• 16 GWh in Burstyn Island<br><u>August (day 1-20):</u><br>• 48,252 GWh in IPS<br>• 20,66 GWh in Burstyn Island</td></tr>
<tr><td>Balancing Energy</td><td>TSO<br>Balancing Service Providers (BSPs)</td><td>Balancing Energy for frequency regulation</td><td></td><td>• Market not full working yet, several hours without price establishment<br>• Price caps with regards to Day-Ahead price</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| **Ancillary Service** | TSO<br>Ancillary Service Providers (ASP) | Black-Start Service<br>Balancing Capacity | | • No prequalified service providers<br>• One application from Ukrhydroenergo<br>• No procurement of ancillary service via market |

# 3 Mapping of AS-IS situation to key challenges for vRES integration in Ukraine

The following section maps the As-Is situation to key challenges regarding the integration of variable renewable energies (vRES) in the Ukrainian power system. Based on the description of the present situation provided in the previous section, the identified challenges are categorized in five thematic fields related to grid planning, system operation, marked design, TSO strategy and the regulatory and finance framework, which are analysed in dedicated sections as shown below:

- System Transformation and Planning (section 3.1)
- Grid and System Operation (section 3.2)
- Markets and Flexibility (section 3.3)
- TSO Positioning and Strategy (section 3.4)
- Regulation & Finance (section 3.5)

Each thematic field is subdivided into several categories (topics) (as shown in Figure 12), where the current AS-IS situation is compared to a target situation regarding vRES integration. This comparison maps the respective challenges that need to be overcome in order to reach the target situation.

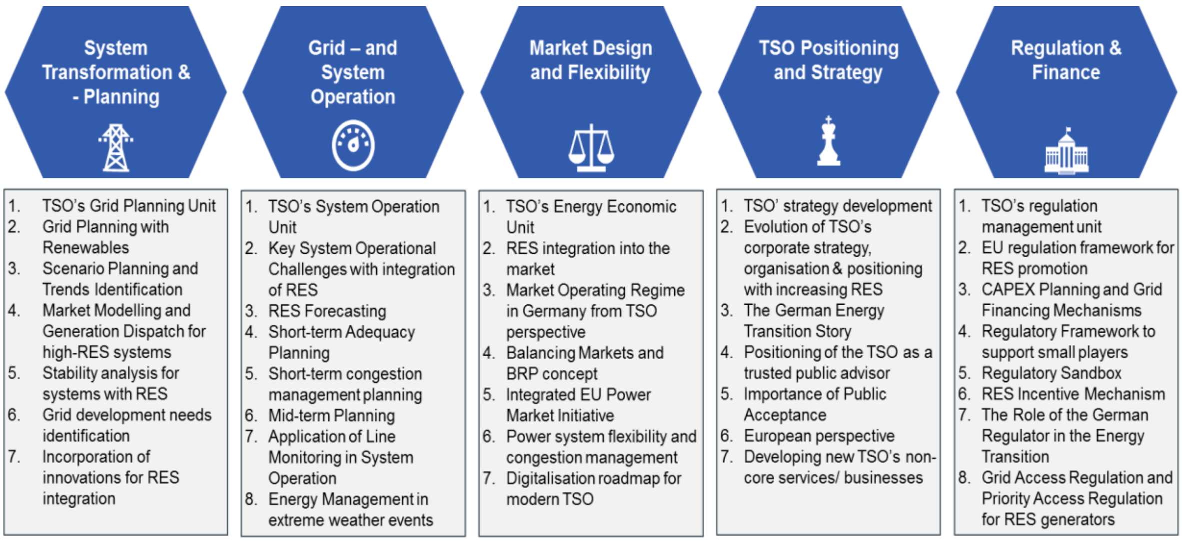



**Figure 12 – Categorisation of the thematic fields into key challenges**

## 3.1 System Transformation & Planning

In the thematic field of "System Transformation and –Planning", the key changes and challenges presented below are identified as the most relevant ones for a TSO. With the integration of vRES, the TSO needs to be aware of RES-related changes in grid planning's organisational structure, processes, methodologies, and tools. Those changes will be mapped with challenges that the TSO shall overcome in the system planning's activity.

### *1. Organisational transformation of TSO's grid planning department*

Grid planning activities and teams are traditionally focused to grid expansion for the facilitation of the connection of centralized large scale generation, located mostly closely to large load centres.

With increasing shares, vRES become the dominant driver for grid development. TSOs need to adapt the team roles and responsibilities to new tasks in accordance with the pace of the development of renewable energy.

Key challenge is to gradually introduce new grid planning practices, roles, responsibilities and competencies in the existing organisation of the grid planning team in order to facilitate this shift in the system power mix.

