ISSN: 2634 - 8845

Journal of Earth and Environmental Science Research

Review Article

Open Access

Driving the Energy Transition in The Face of Grid Congestion

Heleen Groenenberg

Independent Advisor Energy System, Sustain Brain, Wegenbouw 57, 3991 NH Houten, The Netherlands

ABSTRACT

Grid congestion has emerged as a significant barrier to the energy transition, particularly in the Netherlands where renewables are expected to provide 66-80% of power supply by 2030. This article examines how local energy systems can help address grid congestion through three key components: electric vehicles, industrial demand-side flexibility, and energy storage. While vehicle-to-grid technology offers long-term potential, immediate benefits can be achieved through grid-conscious charging practices. Industrial facilities can provide flexibility through electric boilers and thermal storage, while business parks are increasingly forming energy hubs for collective energy management. Both short-duration batteries and long-duration storage solutions play vital roles in system flexibility. The article concludes that stronger incentives for grid-friendly behavior, supportive frameworks for local energy systems, and increased public awareness are essential for successfully managing grid congestion while advancing the energy transition.

***Corresponding author**

Heleen Groenenberg, Independent Advisor Energy System, Sustain Brain, Wegenbouw 57, 3991 NH Houten, The Netherlands.

Received: January 03, 2025; **Accepted:** January 07, 2025; **Published:** January 20, 2025

Background

More renewables and demand volatility constrain grids

The shift towards renewable energy impacts our energy landscape. Renewable energy capacity is expanding at an extraordinary rate. By 2030, global renewable capacity will have increased by 5,500 GW, surpassing the combined power capacity of China, the EU, India, and the US. Half of the world's electricity demand is projected to be met by renewables by 2030, with China and India leading this growth.

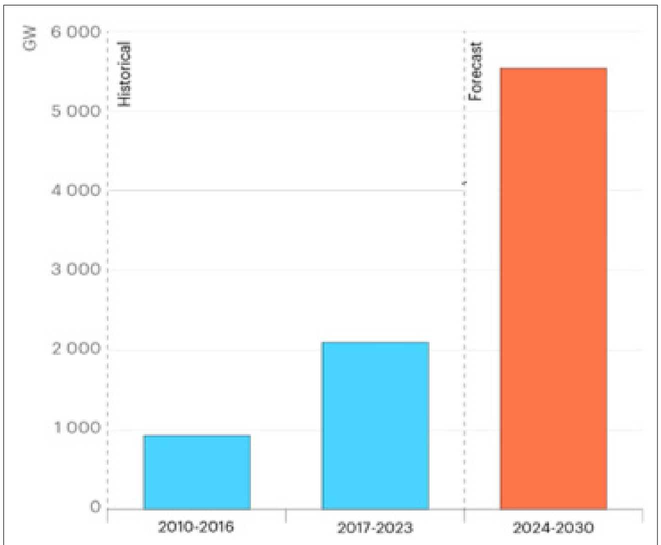

Figure 1: Projected Additions to Global Renewable Energy Capacity, Based on IEA WEO 2024 [1].

In the Netherlands, sustainable sources must account for nearly all energy supply. Wind and solar energy are fundamental solutions, and this will likely put immense pressure on grid infrastructure. Also, electricity demand contributes to these constraints. While electricity demand in The Netherlands has stabilized and even declined in recent years, patterns for electricity demand have become a lot more erratic. Various factors have contributed to this. For a start, increasing renewable energy production and electrification of demand (EVs, heat pumps, e-boilers etc) have led to sharper and more frequent supply and demand peaks. Next to this, high voltage grids transport increasingly volatile (international) loads, which hampers loads from lower grids to feed in. These trends are aggravated as grid operators put increasing restrictions on transportation, and market players apply for more transport capacity then they will actually need. Also, batteries deployed at balancing markets can contribute to congestion.

In the Netherlands grid congestion has become a common concern, arising when electricity supply and demand exceed grid capacity to transmit power. This issue hampers the energy transition and delays critical industrial and residential projects. In the Netherlands alone, the economic cost of congestion has been estimated at 10 to 40 billion euros, encompassing delays in grid connections, missed opportunities for renewable energy utilization, and operational inefficiencies in electricity-intensive industries [2,3]. Despite efforts to expand and strengthen grid infrastructure, grid congestion is likely to persist. It may be an important hurdle for electrification in Europe until 2030 and beyond [4]. Between 2023 and 2030 grid congestion contributes to 40 percent of anticipated 460 TWh increase in electricity demand that may not materialize.

