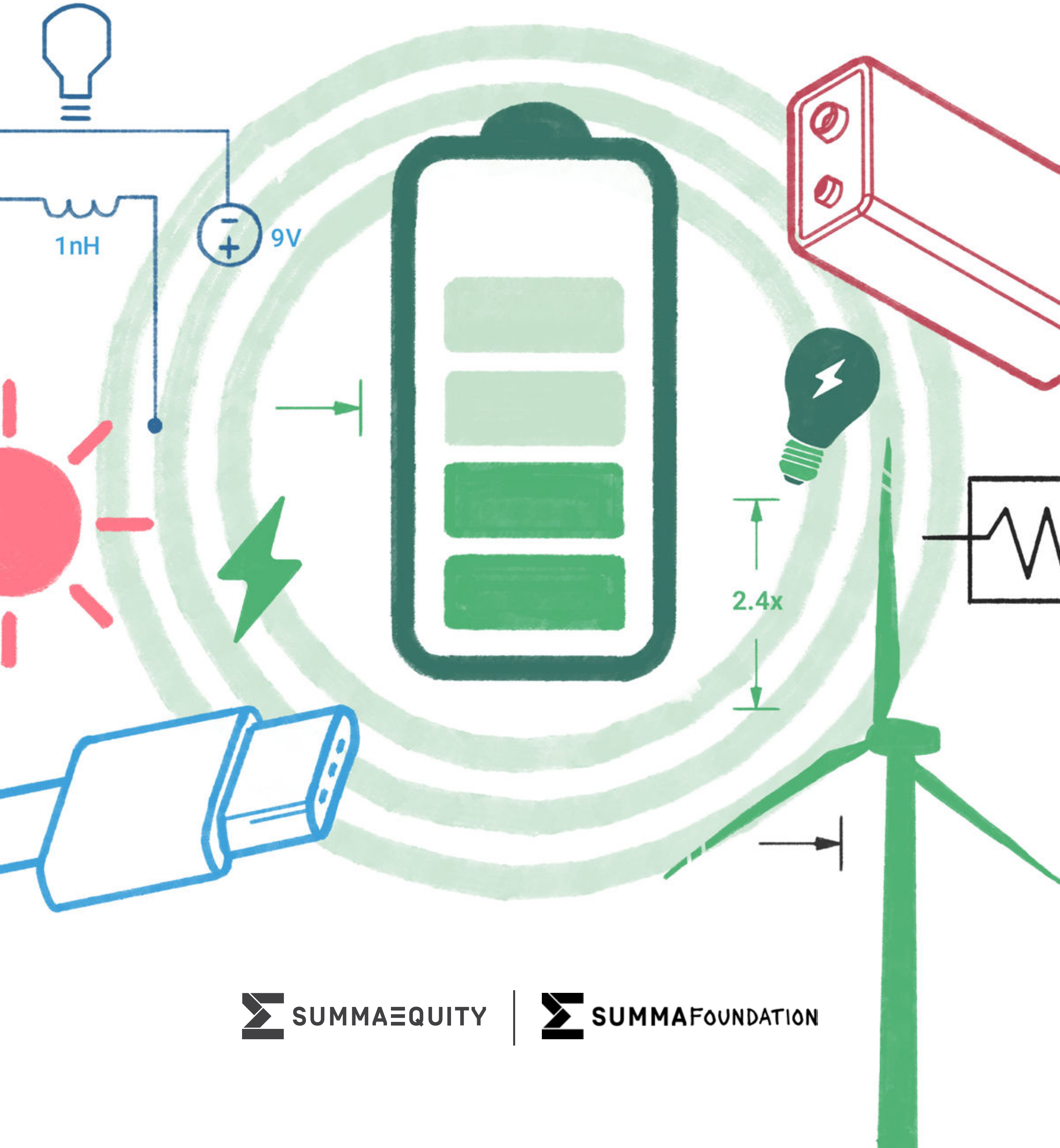
Investing in the energy system of the future



SUMMA EQUITY | SUMMA FOUNDATION

What we talk about when we talk about power: An overview of common terms and concepts

Core concepts

Power:	Instantaneous rate at which electricity is produced or consumed. A measurement of rate/speed/flow of electricity.
Energy:	Total amount of electricity generated or consumed over time.
Voltage:	The "pressure" at which electricity moves through the system. High voltage is more efficient for long-distance transport, low voltage for household use. Transformers are required to move between high and low.
Current:	Flow of electrical charge through a conductor. Either AC (alternating current) where direction reverses (standard for national grids) or DC (direct current) where charge flows in one direction (standard for long distance transmission)
Frequency:	The rate at which AC power oscillates. Must remain stable for the grid to function as changes can cause equipment damage or blackouts. Deviations signal imbalance between supply/demand.

System structure

Generation:	How electricity is produced. Includes thermal combustion of coal, gas, and biomass, renewable energy such as solar, wind and hydro, and nuclear power
Transmission:	High-voltage, long-distance transport of electricity across regions
Distribution:	Lower-voltage, local delivery of electricity to homes and businesses
Baseload power:	Generation that operates continuously at steady output (e.g., nuclear)
Dispatchable power:	Generation that can increase or decrease output on demand (e.g., gas, flexible hydro, batteries)
Variable renewable energy:	Generation that is dependent on weather conditions for production (e.g., solar, wind)

Grid operations:

Frequency regulation:	Fast adjustments in supply or demand to keep the system at correct frequency and prevent instability
Inertia:	The system's natural resistance to frequency changes. Traditionally provided by spinning turbines, increasingly provided via synthetic inertia
Voltage control:	Maintaining voltages across grid
Reserves:	Additional capacity (generation or flexible demand) that can be activated quickly to maintain grid operations

Demand and flexibility

Flexibility:	The ability to shift production or consumption to match system needs or in response to market signals
Demand response:	Consumers adjusting when they use electricity in response to system change

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Preface

The future of energy is electric, and it is arriving faster than almost anyone predicted. The system that powered two centuries of financial prosperity, built on extracting, moving, and burning fossil fuels, is no longer fit for the world we live in.