### *2. Grid Planning with Renewables*

Traditionally, grid planning methodologies and tools are designed according to static load profile with relatively limited planning uncertainties (mainly only on the load side).

vRES increase the level of complexity and uncertainty in grid planning. The locational deployment of vRES is often not under the control of the TSO, depending on resource potential and regulatory conditions.

Key challenge is to adapt the current procedures, methodologies and planning toolchain to ensure effectiveness of the grid planning process. Key aspects to be considered is coping with the intermittency uncertainty of renewables, integration of plausible future development scenarios, alignment in the process interfaces, management of the increasing data requirements, etc.

### *3. Scenario planning and trend identifications*

Typically, future projection of power system's state has been well predictable as uncertainty was linked mainly to forecasting demand growth.

With the deployment of vRES, the future development of a power system is less predictable, as in addition to load, higher uncertainty appears in generation side. The vRES deployment pace and location depends often on the investment environment, affected by fast-changing market and regulatory conditions.

New approaches are needed to ensure optimal decision making under increased uncertainty, based on scenarios that map the different possible future developments, considering all possible trends and uncertainties. Grid development decisions should be taken based on robustness, i.e. which investments are needed for all possible developments.

### *4. Market modelling and Generation Dispatch*

In power systems dominated by conventional generation, generation dispatch is based on "static" merit order and slow demand change patterns. In this respect, the utilisation and operation of different power plant clusters (baseload, mid-load and peakers) is well predictable based on load curves.

vRES have major effect on the system dispatch. Due to their zero marginal cost, vRES shift the existing merit order and displace other power plants, reducing utilisation rates and profits from all other technologies. Lower utilisation rates affect first peaking plants, and generation adequacy studies are needed to ensure the needed generation capacity. Further, due to vRES intermittency, the merit order becomes more dynamic and the net demand (demand minus vRES) presents larger fluctuations.

Key challenge for the TSO is to perform advanced market modelling and generation dispatch studies to anticipate the operation of the generation system, e.g., with regards to unit utilisation, system flexibility, generation adequacy.

### *5. Stability analysis for systems with vRES*

In the classical power system structure, large-scale power plants are responsible for the system stability. Therefore, the classical system planning is mainly based on the active load flow calculation and the thermal loading of the grid elements. For new connection requests, the TSO is also responsible to conduct feasibility study of the generation sources connection and interconnection with neighbour countries.

As converter-connected vRES displace conventional power plants in the system, concerns about the system stability are raised. Key concern is whether conventional units have to be online to ensure system security. The provision of stability services could alternatively be provided by devices like Flexible

Alternate Current Transmission Systems (FACTS), High Voltage Direct Current (HVDC), etc. and the vRES themselves.

The increasing importance of system stability studies in a high-RES system calls for detailed studies of future cases and definition of strategies to ensure system security.

***6. Grid development needs identification***

The grid planning process identifies a list of grid expansion and –reinforcement projects which should be prioritized based on economical, ecological and social criteria. This analysis allows the TSO to defend the need of the projects in front of the regulator. In traditional systems this has been a relatively standard tasks, as power flow directions remain stable.

In Europe, ENTSO-e has proposed a guideline to apply the cost-benefit-analysis (CBA) for the evaluation for interconnection projects based on the sustainability of the project. The ENTSO-e Ten Year Network Development Plan (TYNDP) sets up the frame for the national grid development planning. With higher shares, vRES become the dominating factor for these decisions and this task becomes more challenging as the power flow situation changes radically.

Key challenge for the TSO is to properly apply CBA methods to prioritise and defend the grid development needs and the related investment volume.

***7. Incorporation of innovations for RES integration incl. Dynamic Line Rating (DLR), FACTS, and Energy storages***

In power systems dominated by large-scale conventional power plants, power flow patterns are relatively "static" and unidirectional.

With the integration of vRES, the grid loading behaviour changes, with highly fluctuating, bidirectional flows, creating short-term loading of assets. Typically the TSO has to manage a bigger volume of grid congestions, and to enable reactive power compensation and frequency control services. Solutions are needed to allow increasing the utilisation of grid assets without endangering system security.

The TSO's system planning team has to identify and to investigate different innovative solutions for the power transmission in order to avoid long-lasting grid expansion projects whenever possible, such as better line monitoring (DLR) and incorporation of FACTS and energy storage devices to remove short-term overloading.

## 3.2 Challenges in Grid & System Operation

In the thematic field of "Grid - and System Operation", the key changes and challenges presented below are identified as the most relevant ones for a TSO. With the integration of vRES, the TSO needs to be aware of RES-related changes in grid – and system operation's organisational structure, processes, methodologies, and tools. Those changes will be mapped with challenges that the TSO shall overcome in the activities of grid operation - and system operation.