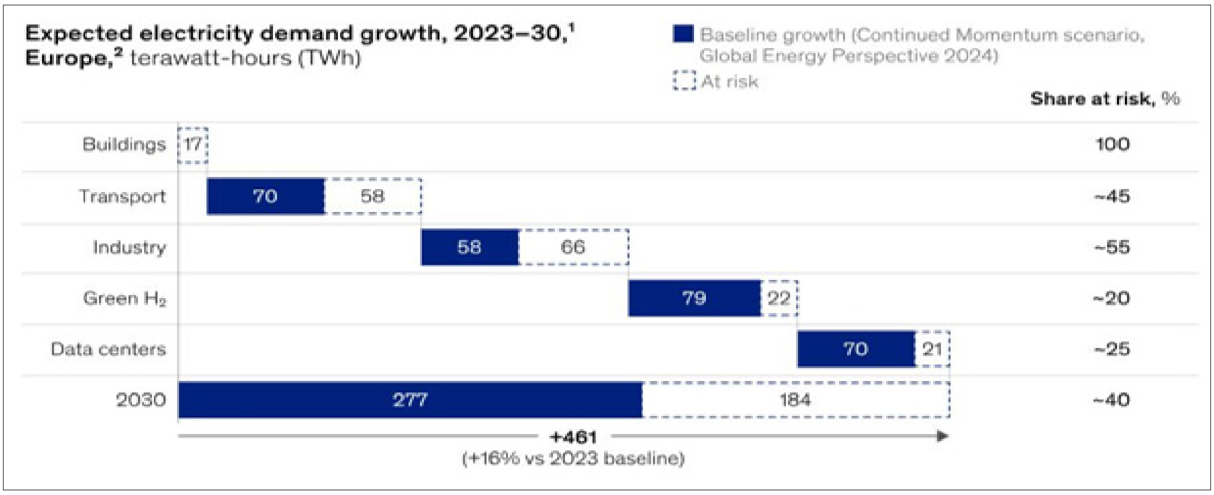

Figure 2: Modelled Electricity Demand Growth (TWh) in Europe 2023-2030 in Baseline and Extended ("at risk") Scenarios Source: McKinsey, 2024 [4].

Rethinking energy systems
As a critical response to congestion grids are being reinforced to accommodate higher and increasingly volatile loads. Yet to what extent this will prepare the system for a fully carbon-free system by 2045 and beyond is not certain. As a result, a profound rethinking of how we generate, store, and use energy is justified. Today, electricity is set to become the dominant energy carrier in future energy systems, but other sustainable energy carriers will also play a vital role in achieving a balanced, resilient, and low-carbon energy landscape.

Sustainable heat solutions offer significant potential for decarbonizing energy systems, sourcing from geothermal, solar, residual or ambient heat, and using heat pumps, heat networks and thermal storage. Collective heat pumps, such as the one in Utrecht that recovers heat from sewage water to supply 20,000 households, exemplify the innovative use of existing resources [5]. Scaling up such initiatives requires financial incentives and supportive policies to encourage widespread adoption.

Biogas and biomethane are particularly valuable as they can integrate seamlessly into existing gas infrastructure. In 2023, the use of biogas in The Netherlands amounted to 8,3 PJ [6]. This equals 12% of national target to deploy 2 bcm by 2030, underscoring the need for accelerated progress. Expanding biogas use can help reduce reliance on fossil fuels while making good use of established gas networks.

Hydrogen has been attributed an important role in the future energy mix, yet two key insights are reshaping its role in the energy transition. Supply of green hydrogen will be scarce, and consequently should be prioritized for sectors without viable alternatives, such as energy-intensive industries and shipping. Next to this, producing green hydrogen locally at competitive costs remains challenging, even with cost reductions in offshore wind. Importing hydrogen or its derivatives (e.g., ammonia) may become a more viable solution in some regions. So, while hydrogen's potential as a versatile carrier for hard-to-electrify sectors is undeniable, its role in the future energy mix remains a work in progress.

Work on all these energy carriers is underway, and while final answers are pending a reevaluation of electricity systems is essential. Currently, electricity grids are designed for zero failure, prioritizing reliability above all else. However, this conservative approach comes at a significant cost, often delaying the connection of new users to the grid. The cost of occasional disruptions could be weighed more often against the economic losses for businesses.

Next to this revision of risk appetite for grids very strong incentives are needed to induce grid-friendly behavior by both producers and consumers. Advanced energy management and local energy systems can advance such behavior, supported by dynamic supply contracts, well-designed transport agreements and grid tariffs for large and small users, as well as regulations and grid code for congestion management. Thus, rather than being showstopper for the energy transition, grid congestion may be turned into a catalyst for change, unlocking potentials for on-site renewable generation, energy storage and demand side response.

