CLEAN TECH

Harnessing energy storage: A pillar for Sweden's renewable future

May 2025

Table of content

Executive summary

Sweden stands at the forefront of a global energy revolution, striving to achieve a sustainable, fossil-free future. However, this ambition comes with significant challenges, particularly in managing the growing complexity of its electricity grid. As renewable energy sources like wind and solar continue to expand, the country faces unprecedented volatility in electricity prices, with dramatic fluctuations exposing vulnerabilities in supply and demand dynamics.

Energy Storage Systems (ESS) offer a transformative piece of the puzzle to these challenges. By enabling surplus energy to be stored and dispatched when needed, ESS technologies provide the stability, flexibility, and reliability necessary to support Sweden's ambitious renewable energy goals. From large-scale Pumped Hydroelectric Storage (PHS) to advanced Thermal Energy Storage (TES), Hydrogen Storage, and cutting-edge Battery Energy Storage Systems (BESS), each technology plays a vital role in creating a resilient energy infrastructure.

This white paper delves into Sweden's evolving energy landscape, while placing it within the broader European context. It examines the drivers behind its energy challenges—including price volatility, grid intermittency, and geopolitical pressures—and the strategic opportunities that ESS present. Across Europe, ESS holds the potential to optimize renewable energy integration, stabilize the grid, and mitigate the economic and strategic risks posed by global disruptions, such as the war in Ukraine and supply chain dependencies on dominant players like China. For Sweden, in particular, these challenges are amplified by its strong focus on renewable energy and battery production, making innovation and collaboration within Europe essential. By fostering partnerships across European nations, addressing geopolitical vulnerabilities, and leveraging collective expertise, both Sweden and Europe can unlock the full potential of ESS to drive the global energy transition. Investments in these solutions will not only secure Sweden's and Europe's energy infrastructure but also position the region as a global leader in creating a sustainable and resilient energy system.

Introduction

CleanTech has become a key driver of the transition toward a sustainable world, playing a crucial role in both technological development and economic growth. The sector is attracting increasing attention from policymakers, industries, and investors, as demand for climate solutions intensifies. The CleanTech space can be categorized into eleven key verticals, seen in Figure 1, that together shape the sustainable economy. These sectors are essential for enabling the transition to a low-carbon future while improving resource efficiency and environmental sustainability.

Achieving Net Zero Emissions (NZE) by 2050 and meeting global sustainability targets, including the UN's Sustainable Development Goals (SDGs), requires substantial investments. An estimated $39 trillion USD is needed in energy generation, while energy storage alone demands at least $8.8 trillion USD in investments to support renewable integration and grid stability, see Figure 2.

The transition to renewable energy is no longer a choice but an imperative. Sweden, with its abundant hydropower resources and progressive energy policies, has emerged as a global leader in this movement. In 2023, renewable and fossil-free energy accounted for an impressive 98% of the country's electricity generation, where solar and wind made up 22%— a share that continues to grow as the country accelerates its transition to renewables. Yet, the very characteristics that make renewable energy sustainable—its reliance on natural conditions—also make it inherently intermittent and unpredictable.

Figure 1. Eleven key verticals of CleanTech

Manufacturing & Heavy Industry
Low-carbon steel, Advanced techniques, Industrial IoT & AI

Agriculture
Vertical farming, Precision farming, Biofuels & Biogas

Recycling & Waste
Waste-to-Energy, Upcycling, Waste Recycling

Transportation
EVs, Fuel Cells, Autonomous & Shared solutions, Charging

Water & Wastewater
Desalination plants, Smart Irrigation, Advanced treatment

Air & Environment
Air Quality Sensors, CCUS[1], Air Quality Control measures

Materials
Biodegradable Plastics, Biochemicals, Smart material

Energy Generation
Solar PV, Wind turbines, Hydropower, Nuclear[2]

Energy Storage
LDES[3], Batteries, Pumped Hydro, Thermal storage

Energy Infrastructure
Smart grids, Microgrids, Power grid

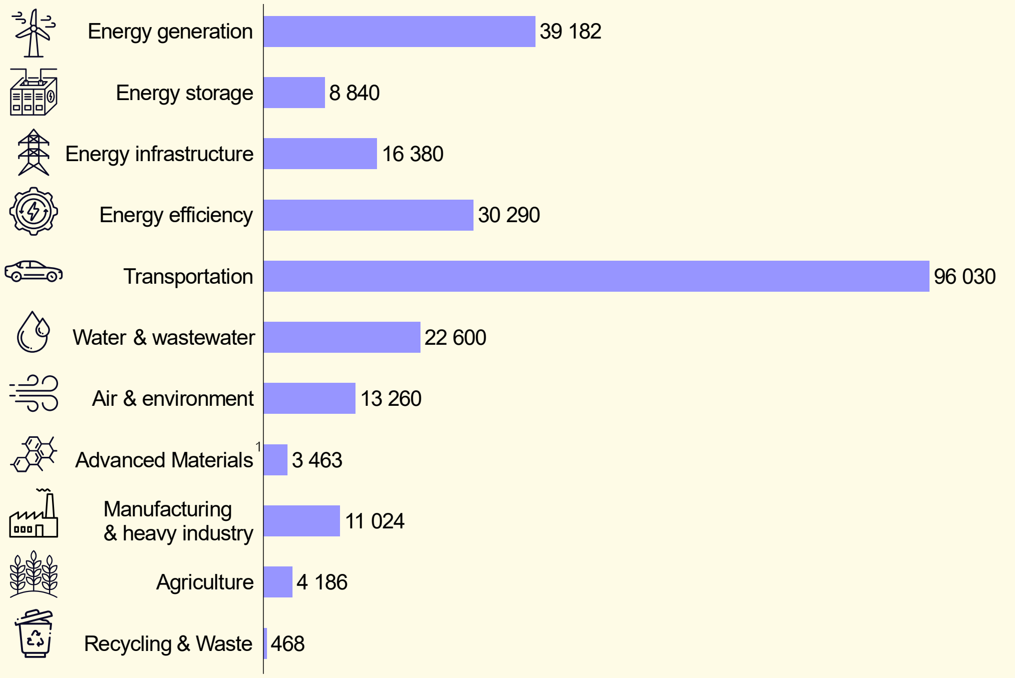
Energy Efficiency
Efficient lighting, BEMS[4], Heat pumps

1) Carbon Capture, Utilization, and Storage; 2) Included in IEA energy transition to Net Zero Emissions; 3) Long Duration Energy Storage; 4) Building Energy Management Systems
Source: Cleantech Scandinavia; IEA; Knowit

This intermittency has contributed to significant price volatility in Sweden's electricity market. Peaks and troughs in energy supply have resulted in stark price disparities, with some regions experiencing record highs and others grappling with negative prices. Such fluctuations do not only strain the grid but also threaten the economic viability of renewable energy projects.