A better system is emerging in its place: one that is sustainable, reliable, affordable, secure, and abundant. At Summa, we are investing to bring that system forward.

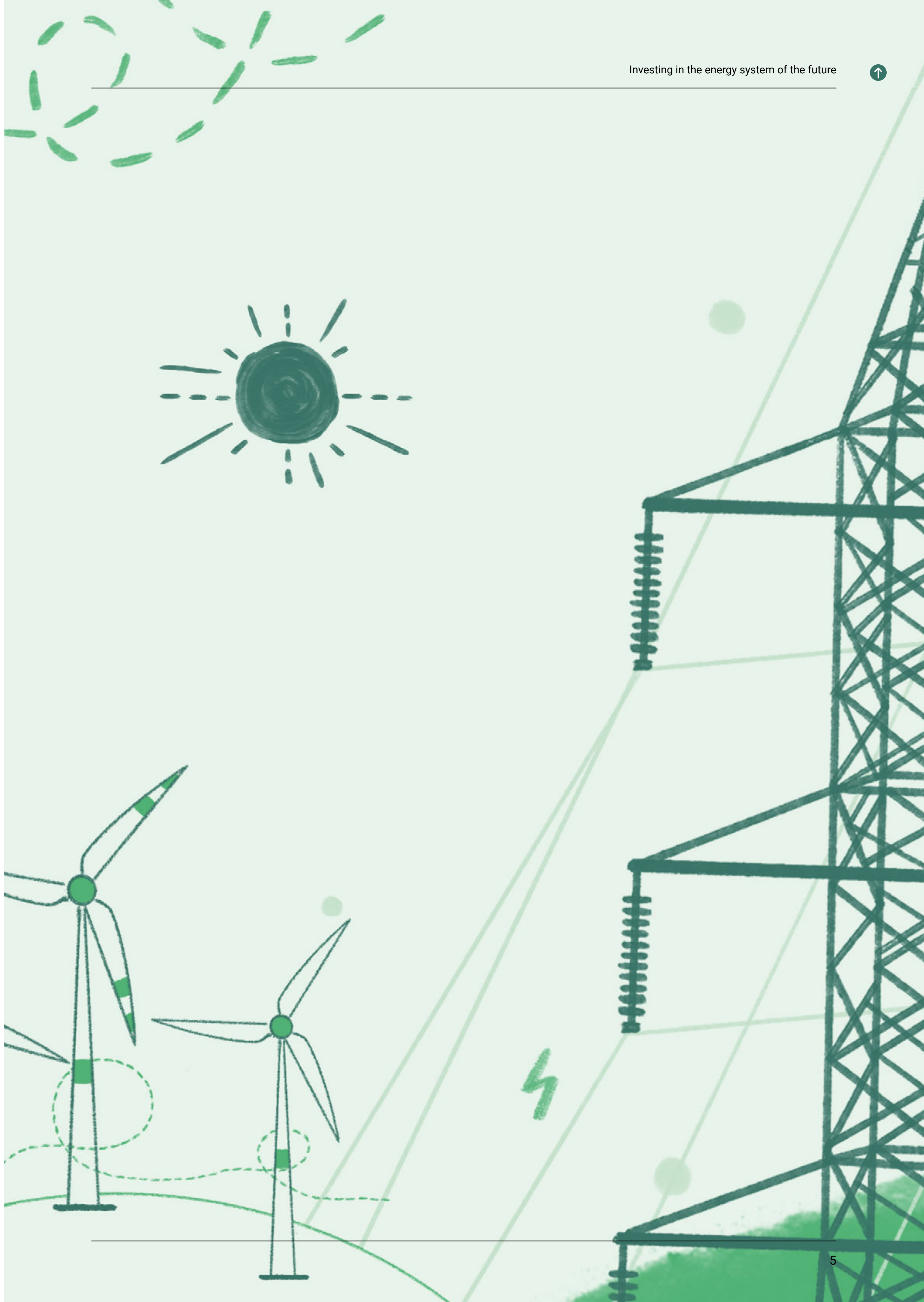
We believe the direction of travel is set. World events have made it clear the majority of humanity can no longer be dependent on fossil fuels and subject to the associated geopolitical uncertainty. Moving electrons is cheaper, cleaner, and more efficient than moving and burning molecules, and electricity is the only energy carrier that gets cheaper and more secure the more we deploy it. Solar costs have fallen by more than 90% since 2010, batteries are scaling at extraordinary speed, and more than 75% of end use energy can already be electrified with commercially available technology. The economics now favor the transition on their own merits, which is why renewables make up the overwhelming majority of new generation capacity, even in markets with no climate mandate at all. This is no longer a question of if, but of how fast.

The transition is moving too slowly to deliver the scale and stability the moment demands. The constraint is not generation but the system around it: ageing grids, market rules designed for a fossil age, and stability services procured from large centralized plants. This is precisely where Summa focuses. Guided by our Theory of Change, we back companies whose products and services unlock the bottlenecks holding the transition back, across four themes that span the full value chain: Sustainable Generation, Enhanced Grids, Electrified Demand, and System Services & Flexibility. This way, we get far more from what we have already built, and accelerate a transition that benefits investors, humanity, and the planet alike. We estimate these activities represent a EUR 1.2 trillion annual market in Europe and North America by 2030, capable of unlocking EUR 5 trillion in investor value and a further EUR 800 billion in annual ecological value.

This report lays out the case in full. It examines the legacy system we have inherited and why it can no longer meet our needs. It sets out the electric, distributed, and digitally coordinated system we envision and why we are confident it is both feasible and necessary. It maps where the transition is progressing, where it is lagging, and how targeted capital can move it forward. It is, ultimately, an invitation to see the energy transition not as a cost to be managed, but as the defining investment opportunity of our generation, and to help build the system we want to pass on.