Features of local energy systems
Local energy systems may help reduce grid loads and align electricity supply with demand. These systems offer decentralized approaches to manage electricity generation, storage, and consumption, contributing to a more flexible and resilient energy network. Three aspects are key in this respect:
Avoiding Demand and Supply Peaks: One essential feature of local energy systems is minimizing peaks in electricity demand and supply, which alleviates pressure on the grid. Market signals may help to an extent achieving this balance. Evidence suggests that large-scale solar and wind farms reduce output in response to negative prices in day-ahead markets. Similarly, households with dynamic electricity contracts often decrease consumption during periods of negative pricing, demonstrating the potential of price-responsive behavior in flattening demand curves [7]. Next to this, a deliberate approach to source electricity locally can contribute significantly to reduced peaks.

Aligning Timing and Location: Achieving concurrency between electricity production and consumption is vital for optimizing local energy systems. This involves shifting energy use to periods of high renewable generation, such as charging electric vehicles during sunny hours or windy conditions. Energy storage technologies further enable this alignment by storing surplus power for later use. Additionally, proximity between supply and demand is critical. Minimizing the distance that electricity travels reduces transmission losses and enhances overall system efficiency.

Behind-the-meter solutions

Various measures can optimize energy use both behind the meter (from a grid operator perspective). Batteries or other energy storage options offer valuable mechanisms for managing excess supply and aligning demand. Solutions like electric boilers or heat pumps convert surplus electricity into thermal energy, which can be stored and utilized when needed. Furthermore, curtailment of solar generation during periods of excessive production prevents grid overload. And even modest improvements in energy efficiency, such as a 10% reduction in energy consumption through better processes, can significantly lower grid loads. Energy management systems (EMS) further enhance these strategies by maximizing self-sufficiency and enabling users to trade surplus energy or provide balancing services to grid operators.

Local energy systems are typically controlled by energy management systems steering the deployment of assets for generation, storage and use. These assets may be considered building blocks of local systems and they are the focus of the remainder of this article. Specifically, this article will address the role of electric vehicles, the role of industrial demand side flexibility, and the role of energy storage.

The role of electric vehicles

Vehicle-to-grid technology

Electric vehicles (EVs) are an important building block in local energy systems. They represent an untapped reservoir of energy storage, with the potential to transform grid management and enhance energy system resilience. To illustrate, an average household requires approximately 10 kWh of electricity daily, or 70 kWh weekly—a figure that closely matches the energy capacity of a standard EV battery. The prospect of streets lined with EVs capable of bidirectional energy flow is extraordinary. Harnessing this resource efficiently could revolutionize energy systems, in spite of frequently mentioned concerns.

Integrating V2G capabilities into EVs does not need to prohibitively expensive. The necessary technological upgrades may add only a few hundred euros per vehicle, making it a financially accessible solution for both manufacturers and consumers. Another concern regarding V2G adoption is the potential degradation of EV batteries. However, the discharging process in V2G systems operates at significantly lower rates compared to the demands of high-speed driving on highways. As a result, the impact on battery lifespan is minimal, ensuring that V2G participation does not compromise vehicle performance [8].

A factor critical to the success of V2G is the availability of standardized bidirectional charging stations. While such systems are already operational in centralized markets like South-Korea, adoption in decentralized regions with multiple market players—such as Europe—requires well-defined standards to ensure compatibility across technologies and providers. Initial implementation of standardized charging stations is projected to take approximately three years, underscoring the need for coordinated efforts among policymakers, technology developers, and market stakeholders [8].

Grid conscious charging practices

While V2G technology offers long-term potential, significant progress can already be achieved through grid-conscious charging practices. Shifting EV charging to off-peak hours, guided by time-differentiated electricity tariffs, can alleviate strain on the grid. For example, a pilot program in Utrecht demonstrated that introducing dynamic pricing reduced peak EV charging demand during early evening hours by 15% [9]. Though seemingly modest, such reductions have a meaningful impact on overloaded grids. Still, despite its benefits, grid-conscious charging remains rare. Several barriers hinder its widespread adoption.

First of all, financial incentives are lacking. For most consumers, energy costs remain fixed, encompassing electricity prices, grid charges, and taxes. Moreover, lease vehicles—which dominate the EV market with a 90% share—typically feature all-inclusive pricing models, further reducing the appeal of dynamic pricing contracts. The introduction of flexible, dynamic supply contracts could make grid-conscious charging more attractive. Also offers for apps or contracts tailored to promote off-peak charging could be helpful. Addressing this gap requires collaborative efforts between energy providers, app developers, and policymakers to deliver solutions that are intuitive and financially appealing.