Amid these challenges, energy storage has emerged as a key component for a reliable, sustainable energy future. ESS technologies enable the capture of surplus energy during periods of high generation and its release during times of scarcity, ensuring a stable and consistent energy supply. Whether it's the long-proven reliability of PHS, the innovative potential of TES, the versatility of Hydrogen Storage, or the rapid response capabilities of BESS, each system addresses critical aspects of Sweden's energy needs.

Figure 2. Global investments needed to meet NZE 2050, per CleanTech vertical [bUSD]

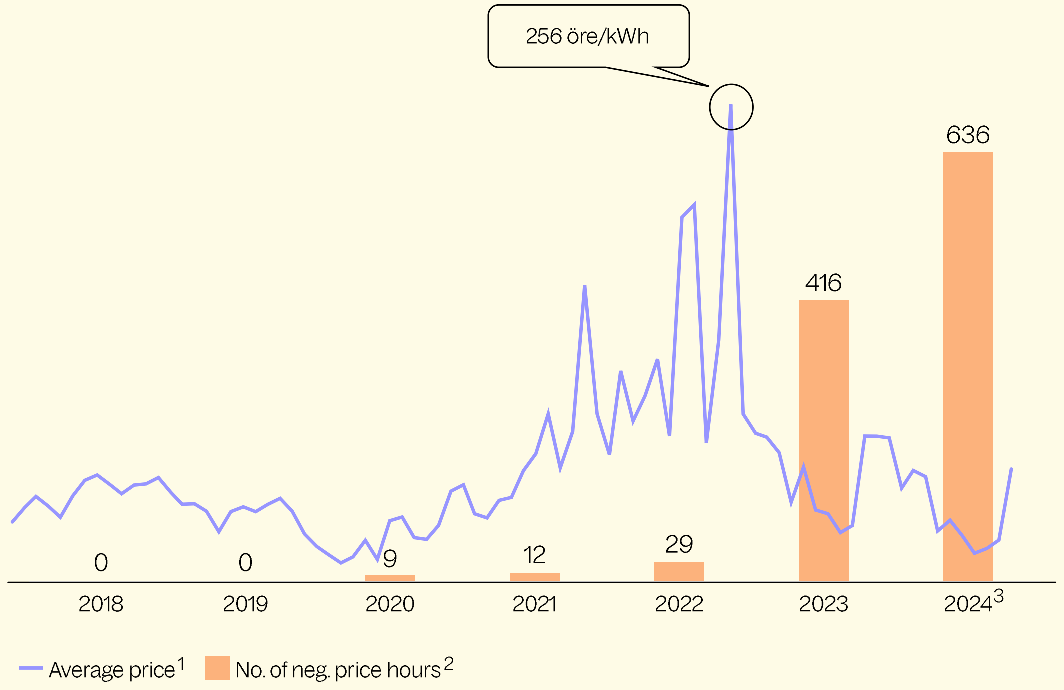


1) Estimated based on average industry ROI
Source: IEA; BloombergNEF; Knowit

Sweden's energy landscape

Sweden is often seen as a front-runner in the renewable energy revolution, but even leaders face growing pains. In recent years, the country has grappled with a paradox: while striving to expand its renewable energy capacity, it has encountered an increasingly volatile electricity market, as shown in Figure 3. Prices have swung dramatically, both on hourly and monthly base—from historic highs of 851 öre/kWh for single hours in southern Sweden to negative prices of -69 öre/kWh during times of surplus generation. On a monthly average basis across the 4 bidding areas, Sweden saw record-high electricity prices of 256 öre/kWh in December 2022, see Figure 3. This volatility underscores a system straining to balance the opportunities and challenges of renewable energy.

Figure 3. Electricity prices and number of negative price hours in Sweden in the past years [öre/kWh, hours]



1) Monthly weighted average prices across the 4 Swedish bidding areas; 2) Average number of hours per year with negative prices across the 4 Swedish bidding areas; 3) January-November
Source: Vattenfall; Svenska kraftnät; Energimyndigheten; Nord Pool; Knowit

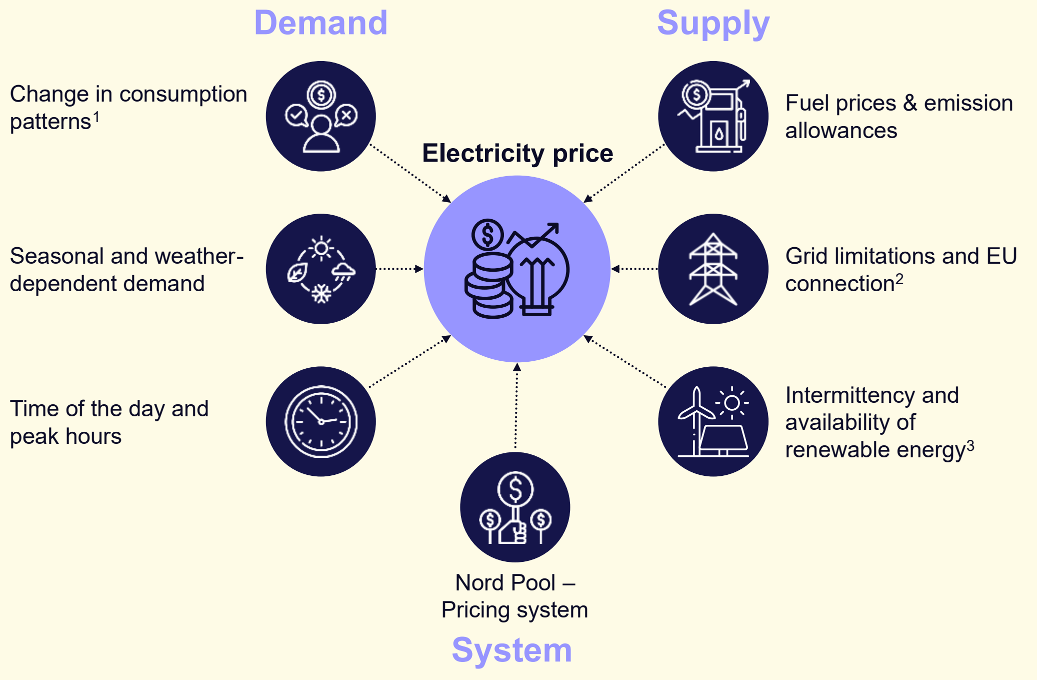
At the heart of this issue lies the dynamic nature of Sweden's power grid. Since 2011, the country is divided into four electricity zones, each with varying capacities for generation and transmission. In the north, where renewable resources like wind and hydropower are abundant, supply often outpaces demand. Yet, the south, with its higher energy consumption and limited transmission capacity, sometimes depends on costly imports from Europe despite the availability of surplus power in the north.

