THE CRITICAL ROLE OF DISPATCHABLE POWER GENERATION FOR A SUSTAINABLE AND SECURE ENERGY TRANSITION

ETN Global White Paper

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About Energy & Turbomachinery Network (abbrev. ETN Global)

ETN Global is a non-profit membership association that brings together **149 member organisations** from **22 countries** across the energy and turbomachinery value chain in Europe and beyond.

Our members

Our diverse network represents a uniquely broad spectrum of expertise and influence:

10 original equipment manufacturers (OEMs), shaping cutting-edge technology and responsible for **84% of global orders** for dispatchable thermal turbines.

63 global suppliers and service providers, delivering practical solutions to market challenges.

29 energy users, including **15 utilities** and **14 leading energy companies**, providing direct insight into operational needs and challenges.

43 international R&D institutions and universities, driving innovation and advancing energy research.

4 international consultancies, offering strategic, global perspectives on the energy transition.

Our vision

To deliver safe, secure, affordable and dispatchable carbon-neutral energy solutions.

Our mission

To globally facilitate information exchange and cooperation to accelerate research, development, demonstration, and deployment of innovative energy solutions in line with our vision.

Preamble

As Europe transitions towards a carbon-neutral future, the energy landscape is undergoing transformative change. The shift from a fossil fuel-dominated system to one primarily based on Variable Renewable Energy (VRE) sources — such as wind and solar — presents significant challenges, particularly in ensuring **security of supply** amidst rising electricity demand across households, industry, and mobility sectors.

In alignment with the European Commission's **political guidelines** and the **Clean Industrial Deal**, which aim to **foster sustainable prosperity and competitiveness**, this white paper highlights four challenges related to security of supply. It outlines solutions and calls for immediate action to address these pressing issues:

1. Flexibility challenge: calling for increase in dispatchable energy solutions and storage

The increasing integration of VRE sources, such as wind and solar, demands a significant expansion of flexibility solutions. By 2030, Europe must double its current resources, and by 2050, flexibility needs are projected to grow fivefold. Without this expansion, Europe risks grid instability, blackouts, and an inability to meet the growing demand for electrification in sectors like households, industry, and mobility.

We therefore urge the European Commission and the European Parliament to implement policies that will enable the necessary increase in the availability of flexible resources to meet the growing energy demand projected by the European Commission's Joint Research Centre and the European Network of Transmission System Operators for Gas (ENTSO-G).

2. Grid stability challenge: calling for incentivisation of dispatchable energy solutions

The growing integration of VRE sources requires effective management of energy deficits to stabilise the electricity grid. Dispatchable thermal turbines, especially those running on hydrogen or carbon-neutral fuels, are crucial for ensuring grid reliability. These technologies provide key services such as load following, peaking, and black-start capabilities. In addition, the integration opportunity with ultra-fast-response solutions like batteries can improve efficiency, lower emissions, and meet long-duration energy needs.

Dispatchable thermal turbines are currently the only viable options for seasonal energy storage and long-duration flexibility. Given their critical role, we urge the European Commission and European Parliament to:

- Recognise the importance of dispatchable thermal turbines in ensuring grid reliability and stability.
- Support this technology through targeted incentives and robust regulatory frameworks.

3. Carbon-neutral fuel challenge: calling for availability & infrastructure improvements

Transitioning to carbon-neutral fuels is vital for achieving decarbonisation goals. However, currently low-carbon and carbon-neutral fuels, like hydrogen and others, are plagued by limited availability and high costs. Additionally, to build confidence and attract future investments in technology solutions that utilise these fuels, it is essential to conduct large-scale operational testing. These two challenges create uncertainties that delay final decisions in the power sector and broader industry regarding investments.

We urge the European Commission and European Parliament to prioritise the rapid deployment of hydrogen and other carbon-neutral fuels as essential components of Europe's energy transition. This requires targeted investments in hydrogen and other low-carbon/carbon neutral fuel production, infrastructure development, and the testing and scaling of hydrogen-fuelled turbines and synthetic fuel technologies.