***1. Organisational transformation of TSO's grid – and system operation team***

The grid – and system operation tasks allocated to dispatchers and operators in systems dominated by conventional power plants are well defined with clear daily workflow. Main changes in these tasks are regarding change in monitoring technologies, but no radical change in the work scope.

The system - and grid operation team will have to gain additional competences to face the new challenges due to vRES introduction. In addition to the classical dispatching and grid operating teams, new topics like vRES forecasting, grid congestion planning, dispatch scheduling, unmanned substations will need to be investigated and applied. This brings radical changes to the organisational structure of the team.

The TSO needs to transform internally the organisation of the system and –grid operation. It needs to constantly review and develop its grid and –system operational strategy and concepts in order to adapt to the challenges of rising shares of vRES.

### *2. Key system operational challenges*

The integration of the Ukrainian power system to the ENTSO-e network is the main concern regarding operational challenges. The Ukrainian power system has to fulfil various system operational standards from ENTSO-e and enable operation in islanded mode after disconnecting from IPS.

In a vRES dominated power system, the power system operation will get more challenges with regards to frequency and voltage stability. The volatile and uncertain vRES infeed make the frequency control more difficult. Ukrenergo estimates that the normative amount of reserves must be equal to 650 MW. The target fluctuations of vRES generation in the amount of up to 450 MW must be taken into account when drafting a daily chart. Additionally, due to increased volatility in power flows, the grid loading is increased (but in a more short-term intermittently manner).

The TSO needs to be aware of all the system operational challenges coming with the increasing shares of vRES, as practically all operational tasks are affected. For example, it needs to include forecasting procedures, or to develop a functioning balancing market to acquire sufficient control resources.

### *3. RES Forecasting*

Traditionally, system operational planning is based on generation that follows the load fluctuations. The load is forecasted based on the schedule of the large consumers and the assumed characteristic load curve of small consumers.

vRES introduce increased uncertainty in system operation, creating high deviations between the operational planning and actual flows. In order to maintain the system reliability and reduce the system operation costs, the TSO should develop forecasting systems to better incorporate vRES in operational planning.

Since the RES forecasting is a new topic for a TSO, it needs to study the different options and develop forecasting systems for wind and solar PV which can cover the need in the system operation. Putting the systems in place and managing the data flows is a major challenge as it affects most existing procedures.

### *4. Short-term Adequacy*

Short term adequacy refers to the ability of the system to cover the load requirements in all operational horizons and under the condition of outage of any power plant or network element. In power systems dominated by large-scale conventional units, the short-term generation adequacy is maintained by balancing reserves, and additional ancillary service providing units.

With higher vRES shares, short-term adequacy becomes more important in the system operation, in order to cope with the increase variability of vRES, and increased grid congestions. Due to fluctuating flow patterns, adequacy should be guaranteed not only in the peak load hour but in every scheduling period

Key challenge for TSOs is to redefine the methodology of short-term adequacy planning considering the vRES fluctuation and other uncertainties.

### *5. Short-term Congestion management planning with vRES*

Until now, the structure of the single buyer market model dominated with long-term trades from large-scale generators and the single buyer enables a reasonable congestion management planning.

With the introduction of the new competitive market structure and in a high-RES system, congestion management becomes more challenging due to the high level of volatility in the system. Short-term congestion management planning procedure should be setup with a high level of automation is able to deal with the increased volatility. Furthermore, Ukrenergo will need to implement the ENTSO-e congestion management procedure guidelines.

Key challenge is to improve the existing short-term congestion management practice by considering the lessons learnt shared from international best practices in short-term congestion management planning, in particular the ENTSO-e procedure.

***6. Mid-term planning***

In traditional power systems with mainly controllable and stable generation, grid and system operational mid-term planning processes are simpler. Grid load situation can be foreseen so that the grid congestion management resources and the outage planning can be easily defined in advance.

The high vRES penetration creates a high dynamic and uncertainty in the power flow structure. Consequently, planning of congestion management need and the adequate acquisition of resources are more challenging and outage planning gets more difficult.

The TSO has to review its mid-term planning methodology with the integration of vRES. The mid-term planning has to properly consider the uncertainties in the power generation.

***7. Special topics: Line monitoring and energy management in extreme events***

In power systems dominated by conventional power generation, the grid load situation is quite predictable and the risk of extreme weather events impacting the system performance is reduced on risks of transmission lines outages.

The power systems with high vRES share are weather dependent. Extreme weather events like solar eclipse, sea storm, sand storm, fog, etc. will play an important role and impact the system stability. Therefore, those events shall be properly forecasted and counter measures in the system operation shall be defined by the system operator in cooperation with the generators. Furthermore, in order to increase the utilization of the grid, innovative solutions like line monitoring should be incorporated in operations.