In December 2024, Sweden experienced a notable electricity price spike driven by low wind power production in Germany. This shortage pushed consumer prices on hourly contracts in southern Sweden to a peak of 8 SEK/kWh. Average prices also remained elevated in bidding zones SE3 and SE4, reaching 2.5 and 3.6 SEK/kWh, respectively. In contrast, northern regions saw much lower prices during the same period — just 17 öre/kWh in SE1 and 9 öre/kWh in SE2.These regional disparities have created an urgent need for innovative solutions to bridge the gap.

Electricity price volatility

Price fluctuations in Sweden are not merely economic anomalies; they are emblematic of the broader challenges posed by transitioning to a renewable electricity grid. While the intermittency of renewable energy sources like solar and wind plays a role due to their dependency on weather conditions, the problem is more complex. A combination of seven key factors, as shown in Figure 4, spanning across system, demand and supply dynamics, contributes to this volatility. These factors underscore the need for comprehensive strategies to stabilize electricity prices while scaling renewable energy capacity.

Figure 4. Key demand and supply factors influencing electricity prices



1) Private and industrial, due to electrification trend e.g., adoption of EV; 2) Grid capacity limitation for long transport of low-cost renewable electricity; 3) Wind and solar are intermittent energy sources, since they are highly dependent on weather conditions. Their availability, along with that of stream hydro, fluctuates based on weather patterns and seasonal variations
Source: Svenska kraftnät; Power Circle; Energimyndigheten; Energiföretagen; Knowit

Key factors behind electricity price volatility in Sweden – Demand side

Changing consumption patterns

The push for electrification, particularly with the rise of electric vehicles (EVs) and industrial electrification, is intensifying grid demand. Homes and industries that once relied on fossil fuels are now competing for the same renewable electrons, creating new pressures on energy infrastructure.

Seasonal and weather-dependent trends

Electricity demand and prices are strongly influenced by weather and seasons. Cold winters drive up heating needs, while hot summers boost air conditioning use, increasing consumption. In recent years, unpredictable weather patterns, such as milder winters, prolonged heat waves, and extreme storms, have created unexpected fluctuations in demand. For example, cold spells or sudden temperature drops can cause demand spikes, straining the grid and driving up prices. As climate variability increases, electricity markets are experiencing more frequent and severe seasonal price swings, requiring greater flexibility in energy supply and storage.

Time of the day and peak hours

Electricity demand fluctuates throughout the day, largely influenced by peak hours when usage is highest. These peaks typically occur in the morning as people prepare for work and in the evening when households return and consume energy for cooking, heating, and entertainment. Industrial operations and commercial activities also contribute to demand spikes during business hours. This variability puts pressure on the grid, often requiring additional energy generation or storage solutions to balance supply and demand effectively. Shifting energy use to off-peak hours through incentives or smart technologies can help reduce strain and enhance grid efficiency.

Key factors behind electricity price volatility in Sweden – Supply side

Fuel prices & emission allowances

Global events, such as the war in Ukraine, have sent shockwaves through energy markets, driving up fuel prices and, in turn, influencing electricity costs in Sweden. Despite Sweden's strong reliance on renewable energy, the interconnected nature of global energy systems means that external disruptions can still impact domestic electricity prices.

This is largely due to Sweden's electricity pricing mechanism, which follows a marginal pricing model, commonly known as the highest price principle or pay-as-clear pricing. This system, used across the Nordic electricity market (Nord Pool) and much of Europe, ensures that the market-clearing electricity price is determined by the most expensive energy source needed to meet demand at any given moment. As a result, even when Sweden generates ample low-cost electricity from hydropower and nuclear, fluctuations in fossil fuel prices—whether driven by geopolitical instability, supply chain disruptions, or policy shifts—can significantly affect electricity costs.

Grid limitations and EU connection

Grid limitations, particularly in transmission capacity, hinder the ability to transfer electricity efficiently across regions. Northern Sweden, rich in renewable energy production, often generates a surplus, while the densely populated south faces shortages, leading to price disparities. Upgrading and expanding grid infrastructure is essential to balancing supply and demand and enabling Sweden's transition to a sustainable energy future.

Intermittency and availability of renewable energy

Sweden's commitment to sustainability is evident in its energy mix—98% of its electricity came from renewable sources in 2023, with hydropower leading at 40% and wind and solar contributing a combined 22%. As wind power grew by 18% in 2024 and solar expanded by a third, the share of intermittent energy sources in the Swedish grid has risen significantly. This growing reliance on weather-dependent generation introduces variability in electricity supply, which increasingly influences price fluctuations—creating periods of both surplus and scarcity depending on availability. For example, during particularly windy weekends, electricity prices can drop below zero due to oversupply, while calm, cloudy winter days may see price spikes driven by limited generation and high demand.

