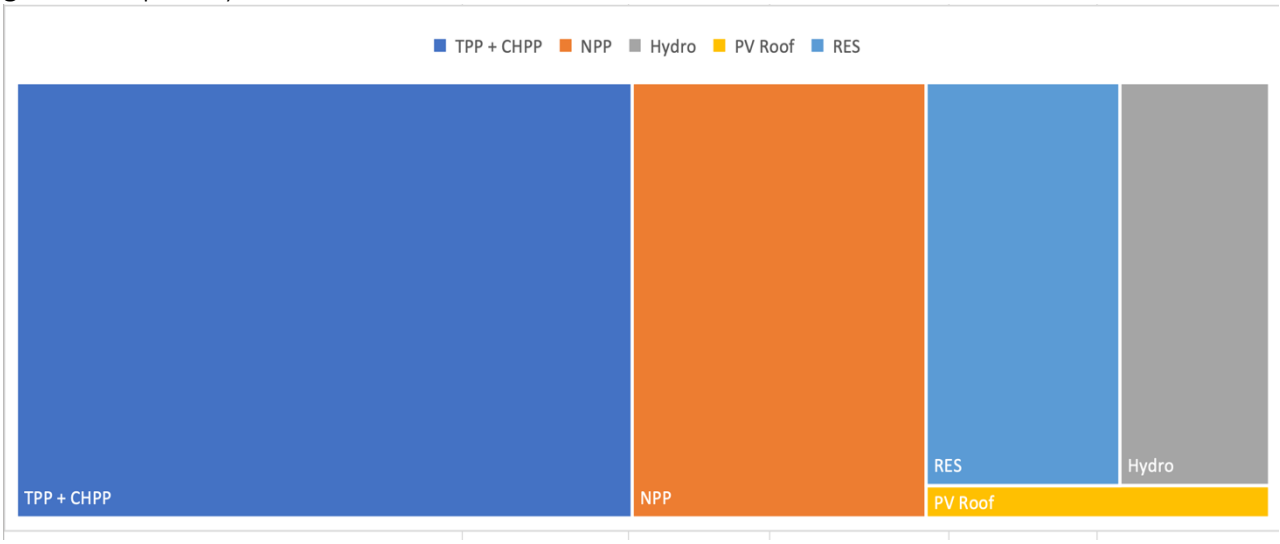
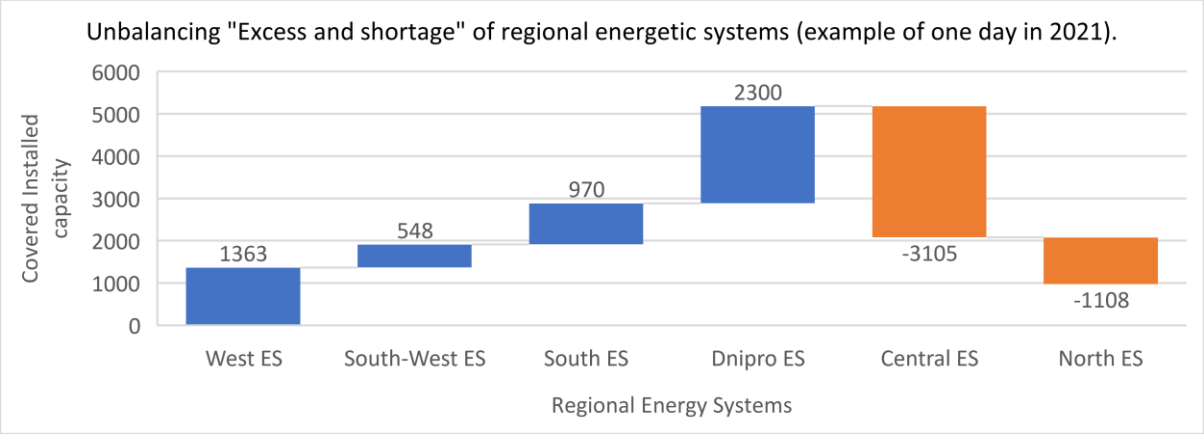
The Ukrainian power system with installed capacity 59 018 MW with electricity production 156 000 GWh per year, was designed and built in the middle of the last century, according to the obsolete principles of centralized and direct dispatchable control. Near 50% of generation installed capacity is coal/gas power plants, but most of the power was generated by nuclear plants (55%), and coal and gas plants were used to balance the system (up to 30% of total generated power).