Early markets are another hurdle for grid-conscious charging. These markets are currently driven by early adopters and risk-takers who invest in a limited number of charging stations. These pioneers face unforeseen challenges and often prioritize quick returns on investment, leaving the broader benefits of grid efficiency unexplored. Finally, and perhaps most importantly, public perception of the need for grid-conscious charging is minimal, largely because grid failures remain rare. Although certainly undesirable, neighborhood-level blackouts would help accelerate the adoption of smart charging solutions, driven by increased awareness and urgency.

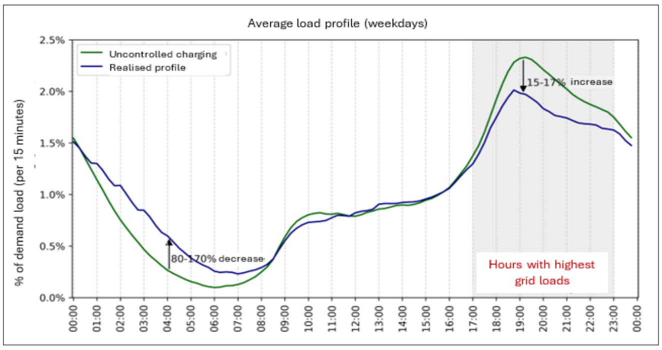

Figure 3: In the Dutch FLEET-Experiment Loads without Steering (green line) Shifted to a Later Timeslot (blue line). Peak Loads were Reduced by 15-17% [8].

Overall, grid-conscious charging holds an immense potential for enhancing grid flexibility and reducing congestion. While V2G adoption depends on addressing cost, battery quality, and infrastructure standardization, grid-conscious charging offers an immediate opportunity to optimize electricity demand patterns.

The role of industrial demand side flexibility

Demand side response by individual companies

Industrial flexibility represents a critical yet underutilized tool for addressing grid congestion and enhancing energy system resilience. By shifting electricity demand away from peak hours and adopting collaborative energy management strategies, industries can in principle play a transformative role in balancing supply and demand. So far, the potential of industrial demand-side response has been untapped, although frontrunners are already demonstrating innovative approaches to flexibility by adjusting their electricity consumption to align with off-peak hours.

Several companies have installed electric boilers to enable demand-side response and participate in balancing markets including aFRR (automatic Frequency Restoration Reserve) and mFRRda (manual Frequency Restoration Reserve with Direct Activation). Examples include a potato processing plant and a paper factory utilizing electric boilers, and an energy service company at a large industrial site employing similar technologies [10-12]. Also, some electricity-intensive processes may be ramped up or down easily to meet system needs. For instance, a large chemical plant operates it chlorine production facilities flexibly to counter imbalances in the grid. A manufacturer of trains, trucks, and buses leverages flexible industrial salt baths to reduce electricity consumption during peak hours [13,14].

Thermal storage may particularly helpful to advance demand side flexibility in industry, and the market for thermal storage solutions now includes a host of suppliers [15