Key challenge for the TSO is to ensure system security against extreme events and to optimise grid utilisation by including innovative solutions.

## 3.3 Market Design & Flexibility

In the thematic field of “Markets and Flexibility”, the key changes and challenges presented below are identified as the most relevant ones for a TSO. With the integration of vRES, the TSO needs to be aware of RES-related changes in the market structure, - mechanisms, -processes, - tools, and in particular in the flexibility’s availability at the market. Those changes will be mapped with challenges that the TSO shall overcome in the market design development’s activities.

***1. Organisational transformation of the TSO’s market department***

Market development plays an increasingly important role in the strategic planning of a TSO. In traditional systems the market dynamics are limited due to strong regulation.

vRES introduction brings radical changes to power market design. The TSO should play an important role in all market design as the institution that can assess the impact of market development on the power system operation. The TSO has to actively participate in the market design discussions and present valuable propositions from the perspective of the system operator. By doing so, the TSO can prevent any negative impact from the market develop on the system operation.

The TSO faces the key challenge develop the competencies in energy economic and market design so that it can present valuable propositions in the market development discussions. This in most cases needs the development of new enhanced departments.

***2. vRES integration impacts to power markets***

Ukraine introduced the competitive electricity market in July 2019, at which electricity can be traded bilaterally on the long-term or via a power exchange for the short-term combined to a Single Buyer model for vRES. vRES generators are paid with the feed-in tariff (FiT) and the produced electricity is completely injected into the grid.

In the transitional phase of RES market integration in Germany, vRES generators were compensated by a subsidy covering the gap between the market price and the FiT. In advanced market development stages, vRES generators should participate to the market without compensation. vRES generators will have to register their dispatch schedule at the TSO and follow the dispatch schedule to avoid imbalance costs as all other generation types. Furthermore, RES auction is identified as an effective mechanism to steer the locational and temporal development of vRES.

Key challenge is to find an appropriate model for the marketing of electricity from renewable energies depending on the penetration level of renewable energies. The model shall be cost-efficient and in the same time it should not deaccelerate the development of renewable energies.

### *3. Market Operating Regime with vRES*

In July 2019, a competitive wholesale market structure has been introduced in Ukraine. In the early phase of the market, aspects such as high concentration of market power, limited number of players in the balancing and ancillary service market were reported. However, the establishment of competitive market model is an important step for the success of RES market integration.

Nevertheless, vRES bring significant impacts on the market such as reducing market prices and increasing price volatility. Events like negative prices in situations of abundance of energy supply or very high prices in scarcity situations can happen depending on the weather situation. The reduction in the average market prices reduces profitability of conventional generation units and can shift power plants out of the market. Consequently, capacity mechanisms could be needed to ensure security of supply. With increasing vRES shares, the design of Day-ahead and Intraday market products is important to maintain liquidity and pricing. The transnational interconnection and coupling of markets enables to increase the uptake of renewable energies, in particular in constraining situations of excess generation from renewables.

Key challenge for the TSO is to design and develop functioning markets and market products in line the increasing generation from renewable energies. New market players, in particular vRES producers, are encouraged to enter the all sub-markets. Further, to security of supply and to maximize the take-up of renewables, the market coupling with neighbouring countries should be prioritised.

### *4. Balancing Market and BRP concept*

With the introduction of the competitive market, balancing - and ancillary service market are also put in place for the market-based procurement of system services. Additionally, the Balance Responsible Party (BRP) concept has been recently introduced as stated in the market rules. However, processes (prequalification, market operation, settlement) are still under development.

Functioning BRP concept is supportive for successful vRES integration as market players take responsibility for the system balancing. As a result, the need and cost for balancing energy activation can be reduced. Besides, balancing market should be designed so that flexibility needed for the frequency regulation is sufficiently available at the market. Especially, small flexible players shall be incentivized to enter the balancing market (e.g., with shorter imbalance settlement period, gate closures close to real-time, low minimum capacity requirement, option for aggregation of flexibility sources, etc.).

Key challenge for the TSO is the establishment of the balancing prequalification process, and the re-design of market according to the increase of vRES and to the need of liquidity. Further adjustments of the BRP setting and Balancing Service Providers (BSP)/BRP settlement procedure are needed, which can motivate market players to reduce their forecasting errors and avoid high imbalance cost.

### *5. Integrated EU market initiative: Market coupling, bidding zones*

Ukraine is working on the ENTSO-e connection in order to increase its electricity exports to other European countries. In a next stage, the Ukrainian power market can be coupled with neighbouring ENTSO-e members. On the one hand, this could allow Ukraine selling electricity to European countries. On the other hand, the balancing market can be integrated with neighbouring balancing markets in order to reduce the size of balancing capacity reservation, and to reinforce the competition in the market.