Clear policies and financial incentives are needed to make these fuels more affordable and widely available, ensuring their integration into the energy grid. Such actions will drive decarbonisation, enhance energy security, and provide the flexibility needed to stabilise Europe's evolving energy system.

4. Aging fleet challenge: calling for incentivisation to extend operational lifespan of existing fleets

The European Transmission System Operator (ENTSO-E) forecasts a net decrease of 107 GW in flexible generation capacity, primarily from dispatchable thermal turbines, by 2030. This decline, driven by economic decommissioning, poses a significant adequacy risk to Europe's energy security. While extending the operational lifespan of existing turbine plants is technically feasible, it is not commercially viable under current market conditions due to high investment costs, fuel price uncertainties, and revenue risks.

To address this critical challenge, we urge for the European Commission and European Parliament to establish financial incentives and supportive regulatory frameworks to encourage the continued availability and modernisation of these essential assets. Such measures are vital to ensuring the stability and reliability of Europe's energy system.

We would furthermore like to highlight that strengthening flexibility and securing energy supply are not only essential for grid stability but also crucial for maintaining Europe's global competitiveness. Leadership in innovation and resilience will ensure Europe remains at the forefront of the energy transition. Falling behind risks grid instability, escalating energy costs, and delays in achieving decarbonisation goals, as well as diminishing Europe's economic standing on the global stage.

ETN Global, representing a collaborative network across the entire energy and turbomachinery value chain, is committed to contributing its expertise and innovative solutions to drive this transition. We are ready to partner with policymakers, industry leaders, and technology developers to turn this vision into reality.

The **four calls to action** presented in this document are designed to support Europe's climate and industrial goals, placing **energy security** and **affordability** at the forefront of the transition.

Together, we can ensure that Europe's energy transition not only meets its environmental objectives but also strengthens energy security, drives economic growth, and enhances the quality of life for all citizens.

List of abbreviations

aFFR	Automated Frequency Restoration Reserve (Secondary Reserve)
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilisation and Storage
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSO-G	European Network of Transmission System Operators for Gas
FAME	Fatty Acid Methyl Ester
FCR	Frequency Control Reserve (Primary Control Reserve)
GW	Gigawatt (Capacity)
HVO	Hydrotreated Vegetable Oil
mFFR	Manual Frequency Restoration Reserve (Tertiary Reserve)
NOx	Nitrogen Oxides
TSO	Transmission System Operator
TWh	Terawatt-hour (Energy)
VRE	Variable Renewable Energy

1. Flexibility challenge: calling for increase in dispatchable energy solutions and storage

The European electricity landscape is undergoing a significant transformation, shifting from a fossil fuel-dominated system to one primarily based on Variable Renewable Energy (VRE) sources, like wind and solar. As more of these non-dispatchable renewable energy sources are integrated, the grid must become more flexible to balance periods when the wind is not blowing, or the sun is not shining.
This challenge is further amplified by the rising demand for electricity, due to increasing electrification in households, industry and mobility.
By 2030, Europe will need much more flexibility to manage the daily, weekly, and monthly variability in electricity supply and demand, as highlighted by the European Commission's Joint Research Centre (*Figure 1*) [2].

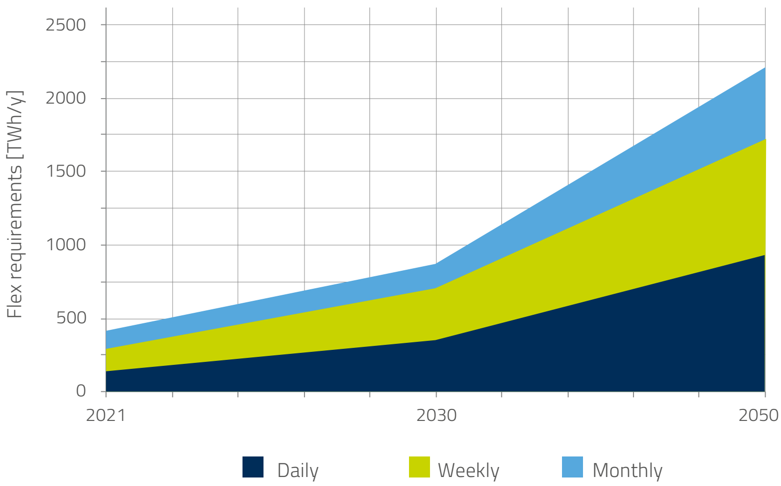

Figure 1: The increasing demand of daily, weekly and monthly flexibility according to European Commission's Joint Research Centre [2].