Gisle Glück Evensen
Partner

Annika Moman
Industrial expert



Executive Summary

The energy system we inherited was built for a different era: centralized, fossil-based, pollutive, exposed to geopolitical shocks, and increasingly expensive. A new system is emerging to replace it, one that is electric, distributed, and digital, delivering energy that is sustainable, reliable, affordable, secure, and abundant. The shift is no longer a question of if, but of how fast. The greatest value for the economy and the planet, lies in the solutions that accelerate the transition.

The legacy energy system is no longer fit for purpose. Built around extracting and burning fossil fuels, it wastes two-thirds of primary energy before use, causes 8.7 million premature deaths from air pollution globally each year, and leaves economies exposed to shocks.[1] A fuel-based system hands leverage to whoever has the fuel, and that is important when you remember the EU imports 96% of its oil and 89% of its gas.[2] After the Russian full-scale invasion of Ukraine, this dependence translated directly into household energy bills increasing by more than 50%, and a collapse in the competitiveness of European industry. This was not a one-off event, as a similar dynamic is playing out across the economy as the impacts of the closure of the Strait of Hormuz reverberate.

A new system is emerging that meets today's needs: one that provides sustainable, reliable, affordable, secure energy in abundance. The future system, and economy, are electric. Moving electrons is far more efficient and cheaper than moving and burning molecules, and electricity is the only energy carrier that gets cleaner, cheaper, and more secure the more we deploy it. More than 75% of end use energy can be electrified with commercially available technologies, and the underlying economics are already favorable.[3] Solar PV costs are down by more than 90% since 2010, battery investment is growing at 30% per year, and electric vehicles and heat pumps routinely outperform combustion engines and gas boilers on efficiency by two to three times, or more.[4]

Sustainable power generation, and the increasing demand for it, are pushing the energy transition forward. Yet critical elements needed for the future electric system continue to lag. There is notable grid investment debt: in the US, new transmission capacity installation has decreased by 21% annually despite a need to double by 2050. In Europe, new transmission lines take on average 10 years to build. System-stability services remain designed around fossil plants, and the electrification of heat, transport, and industry is outpacing the ability of the existing system to support it. These physical, regulatory, and operational bottlenecks are slowing the transition.

We believe there is significant opportunity for investors to unlock these bottlenecks with market-ready solutions that can accelerate the transition using existing infrastructure, while making smarter decisions about what to build new. These solutions represent a material and attractive near-term market.

6

1. IEA, "Key World Energy Statistics" (annual); Lawrence Livermore National Laboratory, "Estimated US Energy Consumption" (Sankey diagram, annual); Vohra, K. et al. (2021)
2. Eurostat, "Oil and petroleum products — a statistical overview"; Eurostat, "Energy production and imports — Statistics Explained"
3. IEA; BNEF; Ember
4. IRENA; IEA

Our analysis indicates an annual value of EUR 1.2 trillion by 2030, generating EUR 5 trillion in investor value and contributing to an additional EUR 800 billion in direct ecological value by moving away from fossil fuels. Our core investment themes include:

Sustainable generation: Supply of reliable and affordable electricity where and when it is needed

Enhanced grids: Unlocking latent grid capacity and improving system performance

Electrified demand: Conversion to sustainable electricity for most end uses

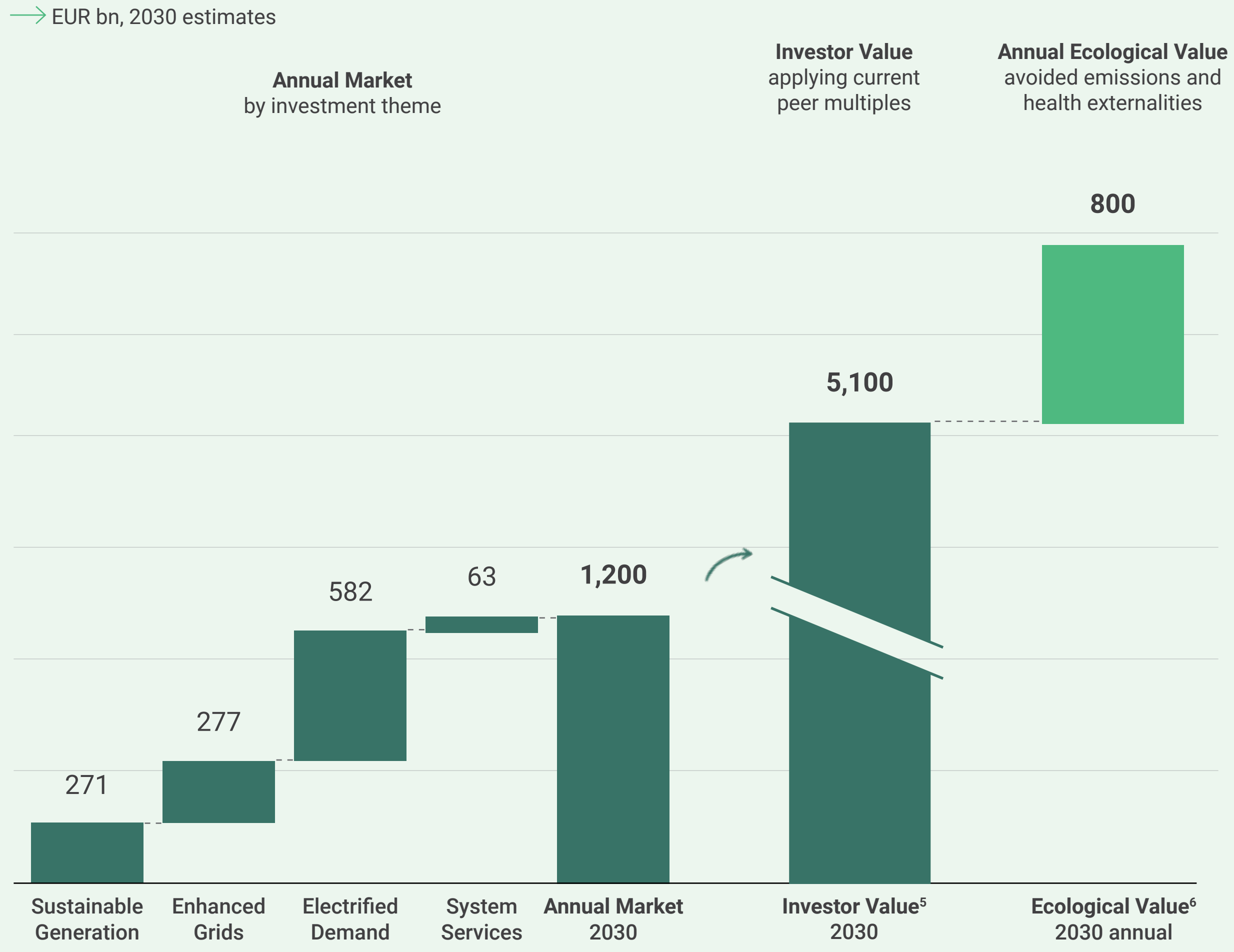
System services and flexibility: Designing, installing, operating, and maintaining a dynamic and flexible modern energy system