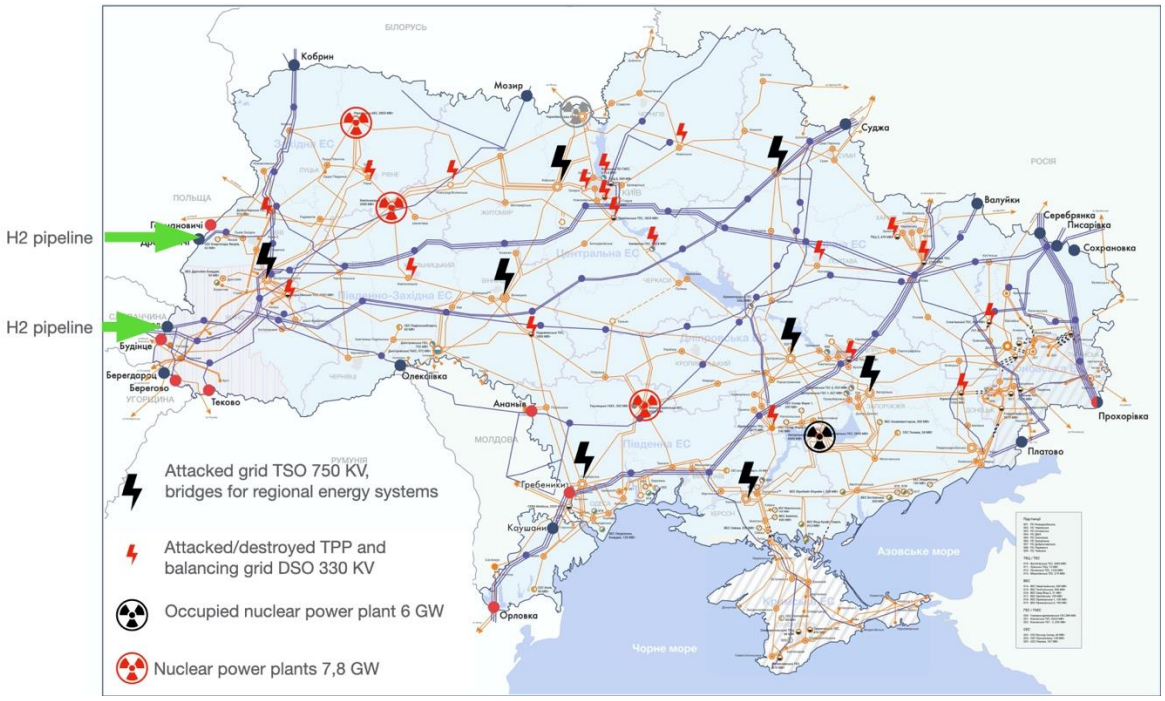
Total installed capacity of power plants of the United Energy System of Ukraine (for 2021). TPP/CHP – Thermal and Power Plants, NPP- Nuclear, RES – renewable, Hydro – big Hydro and accumulation Power Plant, PV roof – private solar roofs.

Ukrainian energy system consists of regional energy systems (energy rings-islands), which are interconnected by high-voltage transmission lines. **These regional energy systems and whole Ukrainian system is not balanced and do not have a decentralized system of energy management and energy storage.** In fact, the central regions (Kiev region was up to 3 gigawatts in deficit in generation) and eastern regions were taking electricity from the surplus southern and western regions. Moving a huge amount of electricity through the old grid, with a technological loss of up to 15 %, from the southern regions.

