Conclusions and Recommendations

Energy Distribution and Storage

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Roadmap for a climate-neutral, sustainable Ukrainian energy sector and its role in an integrated EU energy market

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Energy Distribution and Storage

The energy transition is making it more complex to bring energy to final consumers in three ways. Firstly, many processes that are currently powered by fossil fuels will become electrified, and electricity is comparatively more difficult to stockpile, transport, and transform into thermal energy than fossil fuels. Secondly, most electricity will be generated from renewable sources, which are largely intermittent & decentralized and have to be balanced by steady but flexible dispatchable power – and this balancing in turn may require moving larger amounts of electricity across greater distances, or using small-scale local batteries. Finally, a substantial amount of electricity will be produced by small-scale, usually also intermittent, facilities like rooftop solar panels, and will need to be fed into the grid without leading to disruptions.

The main ways to manage this complexity will be grid enlargement, smart grid management and a big expansion of storage capacity in a wide range of formats, from grid scale to small local systems. The state of technology for many of these fields is not yet sufficiently advanced for large-scale adoption in the near term, but can already be prepared to some extent. This set of conclusions and recommendations focuses on transmission & distribution, smart grids, and energy-storage systems. While hydrogen and its derivatives can be and are likely to be used for energy storage, they are described at more length in section 0 Industrial Applications.

Transmission and distribution

The production of renewable energy being more erratic than that of conventional plants places particular demands on electricity grids. Ukraine's future energy transition will be further complicated by the strain imposed on the country's grid since the full-scale Russian invasion began in early 2022, and especially during Russia's deliberate attempts to destroy power infrastructure during the winter of 2022/2023. From October 2022 to February 2023, Russia launched almost 200 missiles and 46 drones at Ukraine's electricity grid, knocking out 10 GW of generation capacity and 43% of the high-voltage transmission grid. Ukrenergo had to impose rolling blackouts, with up to 12 million people without power at any given moment.

The transmission-system operator (TSO) Ukrenergo connected Ukraine to the synchronous grid of continental Europe within days of the full-scale Russian invasion in March 2022. By the summer of 2022, it had established interconnector capacity of around 2,300 MW per hour and was exporting some 500 MW of power per hour to European Union countries. Ukraine managed to keep its grid functional and was back to exporting electricity again by April 2023. This appears partly to have been achieved through specialist techniques to preserve system balance despite local failures, including procedures that allowed the grid to function as a number of independent islands, preventing collapse if one island is knocked out.

Before the full-scale Russian attack, Ukraine had 17.7 million consumers of electricity, of which 500,000 were commercial customers. By early 2023, electricity production had decreased by a quarter while demand had dropped by 30-35% and shifted massively due to the displacement of people from the east of the country to the west, as well as the disappearance or shutdown of economic activity. In early 2023, hundreds of settlements and more than half a million people remained without electricity, and millions more had only partial access or were on capacity-limiting schedules.

Ukrenergo is fully owned by the Ukrainian government through the Ministry of Energy. It plays a vital role among other things in implementing EU regulations on fundamental data transparency in the electricity market and has observer status in ENTSO-E since April 2022. Ukrenergo owns and operates Ukraine's high-voltage transmission grid and works closely with Energorynok, the market operator, though these two entities are separate and have independent budgets. Ukrenergo is also independent from the generation and distribution companies.

Access to transmission and distribution systems in Ukraine is ensured through publicly available tariffs, which also apply to generators. Distribution system operators (DSOs) are legally and functionally unbundled in compliance with EU legislation. Since March 2023, DSOs are required to develop and submit development plans and investment programs. These plans aim to ensure efficient, transparent, and renewable energy-friendly grid planning, enhancing grid stability, regulatory oversight, and consumer protection while aligning with national energy goals.

Recommendations

Once the hostilities cease, Ukraine will need to immediately shore up and reinforce the **basic physical power transmission and distribution infrastructure**. No major refurbishments or investments should be made until it is clear which parts of the grid will no longer be needed as the power system evolves toward a greater share of renewable energy in the medium term. This assessment should also include an analysis of infrastructure upgrades that can **reduce transmission losses** and the **potential of smart and decentralized grids** (e.g., to boost resilience) – both of which are crucial to **improved energy efficiency** – and lead to an overarching strategy towards future-proof transmission infrastructure.

There are several priority reforms in the legal framework related to Ukraine's transmission system that should be carried out within the period immediately after the end of the war. Domestic law should be **harmonized with Energy-Community legislation** and the energy acquis to maintain consistency with regional energy standards and give **special consideration to renewable-energy sources**. Tariffs should be adapted following an assessment of which structure would best suit the country's needs. Ukrenergo should be included in the EU's inter-TSO compensation mechanism.

Ukraine should also adopt Connection Network Codes within regulatory acts so as to **align its energy infrastructure with European standards** and facilitate seamless integration into the broader European energy market. The connection process of renewable energy into the grid should be streamlined, minimizing bottlenecks, enhancing transparency, and improving efficiency. And a comprehensive grid master plan for the coming decade should be set up, with data on grid development that allows renewable-energy projects to identify areas with optimal grid access.

In the medium term, Ukraine should start to plan and build its **future transmission infrastructure**. These plans should be developed in parallel with the broader strategies for the coming expansion of – mostly intermittent – renewables. Measures including ramping up digitization and **advanced grid management**, creating **demand-side flexibility**, integrating **energy storage** as well as taking steps towards more **interconnectivity** and regional grid integration will be essential to ensure grid reliability, maximize energy utilization and efficiency, and support the integration of renewable energy sources into the energy mix.