With the integration of vRES, Ukraine might face the issues with structural congestion when many vRES are developed at the hotspots in the South. The market design needs to be adapted to steer the investments of vRES. An important step is a bidding zone configuration study. By introducing multiple bidding zones, the price signals at each zone shall steer optimally the allocation of new investments.

Key challenges are to improve cross-border trading through flow-based market coupling, to redefine the bidding zones, and a short-term wholesale and balancing market design aligned with other ENTSO-e member, so that the integration with neighbouring markets is easy to implement**.**

**6. Power system flexibility**

The Ukrainian power system is dominated by nuclear, coal-fired power plants and heat-driven CHP units (with a high level of must-run). Traditionally the system is using these resources to manage load fluctuations.

The introduction of vRES creates issues with the flexibility resources in the system as on the one hand the net load fluctuations increase while the flexibility resources are reduced (as peakers are shifted out of the market). New flexibility options enable the integration of renewables beyond the limits of today's centralized power system. The TSO in its role Single Buyer of the balancing and ancillary services provide and manage a market platform that is accessible for all flexibility providers and aggregate available flexibility from flexible generation and demand options.

A key challenge for the TSO is to identify flexibility options that can cost-effectively ensure the provision of flexibility in the system in the presence of vRES, and to maintain security of supply at reasonable electricity prices. Further it should develop a market platform to steer the new flexibility resources and steer the development of flexibilities on political and regulatory level (ownership and operation).

***7. Digitalisation***

Digitalisation is a cornerstone in the strategy of Ukrenergo. Ukrenergo has made the first steps towards the digitalisation in the energy dispatch, system operation, and enterprise's resource management. Moreover, the company has developed different projects in terms of cyber security and is highly interested in other topics related to unmanned substation, predictive maintenance, smart grid, big data, artificial intelligence, etc. which will have a strong impact on the business.

A digital strategy helps the TSO to understand and prioritize new technologies and their implications. The adoption of a digital strategy will have advantages for the company and lead to a transformation process by enhancing efficiency (automation, resources efficiency and productivity, better decision making based on better data), flexibility (handling of complexity, operation closer to real-time, adaptation to market changes) and brings new business opportunities outside of the regulated system.

The pace of change towards a clean, decentralized and interconnected energy system will become faster with digitalization. The three main challenges to enable a digital shift are:

a) Market and regulation: Update of the market design to enable interactions and empower prosumers and to optimize the use of the existing infrastructure.
b) Communication: Real-time data communication to process data from millions of connected consumers and devices in a secure way.
c) Technological: Use of state-of-the-art methods and tools to better develop, maintain and operate a more renewable and decentralized system.

## 3.4 TSO Positioning & Strategy

In the thematic field of "TSO Positioning and Strategy", the key changes and challenges presented below are identified as the most relevant ones for a TSO. With the integration of vRES, the TSO needs to be aware of RES-related changes in the corporate strategy development, communication, public relations, investment planning and TSO business model. Those changes will be mapped with challenges that the TSO shall overcome in order to become a trusted advisor and an enabler of the energy transition.

### 1. Organisational transformation in the TSO

Ukrenergo's current organisation is aligned with TSO's classical business units such as market, system operation, grid investment, grid operation, company management.

With vRES, the main corporate structure of the TSO will remain. However, the energy transition will requires some changes in terms of functions and competences. Modern TSO needs to have sufficient in-house competencies to understand and to shape the development of energy transition.

Key challenge is transforming the TSO organisation in order to be ready for shaping the energy transition. New company's function will be created and competencies will be developed, for instance in the energy economic, vRES integration engineering, offshore connection engineering, HVDC engineering, etc.

### 2. The German energy transition story

Ukrenergo will reach the vRES 2025 targets already by end of 2019 (4,9 GW). Present connection requests count up to 11 GW. However, Ukraine is quite at the beginning of its energy transition. Lessons learnt from the energy transition in other countries like Germany can be used to accelerate the Ukrainian energy transition.

The goal of the energy transition is to have a clean, reliable, secure and affordable energy system. The TSO will be the key success factor in the whole development to this Target. Ukrenergo shall adjust their activities and prepare for the future adequately for different penetration level of vRES.

A key challenge is to learn from the successes and failures from the German energy transition story in order to avoid making the same mistakes and to accelerate its own energy transition.

### 3. Importance of public acceptance for TSO and the success of the energy transition

Ukrenergo is improving the state company's image in the society by creating more transparency, committing on anti-corruption and compliance, developing corporate social responsibility program with many engagements for the society, and reducing the environmental impact of their business activity. These activities are important for the TSO's public acceptance.