Also, these regional systems were not balanced among themselves and very often were overwhelmed by centralized energy flows. The introduction of private decentralizations energy generation, such as solar roofs of private homes, developed mainly in the western region of Ukraine, where is excess of electricity generation. **Consumption in the central, northern, and eastern regions of Ukraine depended mainly on centralized energy supply.**

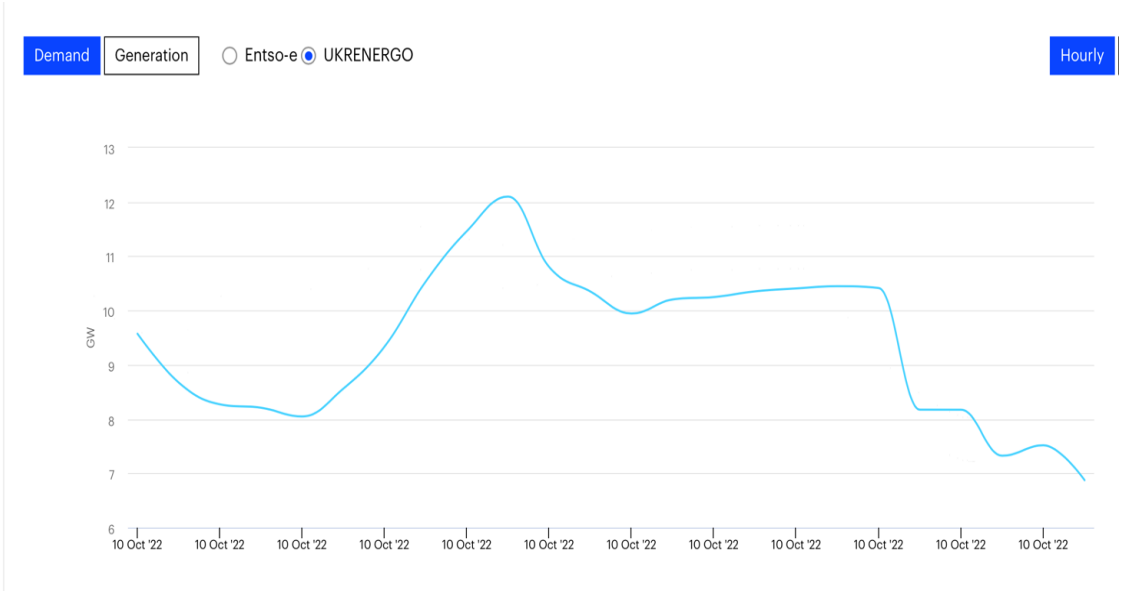


The centralized principle and the lack of regional (decentralization) energy potential have become the main target for energy attacks. By destroying the main transmission lines and high-voltage transformer substations, the aggressor has been forcing millions of Ukrainians to sit without electricity and heat for more than a month.



Power transmission system and main gas transmission (blue lines), points of main rocket strikes

The impact of attacks on the energy system, leads to an inability to balance consumption, to the impossibility of transmitting electricity through the grid between energy regions and leads to emergency shutdowns of nuclear power plants. Needs balancing and storage systems around 5 gigawatts installed capacity. For example, in the Kiev region, power is cut off for 12 – 14 hours a day, and the Lviv region is only 30% supplied with electricity



Daily unbalance of the Ukrainian energy system caused by attacks on the energy system (October 10, 2022) GW.

In Ukraine, there is no interactive online map displaying real data on damages and exploitation of energy aid from international partners. Also have no real-time exchange of operational data between cities and different levels (TSO and DSO).

With support Swiss National Science Foundation SNSF, ETH zurich provides funding to researchers from Ukraine: Grants for "Scientists at Risk». Thanks to this, there is now a research project in ETH Zurich "Rebuilding infrastructure in post-war Ukraine: policy options for a low-carbon and resilient electricity system». With implementation new mapping technology. Which gives an understanding of the behavior of the energy system in shock situations and the need to apply the experience of Switzerland in reforming the clean energy security of Ukraine and Europe. The approximate generation will deficit is (compared to 2021) 10 gigawatts of generating capacity and 4 gigawatts of balancing capacity.

Considering the above, for the gradual transformation of the Ukrainian energy system we recommend.

Combine renewable energy sources, nuclear power plants with hydrogen production and storage systems. Converting surplus electricity to hydrogen would prevent nuclear accidents, and provide a backup source of hydrogen-to-electricity energy. This cover regional supply and demand, this would create a new system of energy security.

The hydrogen produced will be the basis for the development of inter-industry ecological decentralized infrastructure. (electric power, steel production, municipal and freight transport, heat production and private power supply up to 150 kW). This experience is already being tested in Europe.