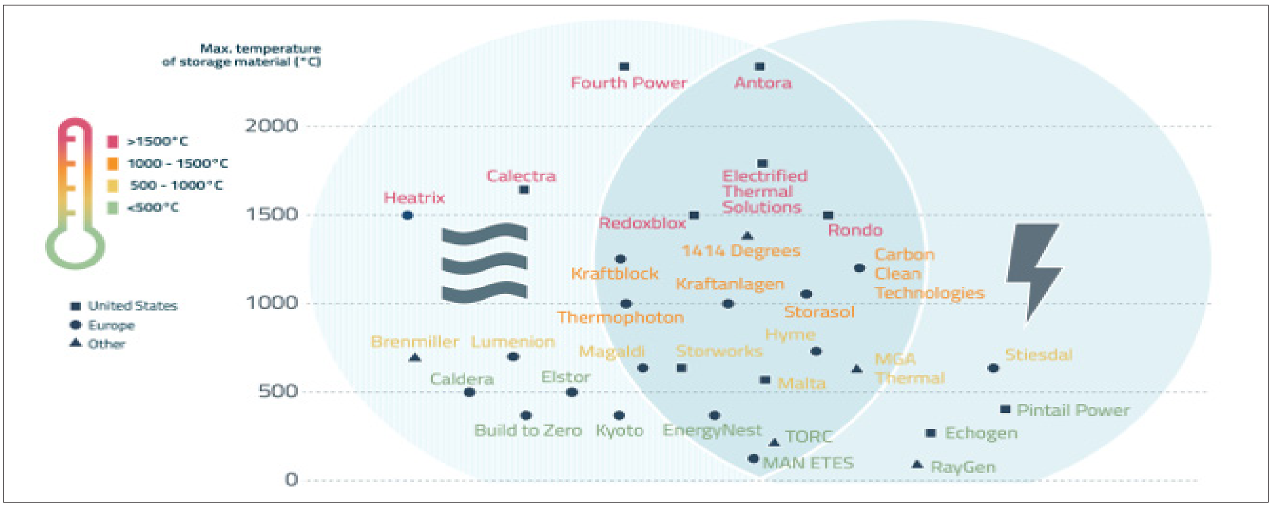

Figure 4: Thermal Storage Companies (non-exhaustive), Ranked by Temperature, Target Application (heat and/or power) [14].

While these efforts illustrate the potential of industrial flexibility to mitigate grid congestion far greater adoption is necessary to fully realize this potential. This holds particularly in heavily congested regions where industrial capacity limits are currently mandated and financially compensated. Despite promising examples, the industrial sector's contribution to demand-side response remains limited. Stronger incentives are essential to unlock the full potential of industrial flexibility.

Energy hubs at business parks

While interest for industrial demand side response in individual companies is modest, enthusiasm for collective energy management solutions is on the rise. Business parks and industrial sites are increasingly adopting collaborative energy management strategies, optimizing shared energy resources to reduce reliance on the grid. These "energy hubs" integrate generation, storage, and demand-side management, offering a coordinated approach to energy flexibility. Key examples include energy hubs near Schiphol Airport, in the city of Utrecht, in Western Harbor Amsterdam, at the island of Tholen, and in Zwolle [16-20].

The Dutch grid code already offered an option for a group of companies to offer congestion management services jointly. Yet this option was available to incumbent grid users with fixed transportation agreements only, and did not allow for new or larger connections. Therefore, a so-called group transportation agreement has been developed in the Netherlands, extending the legal framework for collective energy management. Under a group transportation agreement individual transport rights are pooled and forfeited after a three-year trial period, providing faster access to sufficient electricity for companies awaiting grid connections. For grid operators these agreements are attractive since they allow operators to better manage growing electricity demand within existing contractual frameworks. As a result, this model has gained significant traction, with over 100 business parks in the Netherlands expressing interest in exploring energy hubs, and dozens actively pursuing implementation.

Overall, industrial demand-side response and collaborative energy management present enormous opportunities for mitigating grid congestion and enhancing energy resilience. While some industries and business parks are pioneering flexible practices, broader adoption requires stronger financial and regulatory incentives.

The role of energy storage

Battery storage systems

Battery storage is emerging as a critical tool for improving grid efficiency and supporting the energy transition. With declining costs and increasing deployment, batteries are providing large energy users and producers with new opportunities to manage demand, reduce costs, and enhance system flexibility.

Over the past decade the cost of lithium-ion (Li-ion) batteries has decreased dramatically, driven by developments in the electric vehicle (EV) industry. This price decline is attributable to efficiencies in sourcing and manufacturing that have reduced production expenses, and to scaled-up manufacturing facilities. At the same time, demand for batteries has occasionally fallen short of industry expectations, further reducing costs [21]. As a result, global battery production volumes have surged by a factor of four since 2020. Today, there are over 40 million EVs worldwide, accompanied by thousands of stationary batteries supporting grid functions. The widespread deployment of batteries highlights their transformative potential in energy systems.

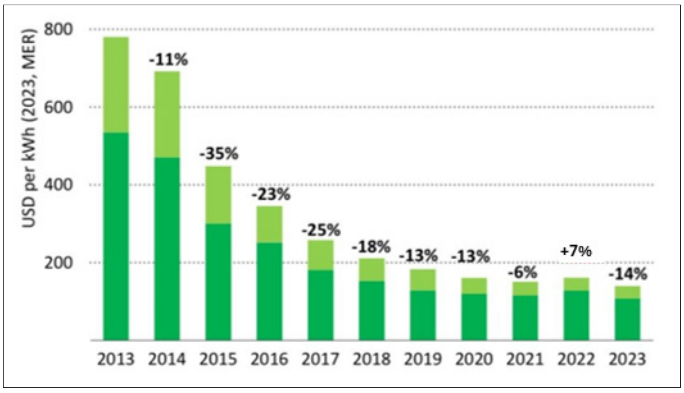

Figure 5: Market Prices Lithium ion Battery Cells (dark) and Packs (light green) 2013-2013. Source: BNEF, 2024 [20].