Summa invests in these themes to create value and solve global challenges. Our Theory of Change provides the structure: we back companies whose outputs directly produce the outcomes required for a sustainable, reliable, affordable, secure, and abundant energy future. Those outputs include more electrified demand, more sustainable generation, a stable grid, and robust system services.

The energy transition we envision is already on its way. But it is moving too slowly to deliver the scale and stability needed to support industrial competitiveness, protect households from volatility, and strengthen geopolitical resilience, all while operating within planetary limits. Achieving this requires investments focused on the solutions best able to accelerate the transition, those that remove bottlenecks and leverage existing infrastructure to drive short- and long-term impact.

Figure 01
The energy transition investment opportunity in Europe and North America

Summa's role in the future energy system: a EUR 1.2 tn annual market by 2030, unlocking EUR 5tn in investor value and EUR 800 bn in annual ecological value



5. Market valuation refers to the estimated enterprise value of companies providing transition-enabling solutions across the four themes, based on current peer-group trading multiples applied to 2030 addressable revenue.

6. Ecological value is the annual societal externality avoided in Europe and North America under the IEA Net Zero 2050 Scenario versus announced policies, scaled to our four themes' share of avoided emissions. It combines avoided emissions (social cost of carbon) and avoided air-pollution health damages (value-of-statistical-life estimates). A conservative lower bound, excluding wider ecosystem, water, and land impacts, reported separately from investor value.

The legacy energy system

The legacy energy system was designed for centralized, fossil-based power and one-way flows. At its core, it is a polluting and extractive industry that is increasingly vulnerable and expensive.

Modern economies, in particular the wealth and prosperity of the western world, have been enabled by an energy system built around hydrocarbons and the industrialization they powered. Hydrocarbons are extracted from a select few resource rich locations around the world, transported long distances, and inefficiently converted to the energy we use to power our homes, industries, hospitals, food systems, and all elements of modern life. This approach has caused environmental damage in the form of air, water, and land pollution, and left our economies vulnerable to geopolitical influences.

The legacy energy system is under pressure from the realities of the present. Built for a different era, it now faces mounting pressure from increasing demand and the emissions it produces.

The electrification of transport, heating, and industry, alongside rapid growth in data centers, is reshaping load patterns and increasing peak demand. Together, climate volatility and structural demand growth are placing stress on an energy system that was not designed for this level of complexity, variability, and intensity.

A chronic lack of investment in infrastructure modernization, inadequate market design, and a fragmented approach to systemic change have resulted in an energy availability and affordability crisis. In Europe, household bills are up more than 50% and energy-intensive industrial operations, for example petrochemicals, are moving to geographies with access to lower fuel costs, causing widespread job losses and local economic harm.

+50%

European household energy bills have increased by more than 50% since the invasion of Ukraine, exposing how the legacy energy system creates both affordability and availability risks.

Designed for fossil fuels: a centralized and noninteractive model

Investing in the energy transition begins with understanding the system we have inherited: what it was designed to do, how it was structured, and how infrastructure, market frameworks, and operational rules interact to deliver energy to the economy today.

The legacy power system was built to economically convert hydrocarbons like coal, oil, and gas into reliable and affordable electricity at scale. This objective drove specific design choices across generation, transmission and distribution, demand, and support services. These design choices were logical for their time and have formed the backbone of the power systems for decades.

The result was a coherent system architecture built on scale, predictability, and centralized control. It was a design that delivered decades of stability and reliability, but one whose embedded assumptions are shaping the constraints we must now navigate in building and transitioning to the next generation energy system.

At its core, the legacy power system is a centrally coordinated machine: large generators produce electricity in real time, operators keep the system in continuous balance, and the grid transports power to end users through a largely one-directional network. This system can be defined in four elements: generation, grid, demand, and the supporting services that are governed by a set of technical realities, market rules, and operational practices. The fundamentals largely reflect the logic of the time when the system was built and continue to underpin how the power system functions today. Understanding them is essential, not to critique the past, but to recognize how the system's original logic both necessitates and constrains the transition now underway.

Figure 02
How the Legacy Power System Works

The power system is a one-way chain: large plants burn fuel to generate electricity, the grid carries it outward to passive end users, and an operator coordinates the whole process in real time. System stability services are embedded in generation, a byproduct of the large spinning turbines that produce power.

Physical infrastructure

Generation	Services	Grid	Demand
Fuel is burned to produce electricity	**Stability and balancing needed to keep frequency and voltage in balance**	**Transmission and distribution carry power one-way to end users**	**Passive consumption by homes, businesses, and industry**
Fuel is combusted to create steam that spins turbines, producing electricity. Plants are sited near fuel and cooling water, concentrating generation in a small number of large facilities.	The spinning mass of thermal turbines provides additional inertia that stabilizes grid frequency. Stability is a byproduct of generation, not a separately procured service.	High voltage lines carry power outward from generation hubs; substations step it down into local networks of poles, transformers, and progressively smaller wires. Largely analog, built for one-way flows.	Each premises connects through a one-way service drop and a simple meter, designed for power to flow in. Equipment draws power on its own schedule, with no communication received back to the grid.