Funding for future-proof grid infrastructure can be secured from a number of sources, not least multilateral development banks like the World Bank, the European Investment Bank or the European Bank for Reconstruction and Development. Government support can be provided through subsidies to private initiatives, or public-private partnerships, mitigating risk and leveraging public resources. **Private-sector funding** can be brought in via green bonds, energy performance contracts, or energy savings agreement, as well as crowdfunding or impact investing platforms.

Smart grids

Smart grids are a constructive part of a future energy system based largely on intermittent renewable energy. These electricity networks deploy digital technologies, sensors, and software to match the supply and demand of electricity in real time. This maintains the stability and reliability of the grid while minimizing costs. They are particularly helpful in functions such as balancing electricity supply and demand, ensuring the long-term ability of the grid to meet the needs of domestic and cross-border trade, and actively boosting the efficiency, reliability, resilience, stability, and flexibility of power grids. Smart-grid technology is largely mature, but they are complex to deploy on a large scale.

Recommendations

The development of smart grids in Ukraine could be fostered by eliminating legislative and institutional barriers to their deployment and bolstering the conditions, incentives, motivations, and methods appropriate for their use by electricity companies, businesses, and citizens. This can, for instance, include establishing regulations that mandate that both the transmission system operator and distribution system operators actively **develop comprehensive plans for smart-grid deployment and expansion**. **Approval processes** for smart-grid projects should be simplified, and **tariff structures** should be reformulated to reward electricity companies for enhancing grid efficiency through smart-grid technologies.

Storage systems

Energy storage plays a major role in the system integration and decentralization of the energy market. This include grid-scale energy storage feeding into the electrical grid, storage of electricity for direct use, electrification of the transport sector through the deployment of batteries, and heat storage. By helping manage energy flows and match demand to supply, storage facilities can help improve the efficiency of infrastructure, markets, and consumption patterns.

Grid-scale storage technologies can provide significant system services in a decentralized and decarbonized energy system, including short-term balancing and operating reserves, ancillary services for grid stability and deferment of investment in new transmission and distribution lines, to long-term energy storage and restoring grid operations following a blackout. The Energy Strategy of Ukraine until 2050 aims to increase the capacity of energy storage facilities, including long-term (seasonal) storage devices that use power-to-X technologies, to help balance the power grid.

There are a number of technologies that allow the storage of energy in various forms. According to the International Energy Agency, pumped-storage hydropower accounts for over 90% of total global electricity storage. Before the full-scale Russian invasion, Ukraine had a total installed pumped-storage hydro capacity of 6,317 MW. Lithium-ion batteries are another common form of electricity storage. They can be used as portable energy storage systems (such as batteries in cars) as well as for grid-scale storage. They require a large amount of resources, however; most of these can be found in Ukraine in some quantities, but are not yet mined on an industrial scale. Lithium-ion batteries also suffer from problems linked to environmental impact, the supply chain, and waste recovery & recycling – the latter is a particular problem for Ukraine, which has accumulated thousands of tons of used batteries over the past decades and lacks industrial facilities to recycle them.

Other promising types of storage include redox flow batteries, as well as mechanical solutions such as compressed-air energy storage systems (no such systems exist in Ukraine yet). Hydrogen and ammonia can be used as chemical energy storage (see also section 0 Hydrogen), and other systems may be considered in the future, such as sensible heat, liquid air, gravitational storage, metal air, latent heat, thermochemical heat and flywheel energy storage.

There are many battery manufacturers in Ukraine, producing a wide range of electrochemical battery systems, including lithium-ion batteries, lead-acid batteries, and alkaline accumulator batteries. Given the breadth of applications required, stakeholders in the Ukrainian energy system should assess all options, pursuing a technology-open approach.

Recommendations

In the first years after the war, Ukraine should facilitate the access of residents to **small-scale storage systems connected with solar-power generation**, and carry out an evaluation of the best locations for grid-scale storage capacity, as well as a plan to expand grids to accommodate it. A **range of different storage technologies** should be explored, and **regulations and monitoring** based on EU law should be introduced to ensure environmentally sound mining and recycling. Regulations supporting **recycling and second-life use** for batteries should also be developed.

In the longer term, Ukraine's recovery will involve large-scale increases in renewable energy, requiring **much more storage capacity**. This will help make energy systems – infrastructure, generation, consumption – **more efficient, resilient and cost-effective.** It should be accompanied by more system integration, for instance by connecting car batteries to the grid. **Battery recycling** should be improved and the **mining of raw materials** critical to battery production should be safeguarded and expanded where possible. Battery-storage systems should be granted **exemptions from certain tariffs and given benefits when they store only renewable electricity to encourage their widespread adoption and integration into the energy grid.**

Other actions to bolster the use of batteries through a streamlined regulatory framework should include **support to domestic suppliers involved in battery manufacturing and improving access to grid services. Ukraine should** implement the recently introduced EU Batteries Regulation, adopt a dedicated law to ensure a **stable and sustainable supply of raw materials** needed for battery manufacturing and other energy storage technologies, adopt a **circular-economy law** that acknowledges battery materials as valuable raw materials, and develop regulations that facilitate **synergy between renewable energy and battery technologies**. Maintaining a **technology-open approach** throughout these processes will be of paramount importance.