The daily flexibility need alone is expected to grow by 209 Terawatt-hour (TWh) from 2021 — equivalent to adding the yearly electricity consumption of a small European country. Looking to 2050, the total requirement for flexibility (daily+weekly+monthly) will have a dramatic fivefold increase.
According to the European Network of Transmission System Operators for Gas (ENTSO-G) the flexibility in energy to support the aforementioned changes is projected to increase by 40-65% [1] by 2050.
As Europe relies more on renewable energy, the grid will need to be much more robust and capable of compensating for peaks and troughs in demand to ensure that a reliable electricity supply is always available. Without enough flexibility, the grid could experience issues such as blackouts, especially as overall demand rises, and the renewable energy share becomes more prominent. This necessitates significant investments in dispatchable energy solutions, energy storage systems, and smart grids, to maintain grid stability and ensure reliable, affordable, and low-emission electricity supply for Europe's future.

Call to action 1.

The European Commission and the European Parliament must take decisive actions to ensure Europe's electricity system can meet the rapidly growing demand for flexibility. Policymakers are urged to implement policies that will enable a two-fold increase in the availability of flexible resources, such as dispatchable energy solutions, smart grids and energy storage, by 2030, while preparing for a five-fold increase by 2050.

2. Grid stability challenge: calling for incentivisation of dispatchable energy solutions

As the integration of VRE sources increases, managing VRE deficits becomes crucial to stabilise the electricity grid. A mismatch between instantaneous demand and supply can jeopardise the balance of the electricity system if not backed up by demand response together with dispatchable generation and storage solutions.

To meet flexibility requirements, we need a portfolio of sustainable dispatchable solutions that can provide reliable flexibility services, including *load following*, *peaking*, backup capacity (spinning reserve), grid services (rotating *inertia*, *frequency control*), and medium-to-long-term storage solutions as well as black start capabilities.

While **batteries** are effective at storing and quickly providing electricity for short-term supply gaps (up to several hours duration), solutions for longer-term storage durations and dispatchability needs remain open, underscoring the need for alternative options.

Pumped hydropower is another technology that can provide longer-term flexibility but is limited by geographical constraints.

Compressed air storage is limited by available reservoir volume.

Large-scale underground storage in salt caverns or depleted gas fields can provide local opportunities.

Nevertheless, **hydrogen** represents a more energy-dense option for long-term storage using salt caverns.

Carnot batteries can also provide energy storage at a utility scale without geographical constraints, but they are still at a low Technology Readiness Level.

The storage capacity of **electrochemical batteries** is increasing, but these are mainly used for daily flexibility and ancillary services.

Thus, **power-to-hydrogen-to-power** remains the only viable option for seasonal energy storage at large scale with the current state of technology.

Dispatchable thermal turbine-based power generation is well suited to fill this gap with its adaptability to use *Carbon-neutral fuel*. As shown in *Table 1*, thermal turbines are a scalable enabling technology that can provide clean and flexible generation and cover electricity grid requirements from *Frequency Control* Reserve (FCR) to *Seasonal Flexibility*. From modular and flexible *Open Cycle Turbines* to high efficiency *Combined Cycle Turbines*, thermal turbines can operate as clean generation options either by using clean fuels – such as sustainable hydrogen or e-fuels – or with the use of *Post-combustion Carbon Capture* Utilisation and Storage (CCUS). Such fuels can be stored for long periods of time before reconversion to power and heat through dispatchable thermal turbines, making them an essential technology in decarbonisation strategies while also helping to overcome 'no-wind' periods and geopolitical upsets.

Table 1: Flexibility matrix of clean thermal technologies options (vertical axis) and the flexibility services they can provide (horizontal axis).