Institutional design

Economies of scale	Bundled with generation	Slow capital, fragmented planning	Passive metering
Larger plants produce cheaper electricity per unit, concentrating investment in fewer, bigger assets at sites with fuel access and cooling water.	Governance standards, reserve requirements, and connection protocols assume large dispatchable plants that inherently provide stability alongside electricity.	Grid investment is funded through regulated cost recovery. Distribution was built bottom-up to serve local needs. New lines take a decade or more to permit and build.	Meters record what was consumed, with limited visibility on time and magnitude. Occasional price signals are the only communication received regarding the grid status.

System Operator spans the full value chain - operates the full system in real time

Real-time balancing
Supply and demand must match at every instant. The operator dispatches generation and activates reserves to maintain balance. The system has no buffer.

Marginal-cost pricing
Generators bid to supply; the operator dispatches cheapest first until demand is met. The last unit needed sets the price for all, and that unit is frequently a fossil-fuel plant.

Governance standards
Reliability codes, reserve requirements, and connection protocols assume large, dispatchable plants providing one-directional flows with inherent inertia.

Note: This exhibit describes the predominant architecture of the existing system. There are nuances and exceptions locally and regionally.

Unlike other services today, electricity generation and demand must match at every moment. This fundamental constraint affects every aspect of the legacy system.

Real-time system equilibrium as the core operating constraint
Electricity systems operate under a fundamental constraint: generation (the supply of power) and demand must match at every moment. Frequency and voltage stability depend on this continuous equilibrium. If balance is lost, instability or outages follow. Unlike many other systems, the power grid has historically had no meaningful buffer.

A simple way to understand this is to compare it to a streaming service. When you press play, the platform downloads several seconds of content in advance to create a buffer. That buffer absorbs disruptions. Without it, streaming would be unreliable or extremely costly. The traditional power system, by contrast, was designed to function without such flexibility. It must respond instantly, in real time, to fluctuations in demand.

This requirement for continuous balance underpins every aspect of system design. Engineering standards, operational protocols, and market structures were all built around the need to maintain equilibrium. Dispatchable power plants, reserve capacity, and automated control systems work together to respond to second-by-second variations in consumption.

This challenge is exacerbated by the AC nature of our grid. Though a DC system would not eliminate the real-time equilibrium requirement, it would greatly reduce the friction of deploying tools to mitigate it. Batteries would couple more directly, providing more buffer capacity, and frequency would no longer be an issue.

Understanding this real-time constraint is essential. It explains both the strengths of the legacy system, its reliability and precision, and the structural challenges it faces as we transition toward a more distributed, renewable, and dynamic energy landscape.

Centralized, large-scale generation as the organizing principle of system design
Historically, the technologies capable of delivering reliable, affordable electricity at scale were large thermal and nuclear plants. These plants use combustion of hydrocarbons or nuclear fission to heat water and create steam which in turn drives turbines to create electricity.

These turbines serve as the core of the power system. They generate power, and their rotating mass of turbines also provides the inertia that buffers the network against sudden disturbances and helps keep frequency and voltage within acceptable limits. They are the first line of defense in maintaining that essential real-time system equilibrium. They produced reliability alongside electricity, which is the insurance that the power network at large can stay online.

Thermal and nuclear plants also benefited from economies of scale. Larger facilities typically meant lower costs per unit of electricity, reinforcing a model built on centralized, high-capacity assets with long operating lifetimes. However, these large plants have to be located where fuel logistics and cooling water are available, creating geographic concentration.

As these assets were deployed, grid infrastructure expanded outward from centralized generation hubs toward cities and industrial centers. Planning frameworks assumed a relatively small fleet of controllable generators would anchor reliability. Operational practices, market design, and investment decisions were all organized around this centralized model.

Designed for distribution, not interaction

With centralized generation as the organizing principle, the grid was engineered to transport electricity outwards, from large production hubs to dispersed end users. The underlying logic was clear: supply is centralized, demand is distributed, and the grid's role is to connect the two.

The legacy grid is not a single piece of infrastructure but rather a heterogeneous set of interconnected physical and digital assets under different ownership and management. At its heart, the grid consists of wires: high voltage transmission lines transporting power from the generation assets through a series of distribution grids to end users, being stepped up or down in voltage as necessary. It is an architecture built for scale and reliability, optimized for predictable, one-way flows.

Much of the existing control infrastructure reflects this origin. Many of the systems that operate the grid today are analog, and the controls themselves are mechanical devices. 70% of the US power grid is over 25 years old, with much of it 50 years old, predating digital controls completely.[7] Response times are in the tenths of seconds, rather than the milliseconds of today's power electronics, leading to mismatched response times to faults or other variations across the system.

Additionally, the grid architecture did not anticipate power production by consumers, such as solar panels on homes, seeing them instead as passive users of power. This led to "dumb" meters and controls capable of responding to one input, rather than dynamic response, giving limited visibility and limited capacity to integrate assets that behave differently from traditional one-way demand.

7. US DoE, "Pathways to Commercial Liftoff: Innovative Grid Deployment"

Investing in the energy system of the future

Governance, process, and pricing in a centralized, fossil-based system

The centralized thermal system has impacted more than the power system's physical infrastructure of turbines, wires, and substations. The thermal paradigm has also defined the complementary services, governance, and market making that was created alongside the physical to ensure a robust power system.

Operational governance evolved to keep the centralized system synchronized and resilient. System operators schedule resources, manage reserves, and coordinate interconnections with specific standards and frameworks adopted for how support services can be activated to maintain a constant balance between supply and demand. These operators and standards assume the availability of controllable, dispatchable generation and a network designed for one-directional power flows. Reliability services, balancing mechanisms, and grid codes were all constructed around this foundational premise.