As a result, the majority of the publicity accepts the key role of Ukrenergo in the energy transition and understands the need of grid development in the energy transition. Therefore, low resistance for new grid projects due to a transparent and open communication. However, the TSO should be aware that this situation can change quickly, when the TSO is building additional lines across the country to integrate efficiently Renewables.

The key challenge is to develop a transparent, open, bidirectional and standardized communication and public stakeholder management strategy in order to strengthen the public acceptance. Besides, the TSO needs to continuously develop new initiatives and innovations applied in grid projects, which reduce the impact of the new project on the people and the environment (e.g., new pylon design, vegetation development concept, etc.).

### 4. TSO evolution in terms of corporate strategy, organisation and communication strategy in the energy transition

Ukrenergo's current business model has been developed based on the former power system, which comes from a state-owned, monopoly, and vertically integrated structure with low vRES rate.

With the integration of vRES, the TSO itself will further evolve in different corporate functions, processes, and -activities. The TSO's long-term development plans such as organisation, Human Resources (HR), investment are significantly impacted by the development of vRES.

The key challenge is the RES-oriented transformation of the organisational structure, competence requirement, and human development. Changes in the corporate culture with focus on the energy transition should be performed. Corporate strategy should be developed in a dynamic business environment, which is driven by the energy transition.

***5. Positioning of the TSO as trusted public advisor for the energy transition***

In the implementation of the energy transition, a long-term prediction of the sector development is useful for the strategic planning of the TSO. Until now, Ukrenergo mainly follows the energy targets and strategy defined by the ministry.

The TSO shall be the elementary service provider for the implementation of the energy transition. Therefore, the company should analyse possible future developments in a self-developed long-term grid study that is useful for the strategic planning of the TSO.

Ukrenergo should position itself as a trusted public advisor in the discussion of the sector development by studying a set of political scenarios and the resulting need of grid development. A key challenge is to provide an independent assessment of the political targets from the perspective of the TSO and help the government set the agenda to the right direction.

***6. The European perspective of energy transition in the Clean Energy Package***

With the ambition of ENTSO-e integration, Ukraine is also obliged to commit to EU energy targets defined in the clean energy package (CEP) at the national level with the ambitious goals for vRES development, CO2 emission reduction, energy efficiency increase, and providing interconnection capacity for cross-border trading. The national implementation is very ambitious. Being directly impacted by those targets, Ukrenergo needs to know how to interpret these targets into company's objectives, strategies and actions.

The identified key challenge for Ukrenergo is to interpret the impact from the EU CEP on the Ukrenergo's business objective, - strategy, - activities and - processes. Besides, Ukrenergo needs to be able to advise the publicity and the politic about the impact of the CEP on the Ukrainian energy sector from the perspective of a TSO.

***7. Developing new non-core services/ businesses for TSOs***

Grid development, - construction, - operation, and system operation are the core business of the TSO. Usually, the core business is regulated due to the position of natural monopolist of the TSO. But, with the changing business environments (trend of decentralised energy system, digitalisation, etc.), TSO is able to seek for new business opportunities outside of the regulatory business in order to ensure its profitability when the TSO business environments becomes more challenging.

In the future, the TSO shall be able to provide non-core services and to enter non-core businesses, which help the TSO to growth outside of the regulated business. For example,

- TSOs provide to grid users in the connection and maintenance services for the full connection bay going from customer's transformers to the grid;
- TSOs provide the usage of their pylons and its own telecommunication lines as telecom services;
- TSOs provide valuable system data (e.g., from forecasting systems, balancing market).

A key challenge is to identify the non-core businesses and get the approval and capital resources from the shareholders to develop these new businesses, developing human resources to realise these businesses and identifying the leverages for core- and non-core business.

## 3.5 Structural Reform: Regulation & Finance

In the thematic field of "Regulation and Finance", the key changes and challenges presented below are identified as the most relevant ones for a TSO. With the integration of vRES, the TSO needs to be aware of RES-related changes in the regulation, which definitely have impact on the system development and the TSO's financial viability. Those changes will be mapped with challenges that the TSO shall approach in every single activity in the regulation management.

### *1. Organisational transformation in TSO's regulation management*

The regulatory environment is in high transition in Ukraine: single buyer model is abandoned, competitive wholesale market has been introduced accompanied with changes in the regulatory regime. Currently grid investment incentive regulation is cost-plus. Further, TSO ownership unbundling is planned.

Target is the evolution towards incentive-based regulation in 2020-2021. The introduction of vRES should be properly considered, as it becomes key driver for Capital Expenditures (CAPEX) plan. For this, the TSO shall actively shape its regulatory framework by active exchanging and communicating with relevant stakeholders. The regulatory management group is responsible these tasks.