Battery storage has already proven its value in diverse settings. While batteries offer significant benefits, certain misconceptions about their role in grid management persist. A general misunderstanding is that "grid operators need batteries". This statement is inaccurate. Grid operators require first and foremost flexibility, which can be achieved through various means, including curtailment and demand-response programs. Batteries are just one of many potential solutions. Still, it might be very practical if grid operators would be allowed to operate batteries themselves to address grid congestion. Another misconception is that "all excess renewable energy must be stored". It is neither practical nor necessary to store all surplus wind or solar energy. In many cases, curtailment is a more cost-effective option for relieving grid pressure.

Exactly how effective battery storage systems are in countering grid congestion will depend on how they are utilized. Applications behind the meter can only impact the grid positively. Batteries may enable households and businesses to achieve greater energy independence, provide backup power during outages, and avoid costs associated with feeding electricity back into the grid. However, batteries may also play a critical role in managing imbalances between supply and demand, especially in balancing markets where prices fluctuate more significantly than in day-ahead markets. This can make batteries a profitable investment. However, if multiple batteries in a region respond simultaneously to the same price signals, they can inadvertently exacerbate congestion. To prevent this, grid operators enforce conditions such as capacity restrictions or time-limited contracts in transportation agreements with parties operating stationary batteries.

Besides grid congestion, another negative impact from batteries deployed in balancing markets became clear in the fall of 2024 in The Netherlands. Batteries tended to respond too quickly to imbalance price signals, resulting in large and fast fluctuations and negatively impacting grid frequency. In particular, this increased instances with both a surplus and a shortage within a 15minute timeframe causing a situation with reversed pricing. The transmission system operator had already called balancing responsible parties and market players to reduce ramp rates, but to no avail. It therefore decided to publish information on balancing needs and prices with another two minutes delay (i.e. after five instead of three minutes), effectively reducing system information for market participants. Clearly, this is hardly a robust approach. In an increasingly decentralized energy system market players will need more rather than less information to tune their behaviors to system needs.

All in all, battery storage is a powerful tool for addressing short-term fluctuations and enhancing grid flexibility, complementing other flexibility solutions like demand-response and curtailment. As costs continue to decline and adoption increases, batteries will play an increasingly important role in modernizing energy systems and supporting the energy transition.

Long duration energy storage

Long-duration energy storage (LDES) solutions differ markedly from lithium-ion batteries. These solutions serve merely to boost energy independence and security and are increasingly recognized as critical components of the future energy system, addressing challenges related to the variability of renewable energy sources. There is an emerging consensus that LDES systems typically can discharge at their rated power for 10 hours or more [22].

Figure 7 presents an overview of both long and short duration storage solutions [23]. Solutions range from household-scale systems to citywide or industrial storage facilities. Depending on the technology, discharge durations vary from quick, hourly responses to long-term reserves lasting several months. Although lon duration options are often referred to as "seasonal storage," storing energy for months is not always necessary. For most energy systems, the ability to store energy for days or weeks is sufficient to balance supply and demand, even during winter. Combining different types of storage technologies increases the flexibility and resilience of the energy system. For instance, hybrid setups may integrate short-duration lithium-ion batteries with long-duration flow or thermal storage to optimize performance across varying energy demands.

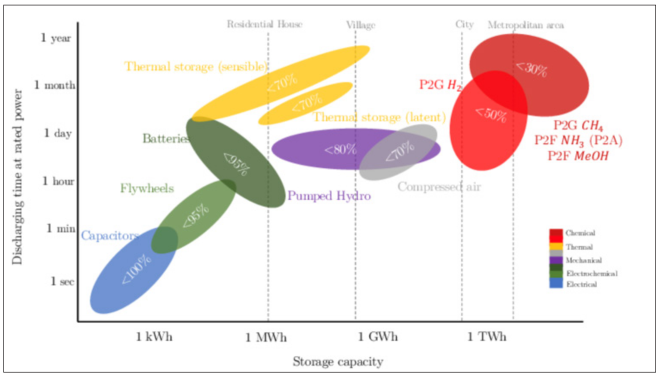

Figure 7: Characterization of the main energy storage systems (ESS) by storage capacity and discharging time at rated power (i.e. maximum output power). The percentages refer to energy efficiency [23].

A combination of storage solutions is key to create a flexible and robust energy system. Among long duration storage solutions, flow batteries stand out due to their unique design, scalability, and safety features, making them particularly suitable for industrial applications and renewable energy storage. In flow batteries the electrolyte solution in the storage tanks is separated from the electrochemical process, characterized by the size and number of electrochemical cells (stacks). As a result, battery capacity (kWh) and power (kW) can be scaled independently. This modular design enables customization for specific applications, from high-capacity storage to high-power output. Next to this, flow batteries exhibit a long lifecycle with minimal degradation, enabling them to offset higher capital expenditures (CAPEX) over time. Unlike lithium-ion batteries, flow batteries do not pose significant fire risks, allowing them to be installed in close proximity to buildings or other batteries.