Clean thermal Generation options	Primary control reserve (FCR)	Secondary reserve (aFFR)	Tertiary Reserve (mFFR)	Daily flexibility	Seasonal flexibility
Combined cycle + CCS	Yes (conditional)	Yes (conditional)	Yes (conditional)	Yes (conditional)	Yes (optimal)
Combined Cycle: H_2/e-fuel	Yes (conditional)	Yes (conditional)	Yes (optimal)	Yes (optimal)	Yes (optimal)
Open Cycle: H_2/e-fuel	Yes (conditional)	Yes (optimal)	Yes (optimal)	Yes (optimal)	Yes (optimal)
Battery integration	Yes (optimal)	Yes (optimal)	Yes (optimal)	Yes (optimal)	Yes (conditional)

Suited to provide the service: Yes (optimal) Yes (conditional): Spinning reserve/seasonal-storage

Moreover, integrated with batteries, thermal turbines can provide fast and flexible response, meeting all grid service needs. These attributes offer important decarbonisation opportunities in the energy transition and a clear path towards a dispatchable carbon-neutral technology suited for a wide variety of applications, along with the opportunity for additional efficiency increases through *sector coupling*.

Historically, thermal turbines have been used for high-capacity, high-volume needs. However, future demands are expected to shift towards a ‘high-capacity, low-volume’ paradigm, according to the European Environment Agency [3].

Such changes in future needs could see dispatchable thermal turbines integrated with ultra-fast response technologies such as batteries and flywheels. These integrated systems can improve response times and reduce the need for spinning reserves, leading to significant reductions in emissions and fuel consumption.

Despite the vital role of flexible thermal turbine-based capacity in guaranteeing the security of electricity supply and resource adequacy, current policies lack detail on the critical role this technology can play in providing the required dispatchable capacity in present and future energy systems.

It is promising that several European countries, in their recent energy and climate plans, indicate hydrogen and decarbonised dispatchable turbine technologies as potential solutions. Even so, the EU needs to acknowledge the vital strategic role of this technology and promote incentives and calls from national governments to secure sufficient investments in strategic technologies, such as thermal generation to avoid risking security of supply.

Call to action 2.

We urge the European Commission and European Parliament to recognise the critical role of dispatchable generation technologies, such as thermal turbines, in ensuring grid reliability and stability. These technologies, particularly when fuelled by hydrogen and other carbon-neutral options, must be supported through targeted incentives and regulatory frameworks to secure their integration into the energy mix.

As the only viable option for seasonal energy storage and long duration flexibility, dispatchable thermal turbines are essential to stabilising the grid.

Policymakers should prioritise their deployment and encourage integration with ultra-fast response solutions, such as batteries and flywheels, to enhance efficiency, reduce emissions, and secure grid resilience.

3. Carbon-neutral fuel challenge: calling for availability & infrastructure improvements

Transitioning to carbon-neutral fuels is the cornerstone of decarbonisation efforts and is already well underway, with turbine manufacturers and asset owners collaborating to demonstrate the technical feasibility of *Low-carbon fuel / Carbon-neutral fuel* and CO_2 capture technologies with successful results through test-bed approach [7].

Various fuels like, **biofuels and synthetic fuels** already provide a market-ready option today. Several full-scale tests have proven the capability of modern dispatchable turbines to operate with biofuels — e.g., Fatty Acid Methyl Ester (FAME), Hydrotreated Vegetable Oil (HVO) — and other synthetic fuels derived from green hydrogen. When combined with the use of *post-combustion carbon capture*, a negative carbon balance could be achieved.

Hydrogen, a particularly promising fuel, produces virtually no pollutants, with water as the only by-product. Thanks to modern combustion systems, Nitrogen Oxides (NOx) emissions are kept below regulatory thresholds – even if 100 vol. % of hydrogen is used [4] and can be even further reduced to almost zero using post-combustion treatments.

Surplus electricity can be converted into hydrogen via water electrolysis, which can subsequently be re-electrified with thermal turbines or converted into synfuels like ammonia, e-methanol, and e-methane. This process enables a closed carbon loop, ensuring carbon neutrality while providing a flexible, scalable energy solution.