Ukrenergo is challenged to understand key lessons learnt from the German regulatory framework evolution from the TSO perspective. Based on that, new functions and a regulatory management team shall be established, who can take over the regulatory support and the interfacing to the regulator.

### *2. EU regulatory framework for RES promotion*

The regulation framework in Ukraine is defined at the national level by the ministry. However, Ukraine will have to align its RES targets with the EU targets because of plan of ENTSO-e connection. EU regulatory framework will increasingly become the frame of the Ukrainian regulatory regime.

The European regulation in the power sector like the Clean Energy Package defines the vRES targets for the whole union. Adequately, a set of regulatory guidelines are introduced in order to accelerate the development of vRES in the member countries. The stakeholders in the energy industry shall be able to understand the implications and challenges on the national context.

Ukraine will need to transform the EU guidelines into national targets fitting to the existing national context. Since these national targets directly impact the TSO business, Ukrenergo needs to understand the EU targets and to be able to actively imply the EU targets on the national context on its own. The result can be consulted with the regulator and other stakeholders. Also the communication and exchange with EU institution like ENTSO-e and Agency for the Cooperation of Energy Regulators (ACER) will be important for Ukrenergo and NEURC.

### *3. The Role of the Federal Regulator for optimal vRES integration*

The regulator in Ukraine NEURC is established according to the European third energy package. Since a rapid development in the regulatory regime in Ukraine is expected, NEURC will be the key stakeholder in the system transformation discussion. It will have to shape the regulation, so that the energy transition development can be steered effectively via regulatory mechanisms.

The German Regulation Agency (BNetzA) has been established with the task of monitoring and supervising the activities of the natural monopoly in the regulated business of electricity and gas grid, telecommunication grid and railway grid. Especially in the electricity, the regulatory regime has been developing strongly in accordance with the energy transition. Besides, the regulator ensures the alignment of national regulation with EU regulations. At the regional level, the regulator is exchanging with other regulators in the association ACER.

A key challenge is to refine the roles and responsibilities among all stakeholders in the energy industry is needed, incl. the regulatory authority, ministry, the TSO, etc. The regulator NEURC should be aware and prepared for the fast-changing requirements on the regulatory regime. An improvement of the exchange between regulator and TSO in order to accelerate the energy transition is needed. Experience exchange with other regulators in association like ACER can be helpful in this direction.

### *4. Regulatory framework to encourage small players (Regulatory sandbox)*

The current regulatory framework does not have a high consideration for the new and small market players or their aggregators, or players coming from other sectors (heating and transportation). For example, no Demand Side Management (DSM) instrument until now except of possibility to have Time-of-Use price system. This prevents new and small market players with high flexibility to provide services to the system.

The regulatory framework should evolve to allow the optimal incorporation of small-scale resources to the market (e.g. decentralized generation and prosumer concepts) and support the system operation (provision of aggregated flexibility for frequency control or congestion management). Business models should not be based on 'regulatory opportunity' but rather emerge from a systemic vision and long-term economic feasibility. Regulatory changes should follow and enable such viable business models.

Ukrenergo should guide the market and regulatory development towards the optimal integration of distributed resources. Key challenge is to position Ukrenergo to become a manager of the energy transition, to develop the systemic vision and test business cases together with the stakeholders from the government and industries (regulatory sandbox).

### *5. RES incentive mechanism (From Feed-In Tariff to Green auction)*

Until now, attractive, high Feed-In Tariff (FiT) that leads to an over-development of vRES creation. The implementation of green tariffs in 2008 increased renewable energy producers subsidy to around 23 EUR cents/kW, which is around 8 times higher than the non-renewable wholesale price. Producers of solar power receive the largest subsidy of between 34 and 43 EUR cents/kWh. In the next step, Ukraine aims to introduce green auctions in 2020. Due to the attractive condition from the green tariffs, many investors start to build new plants. Ukrenergo has received many connection requests up to 11 GW of vRES.

It shows that incentive mechanisms shall be set appropriately depending on the development stage of vRES in the country so that it does not stop the energy transition on the one hand, but also keeps the energy transition affordable for the society on the other hand. Sharing lessons learnt from the German RES incentive regulation evolvement, especially with regards to the newly introduced auction system, are valuable for Ukrenergo. As a result, Ukraine is able to introduce successfully new incentive mechanisms, which help to realise a fast, but also secure and affordable energy transition.

Key challenge for Ukrenergo is to study the RES incentive mechanisms, to participate in the discussions, and to support the national regulator in the assessment of the incentive mechanisms' impact on the system. Especially with regards to the upcoming green auction system, lessons learnt from Germany should be considered.

