Smart grids, same dumb trust?

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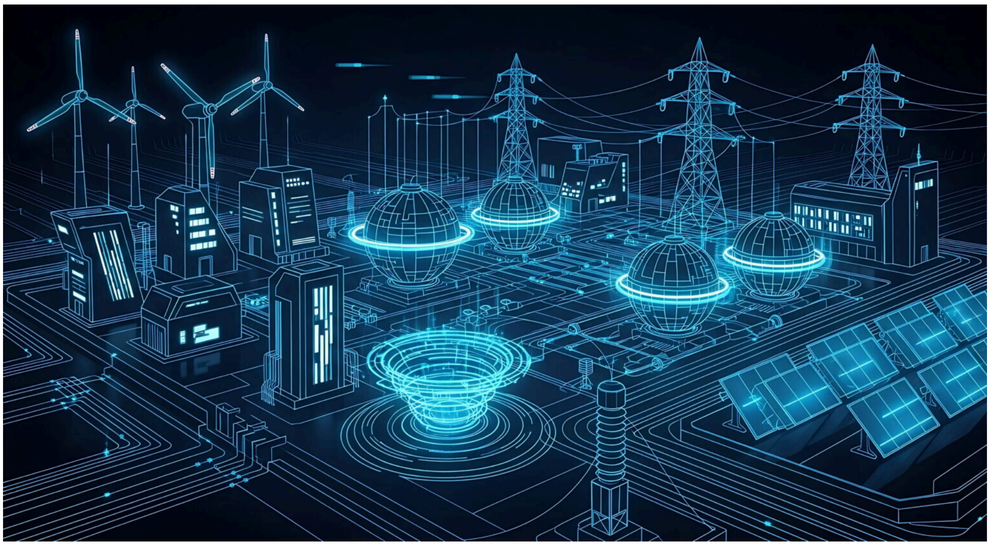
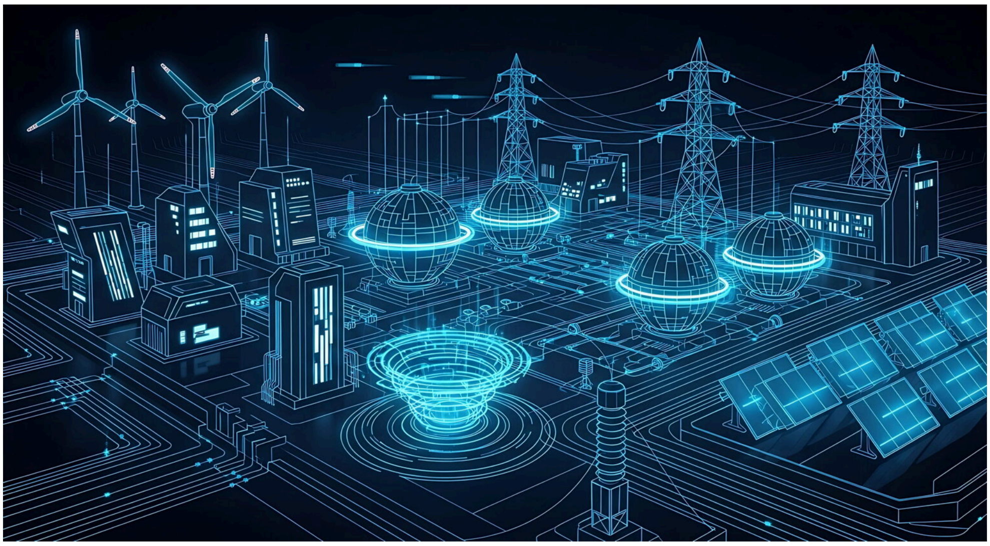


Smart energy system



The strategic importance of energy is clear – power is required for critical sectors such as transportation, manufacturing, agriculture, and healthcare. Even a temporary failure in the energy system can have devastating outcomes. Take the Texas power crisis as an example: infrastructure lacked winter flexibility, which led to power outages, leaving millions of households and businesses without heat and electricity. With hundreds of people losing their lives, the consequences of the incident are comparable to those of a moderate natural disaster.