Key factors behind electricity price volatility in Sweden – System

Nord Pool – Pricing system

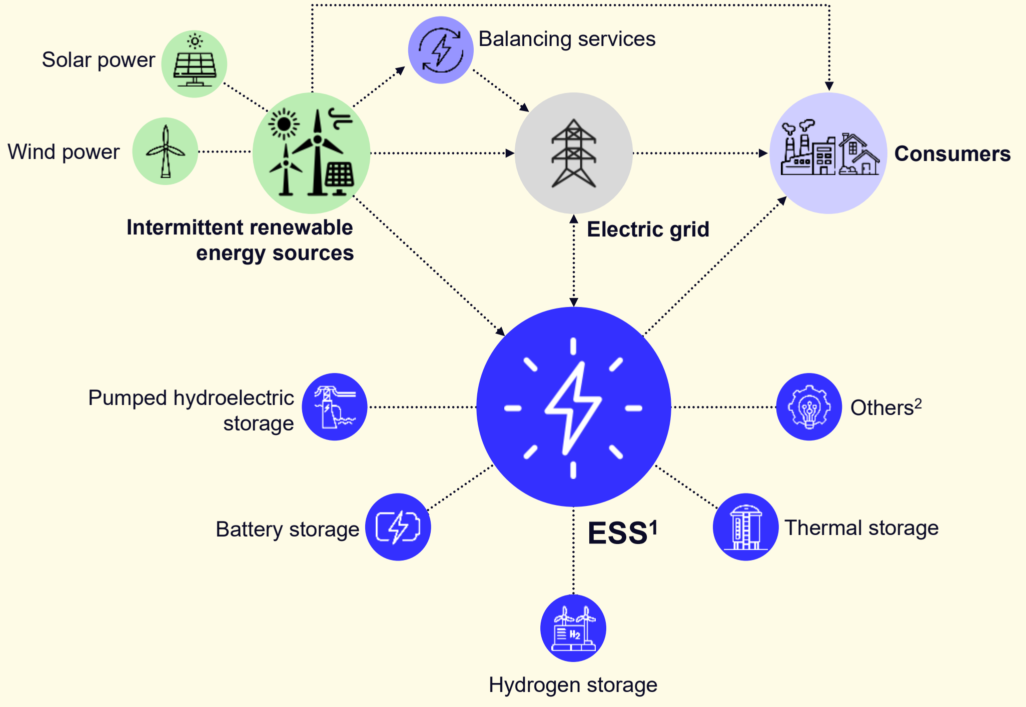
The Nord Pool electricity market plays a central role in determining electricity prices through a day-ahead bidding system. Electricity producers and consumers submit hourly bids based on anticipated supply and demand which results in hourly prices driven by the balance between supply and demand. Factors like weather-dependent demand, renewable energy availability, and grid constraints influence these bids, making Nord Pool a key mechanism in determining electricity price fluctuations.

Unlike demand- and supply-side factors, which can be influenced over time through consumption behavior, technological development, or policy measures, the Nord Pool pricing system operates as a fixed market mechanism. It provides the structural framework within which electricity prices are set, based on transparent and competitive bidding across the Nordic and Baltic regions.

The urgency of adaptation

For Sweden, these challenges are not insurmountable—they are opportunities in disguise. The solution lies in creating a grid that can flex with these dynamics, one capable of storing excess energy during periods of surplus and releasing it when demand surges. Energy storage systems are set to become an increasingly vital part of the energy landscape, seamlessly integrating with the grid and renewable energy sources to balance electricity supply, bridging fluctuations between demand and generation, see Figure 5.

Figure 5. ESS role in the energy system



1) Energy Storage Systems; 2) Other small and niche storage technologies like compressed air, flywheels, superconducting magnets, etc.
Source: Svenska Kraftnät; Energimyndigheten; IEA; IRENA; Bloomberg NEF; Statista; Knowit

Imagine a windy afternoon when turbines generate an abundance of electricity that exceeds immediate demand. Without energy storage, this surplus risks being wasted through curtailment—or worse, causing grid congestion due to overloaded transmission lines. Conversely, think of a calm winter night when demand peaks but generation falters. ESS ensures that energy captured during surplus times is available precisely when needed. It turns unpredictability into reliability and intermittent supply into a consistent resource.

ESS technologies come in a variety of forms, each designed to meet different challenges and opportunities within the energy landscape. Together, they form an important part of the toolkit for addressing Sweden’s power challenges.

Pumped Hydroelectric Storage (PHS)

PHS is a longstanding champion of large-scale energy storage. By pumping water to elevated reservoirs during low-demand periods and releasing it to generate electricity during peak demand, PHS leverages gravity to stabilize the grid. PHS delivers high efficiency (70-85%) and massive capacity, making it indispensable for grid balancing and large-scale, long-term energy storage. However, it requires specific geography and significant upfront investment, which can limit its deployment. Innovations such as underground and seawater PHS are expanding its feasibility, offering scalable solutions for diverse landscapes.

Thermal Energy Storage (TES)

TES captures energy as heat or cold, providing an effective way to store surplus energy and support energy-intensive processes. It encompasses three main types: sensible heat storage, which uses materials like water or molten salts to store energy by heating or cooling; latent heat storage, which relies on phase change materials to store energy during transitions like melting or freezing; and thermochemical storage, which uses reversible chemical reactions to capture and release heat. TES is valuable for industrial heating, district energy systems, and bridging renewable intermittency. Heat loss and infrastructure costs remain challenges but advances in phase-change materials and AI-driven systems are rapidly enhancing its efficiency. TES is evolving with hybrid solutions that combine it with other ESS technologies, further optimizing its potential.

Hydrogen Storage

Hydrogen is more than a storage medium; it's a key to unlocking cross-sector decarbonization. By converting renewable electricity into hydrogen, the green kind, through electrolysis, this technology enables long-duration storage and diverse applications.

Hydrogen storage supports not only the grid but also other applications, such as transportation and industry, providing a bridge between electricity and other energy sectors. However, high cost of electrolysis technology, as well as infrastructure gaps for storage and distribution, remain hurdles. Despite all these, green hydrogen innovations and compact storage systems are pushing the boundaries of what's possible. Hydrogen is very likely to be central to decarbonizing several sectors, especially the hard-to-abate sectors, thus ensuring its role as a cornerstone of the global energy transition.