Market design followed the same logic. Wholesale electricity prices are typically set by the marginal generator needed to meet demand in a given time interval. Generators submit bids of how much electricity they can provide at a given price, the operator orders the bids from cheapest to most expensive, and the price is equal to the most expensive generation required to meet demand. In practice, this marginal unit has historically been fuel-based, typically either coal or gas, anchoring electricity prices to volatile fuel markets.

Because margins depend largely on fuel efficiency and operational scale, this pricing mechanism reinforced the pursuit of larger, more efficient thermal plants.

70%

of the US power grid is over 25 years old, with much of it 50 years old, predating digital controls completely.

The legacy energy system reflects a tight alignment between physical infrastructure and institutional design. The capabilities of large-scale thermal generation shaped both how electricity was produced and how markets were structured, how operators governed the system, and how infrastructure was built. The result was a coherent and highly effective model, one that delivered reliable power at scale and underpinned decades of economic growth.

But coherence does not equal adaptability. The very characteristics centralization, predictability, and tight operational coordination that made the system successful also created structural rigidity. As the energy landscape shifts towards decentralization, electrification, and renewable generation, these embedded assumptions are increasingly being tested.

An outdated system not suited for today's energy needs

The foundations of the legacy power system have delivered reliable electricity for more than a century. Many of the principles, operational practices, and technical standards still in place today trace their roots back to the early days of electrification, when Thomas Edison energized one of the first centralized power stations in New York in 1882. The durability of that design is a testament to its success.

But systems built for one era inevitably reflect the assumptions of that era and not the requirements of the future.

Six constraints cause both systemic pain points and investment opportunities in building the system the future requires:

- Structural energy inefficiency embedded in thermal conversion
- Limited visibility and functionality at the grid edge
- Dependence on centrally controlled, dispatchable generation
- Fragmented grid development limiting regional resilience
- Infrastructure and capacity sized for peak usage
- Pricing decoupled from the cost of production

These constraints relate to one or more of the generation, services, grid, and demand.

Structural energy inefficiency embedded in thermal conversion

Combustion-based generation is inherently inefficient. Roughly two-thirds of primary energy is lost as heat before electricity reaches end use, a consequence of the physics of thermal conversion. Globally, an estimated USD 4.6 trillion worth of energy is effectively lost each year from the use of hydrocarbons as energy.[8] This means the system requires significantly more fuel input than the useful energy ultimately delivered. Historically, these losses were accepted as the cost of securing predictable and controllable output. Today, they represent a structural inefficiency embedded at the core of the legacy model.

Limited visibility and functionality at the grid edge

Because the system was built for outward delivery only, distribution networks and metering systems were designed primarily for consumption measurement rather than active coordination. This limits real-time visibility at the grid edge and constrains the ability to actively manage demand.

As a result, system operators maintain balance primarily through supply-side adjustments, relying on generation and reserves rather than flexibility from end users. The system therefore operates with a relatively coarse understanding of demand and limited capacity to integrate distributed or responsive assets. This structural limitation often leads to higher-cost interventions to maintain stability, costs that ultimately flow through to consumers.

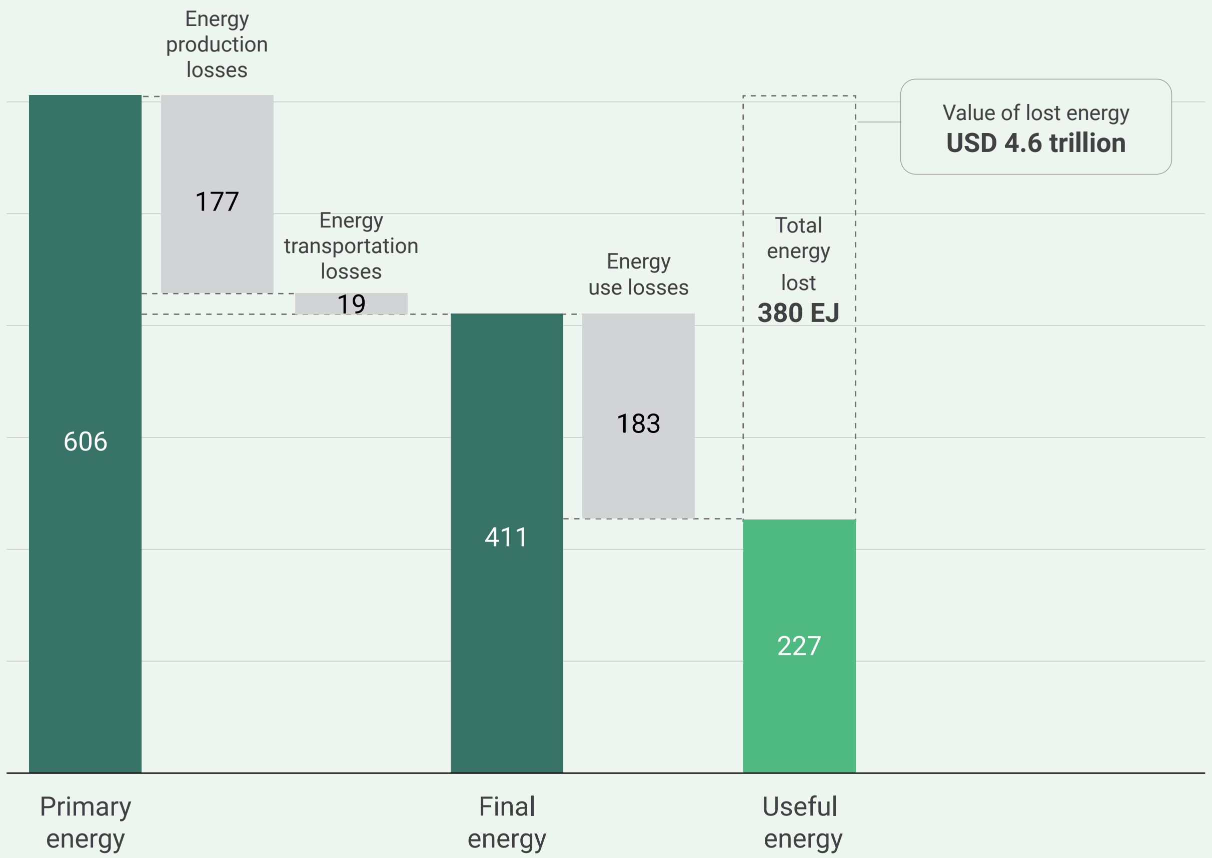
Dependence on centrally controlled, dispatchable generation

The geography of centrally-located power plants, based on fuel and cooling water accessibility, shaped the operating logic as well as the infrastructure.