### *6. CAPEX Planning and grid financing instruments*

Current tariffs are regulated under cost-plus regime; introduction of incentive-based regulation expected 2020-2021. High investment need due to replacements of assets and expansions caused by the integration of renewable energies.

Ukrenergo should adapt the CAPEX planning process according to the incentive-based regulation regime, in particular use given incentive mechanisms to optimize the CAPEX allocation. Ukrenergo should include the regulatory view in the grid development planning and project implementation process

Key challenge is to identify and understand the critical elements of the regulatory framework and their impact on the investment budgets. Afterwards, the TSO shall include these in the planning processes.

### *7. Grid Access and Priority Access for vRES Generators*

The fast development of the renewable energies creates an amount of connection requests, currently counting up to 11 GW. However, the connection capacity of the grid is limited and grid expansion for the transport of the electricity is needed.

Although vRES generators have priority access, their connection to the grid still depends on the current capacity and condition of the grid. Due to capacity limitation, innovative connection concepts and connection regulation shall be developed so that the connection can be realised quickly without having a strong impact on the system reliability of the RES hotspot regions. For example, locational connection tariff can be introduced to steer the connection of new vRES. Innovative connection concepts such as Elia's active network management concept are supportive for the connection of high RES in a constrained system condition. In this concept, connection capacity will be allocated dynamically to vRES generators based on the weather condition. In the worst case, generators accept that the TSO can redispatch the injection in case of overloading of the line.

The first key challenge is to develop a centralized vision of grid connections possibilities, with pre-defined connection points and available capacity, and publicly available. Besides, locational tariff signals for RES projects shall be studied based on avoided cost tariffs, grid studies and assessment of shallow and deep connection cost allocation. Lastly, the TSO can develop flexible grid connection concept like the active network management concept at Elia as explained, so that it can realize the high amount of connection requests from vRES generators.

# 4 Conclusion

In the energy transition towards a green, sustainable and reliable ecosystem, the TSO should play a central role, as responsible for the system integration of vRES. The actual Ukrainian power system's situation shows that the country is in a dynamic transitional phase. Ukraine is preparing itself for the connection to ENTSO-e synchronous area. Additionally, the competitive market has been introduced in order to strengthen competitiveness, increase efficiency, with the goal of being integrated into the European market. Regarding to the green energy production, Ukraine is also experiencing a fast development in the new installations of vRES due to the attractive incentive mechanism.

On the other hand, Ukrainian transmission system is still facing several challenges. Aging power infrastructure, low energy efficiency, high dependence on imports, and missing fast-responding balancing reserves are some key challenges. As the implementation of the energy transition is coupled with many additional changes and challenges, the TSO should be prepared properly in advance in order to perform well in its role as the enabler of the energy transition.

The challenges from the TSO perspective are mapped in general in 5 thematic fields:

1. ***System Transformation and – Planning***: The TSO is required to re-organise the system planning process. The system is developing from centralized energy supply with controllable power plants to decentralized, small and uncontrollable vRES. This trend exposes many uncertainties in the system development that should be considered in the system development.
2. ***Grid – and System Operations***: is becoming more challenging due to the high volatility and uncontrollability of the vRES generators. In order to maintain the system stability, the TSO needs to approach these challenges in the system operational long-, mid- and short-term planning with standardized and automatized processes and toolboxes, coordination at regional level, cooperation with DSOs.
3. ***Market and Flexibility***: The high penetration of vRES affect the market structure. Flexible but expensive power plants such as gas and hydro are increasingly displaced by vRES although their flexibility is needed in a system with high RES. In the Ukrainian context, the flexibility issue will get more serious because of the high must-run production rate coming from nuclear, coal and CHP. This flexibility issue shall be approached and solved through a proper market design.
4. ***TSO positioning and Strategy:*** The TSO business is directly impacted by the energy transition, but it also directly impacts the success of the energy transition. Thus, it is important that the TSO continuously participates and positions itself in the public discussion regarding the energy transition. Herein, the TSO can position itself as a trusted advisor for the energy transition that can share the benefits and challenges from the system operational perspective.
5. ***Structural Reform incl. Regulations and Finance:*** The successful energy transition requires also a consistent development of the regulation. The regulation shall support not only the development of vRES but also a successful integration into the power system. For instance, the regulation is able to steer the pace and the locational hotspots of new vRES installation in order to minimize the impact on the system. The TSO shall play here a strong role in the communicational exchange with key stakeholders in the sector.

This mapping provides the basis for a thorough identification of challenges and gaps in the Ukrainian power system in the implementation of the energy transition. In the next step, the gaps will be approached in a series of capacity building workshops.

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