Battery Energy Storage Systems (BESS)

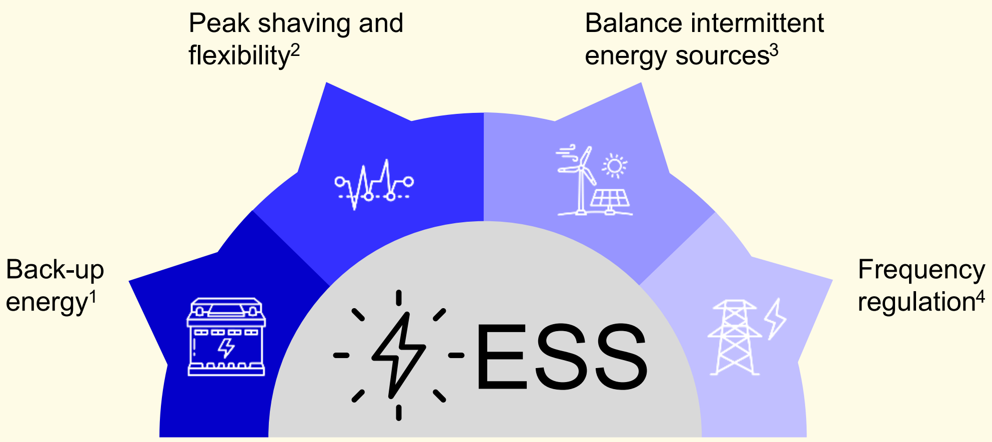
BESS exemplifies agility, with systems capable of storing and releasing energy in milliseconds. They stabilize the grid during sudden fluctuations, integrate seamlessly with renewables, and power microgrids with unparalleled flexibility. BESS offers high efficiency (80-95%) and scalability, making it suitable for both urban areas and decentralized grids. Challenges like raw material dependency and battery degradation highlight the need for innovation in recycling and sustainable production. Emerging chemistries and technologies, such as solid-state and flow batteries, are addressing these challenges, while second-life applications give batteries extended value in stationary storage.

Energy storage systems

Tackling grid intermittency with key functions

ESS offer the transformative ability to act as a buffer between generation and consumption, and ensures that energy flows seamlessly, stabilizing the grid even in the face of unpredictable supply and demand. But ESS is not a one-size-fits-all solution—it achieves this balance through a range of specialized functions that collectively tackle grid intermittency and limitations, see Figure 6.

Figure 6. Key functions of Energy Storage Systems (ESS)



1) Provide reliable energy for critical infrastructure, replacing traditional solutions like diesel generators; 2) Adjust electricity consumption to match supply and price fluctuations; 3) ESS stores surplus energy from solar and wind, ensuring a steady electricity flow even during low generation periods and benefiting spot price arbitrage; 4) Maintain grid stability by dynamically charging and discharging to support a stable 50 Hz frequency
Source: Svenska Kraftnät; Energiföretagen; Vattenfall; E.ON; Power Circle; Knowit

Back-up energy

During emergencies or outages, the ability to rely on a consistent energy supply can make the difference between disruption and continuity. ESS provides critical backup power for essential services such as hospitals, data centres, and infrastructure hubs. Replacing traditional diesel generators, ESS delivers clean, uninterrupted energy that ensures these vital systems remain operational, even in the face of unexpected grid failures. This reliability makes ESS a cornerstone of energy security in a renewable future.

Peak shaving and flexibility

As Sweden's electrification trends accelerate, for example with more electric vehicles on the road and industries transitioning from fossil fuels to electricity, the grid faces intense pressure during peak hours. ESS offers a solution by smoothing out these consumption spikes. When demand is high, stored energy is discharged to alleviate stress on the grid; during periods of low demand, ESS absorbs surplus electricity, optimizing the system for efficiency and cost-effectiveness. This flexibility not only stabilizes the grid but also ensures that renewable energy sources are used to their fullest potential.

Balancing intermittent energy sources

The beauty of renewable energy lies in its abundance; however, its generation is often unpredictable. Wind and solar depend on weather conditions, leading to surpluses in generation during sunny or windy periods and deficits when conditions change. ESS transforms these fluctuations into a steady, reliable flow of electricity. By storing surplus energy during high production and releasing it during low production, ESS ensures a consistent energy supply. Additionally, this balancing function enables spot price arbitrage, allowing producers and consumers to benefit from fluctuating market prices while maintaining stability.

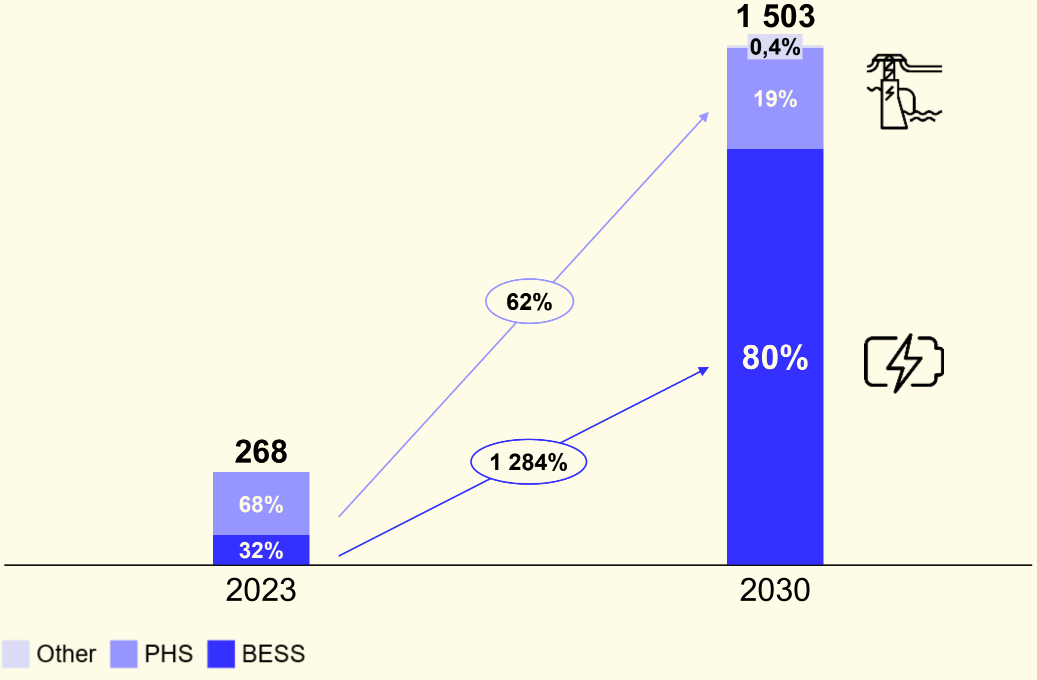
Frequency regulation

Behind the scenes of a stable energy grid lies a delicate balance: maintaining the grid's frequency at a constant 50 Hz. Even minor deviations can lead to disruptions, making frequency regulation critical. BESS excels in this area, responding within milliseconds to balance sudden changes in supply or demand. Through dynamic charging and discharging, BESS ensures that the grid remains stable, even during unexpected fluctuations. This capability highlights the precision and agility of BESS technologies in safeguarding energy reliability.