Figure 03
The legacy energy system is highly inefficient with significant energy lost as heat from combustion

The current fossil energy system is inefficient.
Two thirds of the energy is lost in combustion as heat.

Global energy flows and waste, EJ per year, 2019



8. Ember Energy, "The Electrotech Revolution" (2025)

System operations were designed around the assumption that a relatively small number of large, controllable units would respond predictably to dispatch signals. Operators schedule output, manage reserves, and maintain stability based on this model. Reliability standards, reserve requirements, and institutional roles were therefore calibrated to the characteristics of thermal generation.

Over time, this has created a structural dependency on centrally visible, dispatchable assets. The system's ability to maintain balance and manage contingencies remains closely tied to resources that can be directed and coordinated in real time. While highly effective for the technologies on which the system was built, this dependency constrains the integration of new generation and flexibility solutions that may be more efficient, distributed, or user-centric, but do not share the same physical characteristics as thermal plants.

99%

In many markets, peak demand occurs for fewer than 100 hours per year. For the remaining 99% of the time, much of the infrastructure built for that peak remains underutilized.

Fragmented grid development limiting regional resilience

While generation evolved around centralized assets, many grid networks developed in a far more fragmented way. Distribution infrastructure was built locally, often to address specific regional needs rather than as part of a coordinated national or continental strategy. In many markets, this bottom-up approach continues to shape grid expansion and reinforcement decisions today.

The result is a patchwork of networks optimized for local reliability, but not necessarily for interoperability or shared resilience. When disruptions occur, whether from faults, extreme weather, or other shocks, locally bounded systems have limited ability to import or export power across regions. Instead, they must either accept lower reliability or invest in redundant back-up capacity, rather than co-investing in shared robustness at scale, increasing overall system cost.

There are, however, signs of progress. In Europe, recent updates to the Renewable Energy and Electricity Directives are enabling greater cross-boundary cooperation and energy sharing. The emergence of localized energy communities allows participants to generate, share, and manage renewable electricity more flexibly. These models can reduce strain on the broader grid while enhancing resilience for connected users, illustrating how more coordinated approaches can strengthen the system as a whole.

Infrastructure and capacity sized for peak usage

Electricity systems have historically been designed around peak demand. Generation capacity, transmission lines, and distribution networks are sized to meet the highest level of consumption, even though in most markets, that peak occurs for fewer than 100 hours per year.[9] For the remaining 99% of the time, infrastructure remains underutilized.

This design principle has ensured reliability during extreme heatwaves or cold spells, but it comes at a cost. Consumers ultimately pay for standby generation and grid capacity that sits idle for most of the year. Utilities, in turn, must hold this capacity in reserve and cannot freely allocate it to new loads, as it serves as insurance against short-lived demand spikes.

Pricing decoupled from the cost of production

Wholesale electricity markets were built around the economics of thermal generation, with prices set by the marginal unit needed to meet demand in each interval. Historically, this marginal unit has been a fuel-based plant. This mechanism created an efficient way to coordinate dispatch in a system dominated by controllable thermal assets, but it also structurally links electricity prices to the volatile markets for oil, gas, and coal.

As a result, price signals today continue to reflect the economics of the legacy architecture, even as the generation mix evolves. When the marginal cost of production diverges significantly from the average cost, particularly in systems with large shares of low-marginal-cost renewables, end users can end up paying substantially more than the underlying cost of generating electricity. The pricing model remains anchored in yesterday's system logic, even as the physical system begins to change.

9. IEA, "Electricity Grids and Secure Energy Transitions" (2023)

Externalities: the energy system is pollutive, extractive and increasingly vulnerable and expensive

Fossil fuels impose large and often invisible societal and environmental externalities. The extraction and combustion of fossil fuels damage ecosystems, degrade lands, and drive climate change, while air and water pollution create severe public health burdens. These impacts translate into economic losses through climate-related damage to infrastructure, higher healthcare spending, and reduced productivity. The burdens fall unevenly, with low-income and marginalized communities disproportionately exposed to pollution and economic volatility. At the global level, dependence on fossil fuels amplifies geopolitical risks, including energy-security challenges and tensions tied to resource dependence.

Human health: the hidden cost of the legacy energy system

The extraction, transport, and combustion of fossil fuels releases fine particulate matter, nitrogen oxides, sulfur dioxides, carbon monoxide, and volatile organic compounds. This is the root of a major global public health crisis.