Despite its potential as a secure, and dispatchable option, the widespread adoption of hydrogen-fired turbines faces significant barriers, including the limited availability and high costs of hydrogen [4], [8]. While full-scale testing of 100% hydrogen turbines has begun, these efforts remain constrained by these challenges. To build confidence in these solutions and attract future investments, it is essential to conduct large-scale operational testing. Achieving this will require a sufficient and reliable supply of hydrogen to be available in the coming years.

These two challenges create uncertainties that delay final decisions in the power sector and broader industry regarding investments in low-carbon or carbon-neutral fuels, dispatchable thermal turbine technologies, and CO_2 capture technology options.

Call to action 3.

We urge the European Commission and European Parliament to prioritise the rapid deployment of hydrogen and carbon-neutral fuels as essential components of Europe's energy transition. This requires targeted investments in hydrogen and other low-carbon/carbon neutral fuel production, infrastructure development, and the testing and scaling of hydrogen-fuelled turbines and synthetic fuel technologies.

Clear policies and financial incentives are needed to make these fuels more affordable and widely available, ensuring their integration into the energy grid. Such actions will drive decarbonisation, enhance energy security, and provide the flexibility needed to stabilise Europe's evolving energy system.

4. Aging fleet challenge: calling for incentivisation to extend operational lifespan of existing fleets

According to the European Transmission System Operator (TSO) (ENTSO-E) [6], the existing flexible generation capacity, currently dominated by dispatchable thermal turbines, will see a net decrease in capacity from 2025, if no remedial actions are taken, as shown in *Figure 2.*

Figure 2: ENTSO-E forecast for flexible generation capacity additions and reductions compared to the National Trends scenario (Non-cumulative) [6].

This substantial reduction in flexible capacity, mainly triggered by economic decommissioning, will inevitably create a substantial adequacy risk. Appropriate incentives and targeted interventions will be necessary to mitigate these risks.

Extending the lifespan of existing dispatchable thermal turbine plants is technically feasible for many, but it is not commercially viable under current market conditions due to high capital investment requirements, uncertainty about fuel price and availability, and revenue risks, all of which complicate investment decisions.

Call to action 4.

We urge the European Commission and European Parliament to implement appropriate financial incentives and supportive regulatory frameworks that encourage the extension of the operational lifespan of existing dispatchable thermal turbine fleets to ensure energy security for the future.

Conclusion

The European electricity system is undergoing a major transformation, transitioning from a fossil fuel-dominated system to one primarily reliant on Variable Renewable Energy (VRE) sources such as wind and solar.

As more non-dispatchable renewables are integrated, the grid's flexibility must significantly increase to handle periods when these sources are unavailable—such as when the wind is not blowing, or the sun is not shining.

By 2030, Europe must double its flexibility resources to meet daily, weekly, and monthly variability in electricity supply and demand, with a fivefold increase required by 2050. This growing need, as highlighted by the European Commission's Joint Research Centre, underscores the critical importance of secure, affordable, and low-emission electricity to avoid grid instability and blackouts.

To address these challenges, the European Commission and European Parliament must take decisive action to boost availability of flexible resources, including energy storage systems, smart grids, and dispatchable power generation technologies. This means supporting rapid deployment of these technologies to provide the necessary capacity to balance supply and demand effectively.

Dispatchable thermal turbines, especially those powered by low-carbon/carbon-neutral fuels, are essential for providing reliable grid services and flexibility, thereby ensuring a stable and resilient energy system. However, current EU energy and environmental policies, including decarbonisation maps, lack clarity on the critical supportive role of dispatchable thermal turbines in the energy transition and future carbon-neutral energy system. Additionally, limited availability of low-carbon and carbon-neutral fuels, high-costs and insufficient large-scale operational testing are delaying necessary investments.

This uncertainty is slowing the decarbonisation of the power sector and wider industry. Companies are forced to allocate significant financial and human resources to contingency planning instead of project execution due to unclear policy directions. Clear decarbonisation policies and pathways would facilitate decision-making for utilities, energy companies, and technology developers, accelerating the energy transition. Such clarity would enhance the appeal of energy-related careers, address public concerns about electricity reliability, and support the development of a skilled and future-ready workforce.