Naturally, energy security is a high priority within European politics. To limit dependence on Russian fuels and achieve decarbonisation targets, the EU introduced the "REPowerEU" initiative. To date, the results have been largely positive: member states have substantially reduced consumption of Russian oil, gas, and coal. Simultaneously, power generation from renewable sources has expanded dramatically.

Despite its many merits, the energy transformation also introduces a new set of increasingly complex and interconnected issues. And, as always, the path to independence is lined with emerging risks and significant political challenges.

Variable generation – when producers have to pay

The introduction of renewables, particularly wind and solar, has created significant challenges for energy systems. Power generation from these sources depends heavily on the time of day and weather conditions – indeed, solar panels generate most power on sunny days, whereas wind turbines are effective primarily during winter months. In summary, unequal production leads to unequal supply. As a result, the system must continuously adjust to balance energy surpluses and deficiencies.

To avoid power outages when production is lacking, the shortage should be compensated on demand, e.g., through fast-response backup generation, or by importing the necessary amount from reserves and neighbouring grids. When energy production exceeds demand, however, energy prices fall below zero, forcing producers to pay grid operators and large consumers to utilise or store the excess energy.

Although negative energy prices are merely a natural consequence of the free-market dynamics – cost being determined by the supply-demand balance – they reveal a systemic challenge within the energy system – its inability to predict potential fluctuations and adjust accordingly. As the share of renewables in the European energy mix continues to rise, so will unpredictability around power generation. Therefore, energy transition demands a smart, flexible solution.

Grid resilience – a common sense response

The stability of a system is deeply intertwined with its resilience. Resilience – the capacity to accommodate rapid changes – rests on the three pillars: interconnectedness, tech-powered adaptability, and storage robustness.

Interconnectedness is self-explanatory: large grids connect more districts, power plants and storage facilities – thus having a higher chance of balancing the unequal power provisions.

Adaptability requires the application of corresponding technologies, which are able to predict fluctuations in power generation, learn from existing consumption patterns, and steer the energy production and redistribution in the right direction.

Finally, secure storage is a vital element of any resilient energy system. The core principle is simple – saving excess electricity produced during peak hours and thus creating a safety net in case production becomes insufficient.

However, building and operating a reliable grid is impossible without numerous critical materials, technologies and components. In many cases, European nations still heavily rely on exports to cower the demand. Although legislative efforts are made to diversify the supply and increase domestic production (Critical Raw Materials Act), the scaling of environmental technologies has the potential to create new vulnerabilities.

Data is everything

Grid stability goes hand-in-hand with digitalisation, as technology is required to make accurate forecasts and guide production in an "intelligent" way. At the core of it are smart metering devices, which collect consumption data in real time and thus allow suppliers to plan accordingly – delivering only where and when it is needed.

A smart meter cannot operate without semiconductors. In the segment, several steps have been taken to encourage European production – including passing the European Chips Act and grounding ESMC joint venture. Furthermore, European companies such as ASML, Infineon do have a relatively strong position on a market. Nevertheless, dependence on global supply chains remains high – with TSMC (Taiwan) and NVIDIA (USA) remaining the leading manufacturers of semiconductors.

Given the current state of cross-strait relations, with China maintaining regular military activities around Taiwan, the likelihood of conflict escalation is on the rise. The persistent uncertainty surrounding the situation already impacts the supply chain, resulting in higher insurance premiums and shipping costs, as well as fuelling the cycle of export control measures between Beijing and Washington.

In a potential maritime blockade scenario, export disruptions are bound to severely impact various spheres, including telecommunications, AI and data centres, security and defence, and, last but not least, energy and mobility. In conclusion, while efficient, data-driven energy systems are vital for reducing energy dependencies, the pursuit of rapid "smartification" does bear risks of its own.