Long-duration energy storage is essential for enabling the transition to a renewable energy future. The diversification of storage technologies, tailored to different timescales and applications, strengthens the reliability and flexibility of energy systems, ensuring consistent energy supply in a world increasingly powered by renewables.

Conclusion

Renewable energy integration and increasing demand volatility are creating significant strain on grid infrastructures, with The Netherlands as a marked example. This is a critical issue hampering the energy transition, with significant consequences for local economies and the energy transition. Despite grid reinforcement efforts, congestion may well remain a challenge for the energy system beyond 2030. Therefore, a comprehensive rethinking of energy systems is necessary, including the role of various sustainable energy carriers (e.g., heat, biogas, hydrogen) and a shift in perspective on effective grid management. This includes adopting a more risk-tolerant approach to grid design and promoting grid-friendly behaviors.

Stronger incentives are required to induce users of the grid to reduce loads during peak hours. While investments in grid reinforcement are important to address congestion challenges, a more widespread adoption of dynamic electricity pricing, also for smaller users will help promote off-peak energy use and for instance advance grid-conscious charging practices. Time-differentiated grid tariffs can play a modest role reinforcing this price signal. Next to this, real-time insight for market participants in system needs is vital to enable support to system operations. Robust frameworks are required to help prevent adverse effects of flexible solutions, such as overreaction to price signals.

Local energy systems may well support centralized grids by reducing demand and supply peaks, by aligning both timing and location of supply and demand, and advancing solutions behind the meter Local systems may help unlock flexibility potentials from which central grids eventually will benefit too. Pivotal solutions include Vehicle-to-grid (V2G), grid-conscious charging, industrial demand-side flexibility, energy hubs, batteries and long duration energy storage important building blocks for such systems. These assets are key for reducing grid congestion and improving system resilience, and their use may be supported and optimized by energy management systems.

Initiatives to explore opportunities for local energy systems, notably energy hubs at business parks, must be facilitated in various ways. Energy is a basic utility; in situations where markets fall short, public initiatives or support must step in to ensure a functioning energy system. Support to the development of local systems may include financial means (for assessments and design of collective systems), and accommodation of spatial claims to realize new assets for generation and storage. Next to this, data transparency (e.g. for user data or grid topology) is vital to correctly assess and design energy hubs. In the Netherlands, the new Energy Law, adopted by the end of 2024, presents a legal framework to facilitate data exchange while warranting privacy for end users.

The deployment of long-duration energy storage solutions represents a critical step in achieving a resilient and sustainable energy future. To expedite the adoption of these technologies, it is essential to establish clear, ambitious, and actionable long-term targets. These targets will provide the necessary framework to guide investment, innovation, and deployment efforts, aligning industry stakeholders, policymakers, and the private sector toward a shared vision for decarbonization and energy security. Financial incentives, such as subsidies and tax breaks, play a pivotal role in accelerating the deployment of these solutions by promoting market demand and encouraging private sector participation.

Developing alternative sustainable energy carriers-such as sustainable heat, biomethane, and hydrogen-requires a new and realistic perspective. This entails moving beyond theoretical feasibility to practical implementation. A systematic and holistic approach should be adopted to identify the most promising use cases, and ensure scalability. Due attention must be given to the integration of these carriers into decentralized energy systems. This will necessitate strategic planning, identification and acknowledgement of spatial claims, and the development of tailored policies to ensure that alternative carriers are effectively integrated in existing energy systems.

Public awareness and education are vital to develop the energy system of the future. Efforts are being undertaken to raise awareness of grid challenges, and highlight the benefits of flexibility solutions, but turning around grid user behaviors and inducing investment decisions in new assets is not straightforward. Deep awareness must be fostered, possibly similar to the way public understanding of the climate crisis has deepened in the last decade. Educating today's professionals and the next generation is vital to foster a widespread understanding of flexibility and its potential for citizens and companies alike. This cultural shift will enable a more informed and engaged society, capable of embracing new technologies and systems.

Acknowledgment

Apart from referenced materials this article draws on insights from energy experts, policymakers, and ongoing initiatives in the Netherlands and beyond. Their contributions are invaluable in shaping a path toward a cleaner and more efficient energy system.