Through these critical functions, different types of ESS can support the transformation of Sweden's renewable energy strategy into a reliable and resilient system. By providing backup power, smoothing demand peaks, balancing intermittent sources, and regulating grid frequency, ESS tackles the challenges of intermittency head-on. This convergence of technological innovation and strategic application positions Sweden not only to overcome its energy challenges but also to lead the way in building a stable, sustainable future powered by renewables.

As the world accelerates toward a renewable energy future, the role of BESS is expected to grow at an unprecedented pace compared to other alternative ESS technologies. By 2030, global installed energy storage capacity is projected to reach 1 503 GW, out of which BESS is expected to account for 80%, underscoring its dominance and critical importance in modern energy systems (see Figure 7). BESS is projected to experience an astonishing 1 284% growth from 2023 levels, surpassing PHS to become the leading energy storage technology.

Figure 7. Growth and division of global energy storage capacity from 2023 to 2030[1,2] [GW]

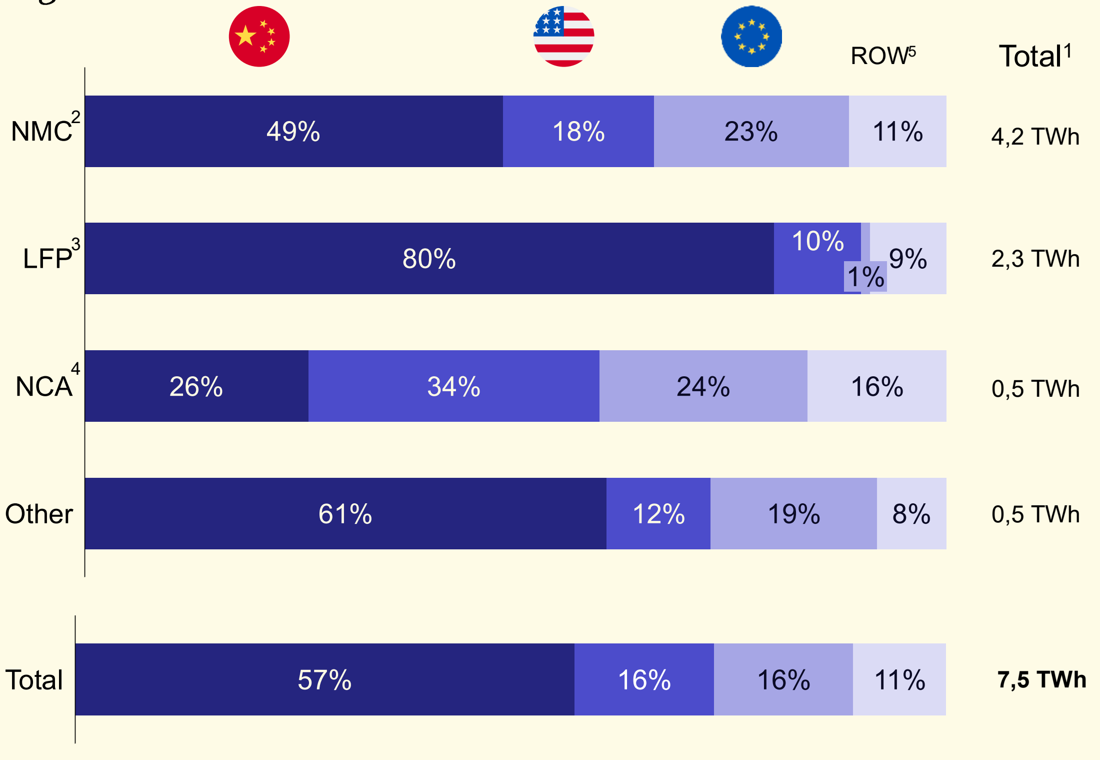


1) According to NZE target by 2030; 2) Numbers refer only to batteries used for energy storage systems
Source: IEA; IRENA; Bloomberg NEF; Statista; Knowit

BESS are poised to outpace alternatives like pumped hydrogen due to their scalability, efficiency, and versatility. BESS can be deployed from utility-scale parks to residential systems, offering rapid response times in milliseconds—essential for grid stabilization, frequency control, and renewable energy integration. Unlike hydrogen, BESS achieves superior round-trip efficiencies (85–90%) and requires minimal site-specific conditions, enabling deployment virtually anywhere. With modular, plug-and-play designs and declining costs driven by advancements in lithium-ion technology, BESS has become an increasingly cost-effective solution for short- to medium-duration storage. Its compatibility with digital tools and microgrids further enhances its appeal, while established supply chains and mature technology ensure reliability and scalability. As demand for decentralized, renewable energy solutions grows, BESS stands out as a flexible, fast-to-deploy option that meets both consumer and utility needs.

Although Europe is making efforts to grow its BESS capacity, with its global share projected to increase from 13% in 2023 to 16–17% by 2030, this growth is overshadowed by China's continued dominance. By 2030, China is expected to account for 57% of total global BESS capacity, solidifying its position at the centre of the global energy storage market, as highlighted in Figure 8. This trajectory reinforces China's influence over the supply chain, technology development, and pricing, leaving other regions striving to keep pace.

Figure 8. Production capacity by different battery chemistries and regions



1) Forecasted capacity; 2) Nickel Manganese Cobalt, including Nickel Manganese Cobalt Aluminium; 3) Lithium-ion Phosphate; 4) Nickel Cobalt Aluminium Oxide; 5) Rest of the world
Source: SPGlobal; IEA; Knowit

Comparing battery chemistries trade-offs and applications

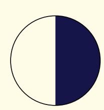
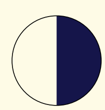
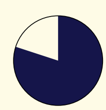
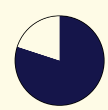
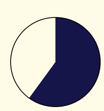
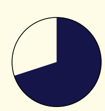
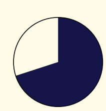
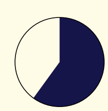
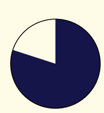
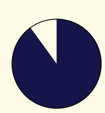
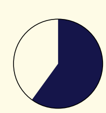
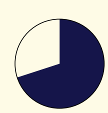
Varieties of Lithium-ion batteries are the leading technologies within the BESS market. Their dominance is driven by a combination of technological maturity, scalability, and continuous cost reductions. Since 2010, the cost of lithium-ion batteries has decreased by over 90%, largely due to advancements in manufacturing processes and economies of scale.