We therefore urge the European Commission and European Parliament to consider our four highlighted calls to action and to propose clear policies and financial incentives to support dispatchable thermal turbine technologies and prepare Europe's grid for the future.

Glossary

Carbon-neutral fuel

Carbon-neutral fuel is a fuel whose net carbon emissions are zero, achieved by balancing the CO_2 released during its use with an equivalent amount of CO_2 removed or offset.

Combined Cycle Turbines

Combined Cycle Turbines are high-efficiency power generation systems that combine gas and steam turbines. Exhaust heat from the gas turbine generates additional electricity via a steam turbine, achieving over 60% conversion efficiency. Ideal for baseload generation.

Frequency Control

Frequency control refers to the process of maintaining the grid's frequency (usually around 50 or 60 Hz) within a safe range. If the frequency deviates too much due to an imbalance between electricity supply and demand, it can damage equipment and cause blackouts. Frequency control involves adjusting the output of power plants or using storage systems to quickly balance the grid. In Particular:

- **Primary control reserve (FCR)**: Fast-acting frequency control stabilizes short-term imbalances, typically within seconds, to keep grid frequency stable.
- **Secondary reserve (aFFR)**: Automated frequency restoration reserve manages ongoing imbalances after FCR, responding within minutes to adjust power output.
- **Tertiary Reserve (mFFR)**: Manual frequency restoration that provides backup for longer imbalances, typically activated within 15 minutes.

Inertia

Inertia is the power system's resistance to sudden changes in frequency, typically provided by the rotating mass of large generators in thermal or hydroelectric plants. It helps keep the grid stable by slowing down the rate of frequency changes when there's a sudden imbalance between supply and demand.

Load Following

Load following is the ability of a power plant to adjust its electricity output based on changes in demand throughout the day. Unlike base-load plants that run continuously at a steady output, load-following plants increase or decrease production as needed to match electricity demand fluctuations. In particular:

- **Daily flexibility:** Short-term adjustments to meet daily demand fluctuations in the power grid
- **Seasonal flexibility**: Long-term adjustments to handle predictable seasonal changes in energy demand and supply.

Low-carbon fuel

Low-carbon fuel is a fuel that generates significantly fewer carbon emissions when burned compared to traditional fossil fuels. These fuels still emit some carbon, but the total emissions are lower, either because the fuel is inherently cleaner or because it is produced in a way that has a reduced carbon footprint (e.g., biofuels, hydrogen, or synthetic fuels).

Open Cycle Turbines

Open Cycle Turbines are simple, single-cycle thermal systems where exhaust gases are released directly without additional recovery, resulting in moderate efficiency (~35-45%). This simplicity, together with the lower cost and the capability to quickly start-up and adjust to a given load, make them suited for peak demand and rapid-start applications. The term "Gas" turbine refers to the state of the fluid (air) used, as opposed to "Steam" turbines.

Peakers

Peaking power plants, or peakers, are designed to quickly ramp up production during these peak demand times to ensure enough electricity to meet the increased demand. Unlike base-load plants that run continuously, peaking plants are only used when demand spikes, making them crucial for maintaining the stability of the energy grid during periods of high usage.

Peaking

Peaking refers to the periods when electricity demand is at its highest, often called "peak demand" times. These typically occur during certain hours of the day or in extreme weather conditions when many people use electricity simultaneously, like in the evening when people return home from work or on a hot day when air conditioners run at full capacity.

Post-combustion carbon capture

Post-combustion carbon capture is a method to capture CO_2 from the exhaust gases of power plants after combustion, mostly using chemical solvents. The captured CO_2 is then separated, compressed, and transported for storage or use, preventing it from being released into the atmosphere.

Sector Coupling

Sector coupling interconnects the power sector with the broader energy sector (e.g. heat, gas, mobility). This way the energy distribution across these sectors can be optimised, advancing decarbonisation in all sectors.

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