References

1. [IEA] International Energy Agency. World Energy Outlook (2024). https://www.iea.org/.
2. Ecorys (2024) Maatschappelijke kostprijs van netcongestie. https://www.ecorys.com/app/uploads/2019/02/Maatschappelijke-kostprijs-van-netcongestie-2024.pdf.
3. [BCG] Boston Consulting Group (2024) Haal de kink uit de kabel – Zes interventies om de congestie op het Nederlandse elektriciteitsnet versneld te verlichten. https://www.bcg.com/publications/2024/netherlands-haal-de-kink-uit-de.
4. McKinsey (2024) Global Energy Perspective 2024. https://www.mckinsey.com/~/media/mckinsey/industries/energy%20and%20materials/our%20insights/global%20materials%20perspective%202024/global-materials-perspective-2024.pdf.
5. Eneco (2024) Heat pump sewage treatment Utrecht. https://www.eneco.nl/over-ons/wat-we-doen/duurzame-bronnen/warmte/warmtepomp-rwzi-utrecht/.
6. [CLO] Compendium voor de Leefomgeving (2024) Verbruik van hernieuwbare energie 1990-2023. https://www.clo.nl/indicatoren/nl038540-verbruik-van-hernieuwbare-energie-1990-2023#:~:text=Het%20aandeel%20hernieuwbare%20energie%20in,2023%20(CBS%2C%202024a).
7. TenneT (2023) Oral communication dhr Tijdink. Sept 2023.
8. E-laad (2024) Oral communication Frank Geerts. October 2024.

9. FLEET (2024) Slim laden met flexibele nettarieven in Utrecht. Openbare eindrapportage. https://ssc-fleet.nl/wp-content/uploads/sites/358/2024/04/FLEET-project-Openbare-eindrapportage.pdf.
10. Anonymous (2022) Respond to fluctuating energy prices with an e-boiler. https://www.industrialheatandpower.nl/nl/nieuws-item/Met-een-e-boiler-inspelen-op-de-fluctuerende-energieprijzen/.
11. Sappi (2024) Investment approved for Sappi Maastricht Mill second e-boiler. https://www.sappi.com/nl/investments-approved-for-the-sappi-mill-in-maastricht.
12. Brightlands Chemelot Campus, 202X. E-boiler mooie stap naar duurzaamheid. Interview met Sonny Schepers https://www.nobian.com/nl-nl/nieuws/vattenfall-en-nobian-dragen-met-flexibele-chloorproductie-bij-aan-stabiliteit-stroomnet
13. Nobian (2021) Vattenfall en Nobian dragen met flexibele chloorproductie bij aan stabiliteit stroomnet. https://www.nobian.com/nl-nl/nieuws/vattenfall-en-nobian-dragen-met-flexibele-chloorproductie-bij-aan-stabiliteit-stroomnet.
14. Industrielinqs (2024) Thermisch zoutbad VDL Veweler ingezet als noodvermogen elektriciteitsnet News item.
15. Future Clean Architects (2024) Decarbonizing high-temperature heat in industry. https://fcarchitects.org/wp-content/uploads/2024/10/FCA-Report-Decarbonizing-High-Temperature-Heat.pdf.
16. SADC (2024). Schiphol Trade Park Energy Hub. https://www.sadc.nl/en/locations/schiphol-trade-park-energy-hub/.
17. Stedin (2024) Eerste energiehub een feit in provincie Utrecht. https://www.stedin.net/over-stedin/pers-en-media/persberichten/eerste-energiehub-een-feit-in-provincie-utrecht#:~:text=Utrecht%2C%2025%20september%202024%20%E2%80%93%20Op,specifiek%20deze%20provincie%20nijpend%20is.
18. EIGEN (2024) The power of smart collective energy systems and innovation at ECAH. https://www.eigen-energyhubs.nl/nieuws/de-kracht-van-slimme-collectieve-energiesystemen-en-innovatie-bij-ecah/.
19. Stedin (2024) In gebruik genomen energy hub REC Tholen leidt tot meer ruimte op het elektriciteitsnet News item.
20. PVB Nederland (2024) Hessenpoort: a hub of energy flows. https://pvbnederland.nl/nieuws-item/hessenpoort-een-hub-van-energiestromen/.
21. BNEF (2024) Lithium-Ion Battery Pack Prices See Largest Drop Since 2017, Falling to $115 per Kilowatt-Hour: BloombergNEF. https://about.bnef.com/blog/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/.
22. Twitchell, Jeremy, DeSomber K, Bhatnagar D (2023) Defining long duration energy storage. Journal of Energy Storage 60: 105787.
23. Nicola Cantisani, Ritschel TKS, Thilker CA, Madsen H, Bagterp Jørgensen J (2022) Modeling, scientific computing and optimal control for renewable energy systems with storage. https://ieeexplore.ieee.org/document/10178226.