However, not all energy storage applications have similar requirements, hence the choice of battery chemistry is often application specific, as is shown in Figure 9. Over the past decade, the energy storage market has been predominantly powered by Nickel Manganese Cobalt (NMC) batteries, favoured for their high energy density. However, Lithium Iron Phosphate (LFP) batteries have gained significant traction, see Figure 10, constituting 80% of new battery storage installations in 2023. This shift is attributed to LFP batteries' cost-effectiveness, enhanced safety, and scalability - qualities that are particularly advantageous for large-scale energy storage applications, as can be seen in Figure 9. In other words, choosing the "right" battery chemistry means finding a balance between trade-offs such as cost, energy density, lifespan, and safety.

For instance:

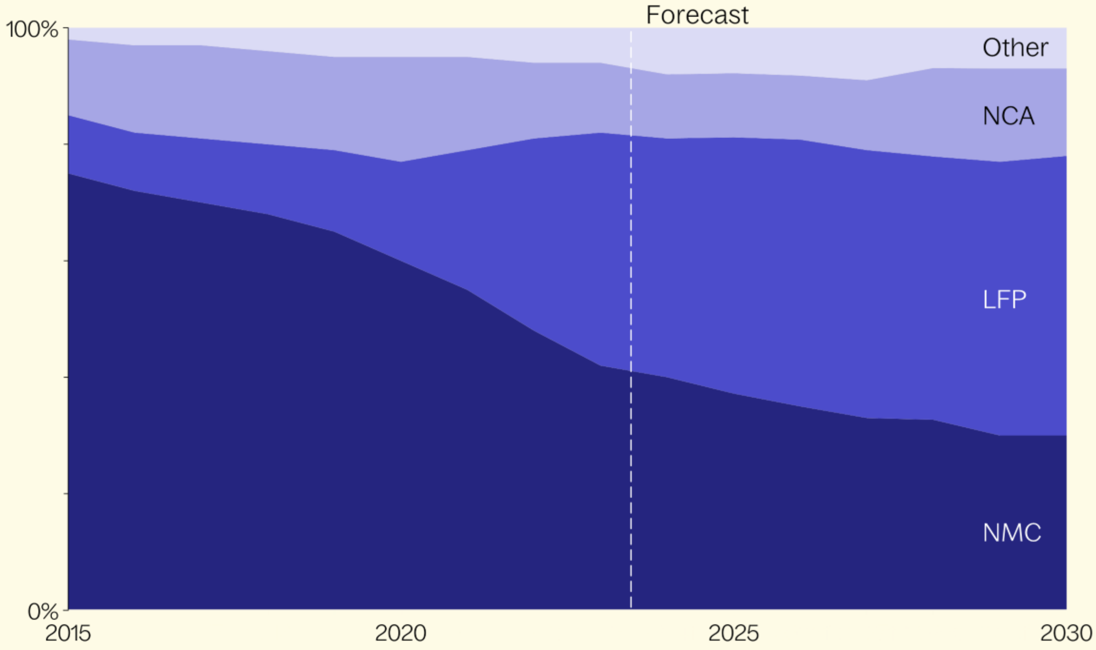
- **LFP Batteries:** With higher thermal stability and lower cost, is well-suited for large-scale energy storage and renewable energy integration, where safety and longevity are priorities and minimizing size is less important. LFP batteries has an energy density of 300 Wh/l, which is lower than several other types of batteries, but for large-scale ESS, this is normally not an issue.
- **NMC Batteries:** Known for their high energy density of 500-700 Wh/l, NMC batteries are often preferred for mid-size systems, such as grid stabilization and back-up power, and it is also commonly used in EVs.
- **NCA Batteries:** Nickel Cobalt Aluminium Oxide batteries have an even higher energy density than NMC batteries, but scores lower in safety and cycle life. NCA batteries are selected for applications requiring high performance or where space constraints exist, e.g., for EVs to achieve long range and fast acceleration.

Figure 9. Comparison of different LiB[1] chemistries by attributes

LiB types	Key applications	Price/KWh	Energy density	Cycle life & safety[2]	Raw material availability[3]
LFP *Lithium Iron Phosphate*	Excel in **large-scale** grid storage and renewable energy integration				
NMC *Nickel Manganese Cobalt Oxide*	Preferred for **mid-size** systems such as grid stabilization, back up power and renewable energy storage				
NCA *Nickel Cobalt Aluminium Oxide*	Chosen for **high-performance** or space-constrained energy storage				

1) Lithium–ion Batteries; 2) Number of cycles and chemistry stability; 3) Reliability on accessible raw material
Source: BloombergNEF; Knowit

Figure 10. Development of share of different battery technologies from 2015 to 2030[1]



1) Forecasted outlook
Source: IEA; Woodmac; Knowit

As the global demand for BESS grows, innovations in battery chemistries are reshaping the energy storage landscape. Solid-state batteries promise higher energy density of 300-1000 Wh/l and improved safety, while second-life batteries from EVs are being repurposed for stationary storage, extending their lifecycle and reducing waste.

By tailoring chemistries to specific use cases, energy storage providers can optimize performance, cost, and sustainability, ensuring that BESS remains the backbone of the renewable energy future.

Strategic actions for BESS success

The increasing focus on CleanTech and battery energy storage in Europe and the Nordics presents significant opportunities for companies and investors looking to enter or expand in this space. With a growing demand for batteries, both for the accelerating EV transition and energy storage systems, investment interest is at an all-time high. However, while there is a strong vision for Europe to establish itself as a leader in battery storage technology, efforts remain fragmented, and uncoordinated investments pose challenges to long-term success. Despite the enthusiasm, not all BESS ventures will thrive. The challenges faced by Northvolt serve as a cautionary tale about the risks of stretching across the full battery value chain and competing directly with China's highly integrated, cost-efficient industry.

To successfully navigate this competitive landscape, businesses and investors must make informed decisions and develop strategies that ensure long-term viability.