No storage – no security

Energy reserves provide a critical buffer when conventional production or supply is disrupted. However, the development of battery storage facilities requires a number of critical raw materials, particularly **lithium**, **nickel**, and **cobalt**. Although the continent is increasing its mining and manufacturing volumes, the processing capacities – converting the mined materials into high-purity chemical components – remain largely outsourced.

For instance, the EU extracts a fraction of its lithium "domestically" – primarily in Spain, Portugal, Germany and Finland; however, the mined concentrates are still exported for processing purposes. Hence, value creation, pricing power, and operational control remain outside European borders.

The leading market for chemical conversion is China, primarily through giants such as Ganfeng Lithium and Tianqi Lithium. Moreover, apart from processing, Beijing also dominates lithium and cobalt refining, as well as cathode and anode manufacturing.

In the case of nickel, domestic production is also insufficient. Around 400,000 tonnes annually enter Europe from abroad – primarily in the form of nickel sulphate, battery-grade intermediates, and Class 1 nickel. A significant share of these volumes originates from Indonesian mines and Asian refineries.

Likewise, cobalt dependency is evident across multiple stages of the value chain, with mining concentrated in Africa, above all DRC, and processing located primarily in Asia.

Such reliance on exports, coupled with the widespread use of long-term offtake agreements and the dependence on external pricing benchmarks, does put a European consumer at a disadvantage. Given how crucial energy storage is for national security, geopolitical turbulences bear significant risks already at the rollout stage.

Bigger grids, lower risks

Finally, connecting new districts, renewable power generation sources, virtual power plants and storage facilities is impossible without the expansion and modernisation of the current electricity network. Expansion does not only entail the increase of the physical grid, but the installation of new transformers, solar inverters and other equipment. The urgency of such measures is widely recognised and demonstrated by the emergence of the EU's Grid Action Plan, which aims to double cross-border transmission capacity. Europe is also a leading investor in domestic power transmission.

First and foremost, similar to the build-up of storage centres, the physical grid expansion requires large quantities of raw materials, primarily copper and aluminium. Copper imports especially highlight the scope of European dependency: the continent demands around 4 million tonnes yearly, whereas only around 1 million is mined domestically. Despite the relatively strong refining capacity of 1.2 – 1.5 million tonnes, as well as rapid growth and modernisation of the recycling infrastructure, the system demands a large-scale, continuous supply from external sources, with the demand covered primarily by Latin American countries. Although the domestic aluminium value chain exhibits a higher level of completion, Europe continues to rely on imports of 8 – 12 million tonnes of alumina and aluminium products each year.

Beyond raw materials, grid expansion requires power transformers – devices used to convert voltage levels and thus connect different segments of the power system. Although Italy leads European sales, China dominates the global transformer trade.

Furthermore, the demand for HDVC equipment is rising, given the rapid expansion of European offshore wind projects.

The good news for Europe is that a big chunk of the energy transition technology is produced internally – primarily due to the operation of giants such as Hitachi Energy and Siemens. Nonetheless, some crucial components are still highly sourced "from the outside". And, given the complexity of modern energy systems and interconnectedness of global supply chains, complete self-sufficiency may never be possible.

Conclusion – no "safe" approach

Despite the many merits of flexible energy systems, the path toward greater energy independence will create new vulnerabilities. The key to a successful energy transition requires companies to continuously explore supply security measures – such as acquiring equity stakes in key producers, forming strategic partnerships, and entering joint ventures across critical segments of the value chain. Additionally, further build-up of recycling capacities will result in more efficient, sustainable material use.

After all, there is no risk-free solution to a complex problem of adapting the energy system to meet the demands of the future. Still, the persistent will of European policymakers to diversify supply and secure critical materials already steers the process in the right direction.

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