Figure 11. Key factors for investors and companies interested in investing in the BESS space should consider

Strategic market positioning	With China's dominance across battery industry value chain, European and Nordic players must invest into market segments where they can differentiate & compete effectively[1] – Northvolt as a cautionary tale[2]
Technology-market fit	Invest in BESS technologies and chemistries that align with market demand, customer needs and regulatory standards considering factors such as energy density, cycle life and cost
Value added offerings	Move beyond hardware sales by exploring high-margin services such as EMS[3], Battery-as-a-Service, second-life applications, and digital optimization tools to compete with Chinese manufacturers
European collaboration	Leverage European industry collaboration, joint ventures, and initiatives to strengthen competitiveness by uniting expertise, securing funding, and build resilient European supply chain
Supply chain resilience	Mitigate geopolitical and material supply risks by diversifying raw material sources, fostering partnerships with local suppliers, and reducing dependency on China
Regulatory leverage	Stay ahead of evolving regulations, capitalize on subsidies, and engage in energy trading and capacity markets to improve financial viability and accelerate BESS adoption[4]

1) Potential areas could be advanced materials manufacturing, recycling, or high-performance battery technologies; 2) Highlighting the risks of undertaking large scale investment across the entire battery value chain; 3) Energy Management Systems; 4) Capitalize on European incentives like the EU Innovation Fund, Horizon Europe, the Green Deal Industrial Plan
Source: Knowit

Strategic market positioning

One of the most critical considerations is strategic market positioning. Given China's dominance across the battery industry, from raw material extraction and refining to manufacturing, European and Nordic players must carefully choose where they can differentiate and build competitive advantages. Instead of attempting to replicate large-scale battery production from the start, companies should focus on strategically chosen market segments where Europe has a strong foundation, such as for example advanced materials and manufacturing steps, next-generation battery chemistries, recycling, or high-performance storage solutions tailored for specific applications. Northvolt's experience highlights the risks of attempting to control the entire value chain, underscoring the importance of thoroughly assessing market demand, customer needs, and internal capabilities before committing to large-scale investments.

Technology-market fit

A key aspect of success in this space is ensuring the right technology-market fit. Not all energy storage applications have the same requirements, making it crucial to invest in battery chemistries and technologies that align with both current and future market demand. Factors such as cost, energy density, cycle life, and material availability play a decisive role in determining the optimal chemistry for different use cases. For example, LFP batteries have become increasingly popular due to their lower cost, strong safety profile, and long cycle life, making them well-suited for large-scale energy storage systems. However, in applications where energy density is critical, NMC or NCA batteries may be a better fit. Looking ahead, emerging solid-state battery technologies promise even higher energy densities and improved safety, while second-life applications for EV batteries are opening new possibilities for stationary storage solutions. Companies that tailor their technology investments to the evolving needs of customers and the energy market will be better positioned for long-term success.

Value added offerings

Beyond hardware, European companies must rethink their business models to stay competitive. Historically, battery manufacturers in Europe have sought to compete with China by emphasizing higher quality and longer lifespan. However, as Chinese manufacturers rapidly improve their battery performance while maintaining cost leadership, European firms must differentiate through value-added offerings. This includes expanding beyond battery sales to include high-margin services such as Battery-as-a-Service (BaaS), Energy Management Systems (EMS), predictive maintenance, second-life applications, and extended warranties. Companies that integrate digital solutions and service-based revenue models will not only increase profitability but also strengthen customer relationships and build long-term competitive advantages.

European collaboration

Collaboration within Europe will also be essential for success. While Europe has significant expertise in battery technology, manufacturing, and R&D, much of this knowledge is scattered, preventing large-scale competition against China's highly coordinated industry. By fostering deeper cooperation through cross-industry partnerships, joint ventures, and technology co-development, European players can accelerate innovation, improve manufacturing efficiency, and build a more resilient battery value chain. Stronger alignment between battery manufacturers, utilities, and grid operators will also be key in ensuring that energy storage solutions are effectively integrated into the broader energy system.

Supply chain resilience

At the same time, supply chain resilience must be addressed to reduce Europe's heavy dependence on China for raw materials and battery components. While achieving full independence in the near term is unrealistic, companies can take proactive steps to diversify sourcing, invest in European material processing capabilities, and build alternative supply networks. Europe has untapped potential in domestic mining and refining, and increased investment in these areas could provide greater stability for the region's battery sector. Although developing such infrastructure takes time, companies that adopt a phased approach to reducing reliance on China will be better positioned to withstand geopolitical disruptions and market fluctuations.

Regulatory leverage

Finally, regulatory alignment and financial incentives will play a critical role in the success of European battery investments. Governments are actively supporting energy storage development through funding programs, subsidies, and market incentives, and companies must ensure they capitalize on these opportunities. The EU Innovation Fund, Horizon Europe, and the Green Deal Industrial Plan provide substantial financial backing for energy storage initiatives, while national capacity mechanisms are increasingly being designed to support BESS deployment. By staying ahead of evolving regulations and ensuring compliance with energy market requirements, companies can improve financial viability and accelerate adoption.

Conclusion

Europe’s CleanTech and battery storage industries are at a turning point. While the region has the ambition to lead in energy storage, turning vision into reality requires a coordinated approach, strategic decision-making, and investments that align with long-term market needs. Companies and investors that focus on securing the right market niche, selecting optimal technologies, integrating value-added services, strengthening collaboration, building supply chain resilience, and leveraging regulatory incentives will be best positioned to compete in this rapidly evolving market. By making informed and strategic moves, European and Nordic players can establish themselves as global leaders in battery energy storage, ensuring both economic success and a more resilient, sustainable energy future.

knowit

Authors

Ramin J. Imani

Manager - Corporate Strategy and M&A

Ramin.imani@knowit.se

Jonas Nodler

Director – Strategy Execution

Jonas.nodler@knowit.se

Kristoffer Biørnstad

Director – Strategy and Innovation

Kristoffer.biornstad@knowit.no

Johanna Murby

Director – Strategy Execution

Johanna.murby@knowit.se

Fredrik Gotthardt

Director – Marketing and Brand Strategy

Fredrik.gotthardt@knowit.fi

More from the CleanTech series

Explore additional white papers that dive deeper into key segments shaping the sustainable economy

Unpacking the CleanTech Space

This white paper offers a broad overview of the CleanTech sector, highlighting eleven key verticals, such as energy generation, storage, efficiency, and recycling, and framing the sector as a critical driver of sustainable growth, climate resilience, and long-term economic opportunity. It emphasizes CleanTech's potential to enhance GDP, reduce environmental costs, and create jobs, while mapping out how decarbonization, digitalization, and electrification underpin the transition to net-zero.

Exploring Energy Generation

This paper explores the landscape of energy generation technologies within the CleanTech space, spanning renewables like wind, solar, hydro, and geothermal, as well as nuclear power. It details market leaders, cost trends, and investment needs, while providing a strategic framework for stakeholders to navigate the evolving energy mix and infrastructure demands aligned with global climate targets.