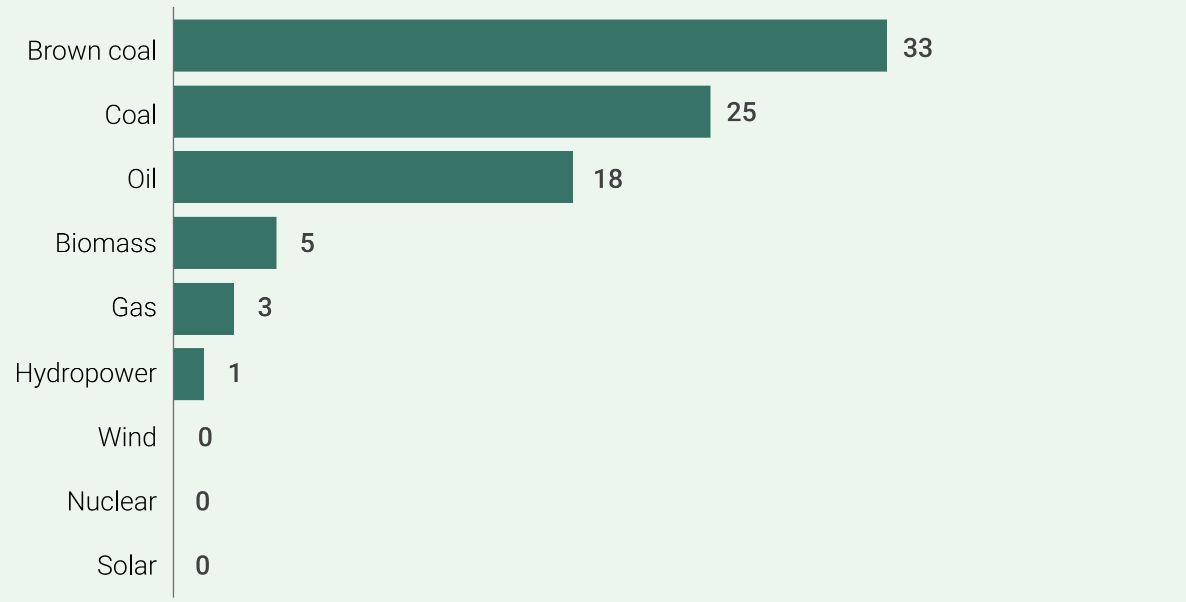
The air pollution from fossil fuel combustion causes respiratory, cardiovascular, and cancer outcomes across the globe. These fossil-fuel related illnesses are estimated to lead to 8.7 million premature deaths annually globally.[10] The illnesses are preventable, economically costly, and disproportionately borne by vulnerable populations such as children, the elderly, and low-income communities.

Furthermore, these illnesses are closely linked to climate change, which amplifies health risks through extreme heat, disease spread, and food insecurity. This climate-change related risk has continued to increase, with heat-related mortality now exceeding half a million people per year, an increase of 63% globally between 1990 and 2021.[11] Fossil fuel health dangers are also costly, with estimates of the US health care costs from fossil fuel air pollution reaching USD 820 billion per year.[12]

Figure 04
Death rates per unit of electricity production

Death rates from fossil electricity far outstrip those of renewables

Number of deaths per TWh, 2021



Note: Death rates are measured based of deaths from accidents and air pollution per terawatt-hour of electricity
Source: Deaths per TWh energy production – processed by Our World in Data. "Deaths per terawatt-hour of energy production" [dataset]. Deaths per TWh energy production [original data].

10. Oxford's "Scientists' Warning on Fossil Fuels"; Vohra, K. et al. (2021)
11. The Lancet Commission on Pollution and Health "The 2025 Global Report"
12. NRDC / Medical Society Consortium on Climate & Health / Wisconsin Health Professionals for Climate Action, "The Costs of Inaction: The Economic Burden of Fossil Fuels and Climate Change on Health in the United States" (May 2021)

Communities located near fossil fuel extraction sites face sustained exposure to polluted air, contaminated water, and excessive light and noise. In the United States, people living within one mile of an oil and gas well have been found to face elevated risk of myriad adverse health outcomes including pre-term birth, impaired fetal growth, childhood asthma, and mental health disorders, among others.[13] Reducing fossil-fuel pollution and accelerating clean-energy transitions is therefore widely regarded as one of the most powerful and impactful levers available to improve global health and address structural inequalities.

74%

of the world's population lives in countries that are net importers of fossil fuels

Security: the geopolitical exposure of the legacy energy system

Global geopolitical externalities of fossil fuels are a core risk embedded in the current energy system. Oil and gas resources are geographically concentrated, giving a small number of countries outsized influence over global markets. In the first half of 2026, for example, it proved relatively simple for Iran to prevent ships using the Strait of Hormuz, through which 20% of the world's LNG passes. As of mid 2026, this exposed importing nations to price shocks, supply disruptions, and political leverage.

The European Union illustrates this exposure clearly: 96% of oil and 89% of natural gas is imported.[14] Globally, 74% of the world's population lives in countries that are net importers of fossil fuels, embedding external dependency into national energy security.[15]

Fossil-fuel supply chains are highly sensitive to geopolitics, conflict, sanctions, and extreme weather. When instability occurs, volatility is transmitted directly to consumers and industry. Europe's heavy reliance on Russian pipeline gas contributed to the strategic vulnerabilities that became evident following Russia's full-scale invasion of Ukraine in February 2022, and the subsequent energy crisis. Immediate gas prices spiked by 300%, eventually stabilizing at levels roughly 50% higher than pre-invasion averages, leading to material impacts for both households and businesses.

While much of that gas demand has shifted to imported LNG, dependency remains, simply in a different form. Reliance on global LNG markets can introduce new geopolitical dynamics, where exporting nations gain potential leverage. For example, US LNG exports have become strategically significant, and energy relationships can intersect with broader political considerations, as seen in past discussions under the Trump administration regarding Greenland and Arctic strategic interests. The Strait of Hormuz blockade made this even more relevant.

This exposure is unique to fossil fuels. The energy generated over time by a single container ship of solar panels would require approximately 50 LNG tankers or 100 coal shipments to match. Once deployed, renewable assets reduce the need for continuous fuel imports, and the geopolitical vulnerabilities that accompany them.

13. PSE Healthy Energy, "Health Effects of Oil and Gas Development" (literature review, updated 2024); also Gonzalez, D.J.X. et al. (2022), "Upstream oil and gas production and ambient air pollution in California," Environmental Health Perspectives, 130(5).
14. Eurostat
15. Ember Energy, "Energy Security in an Insecure World" (2025)

Figure 05
Renewables have potential to drastically reduce import dependence for EU

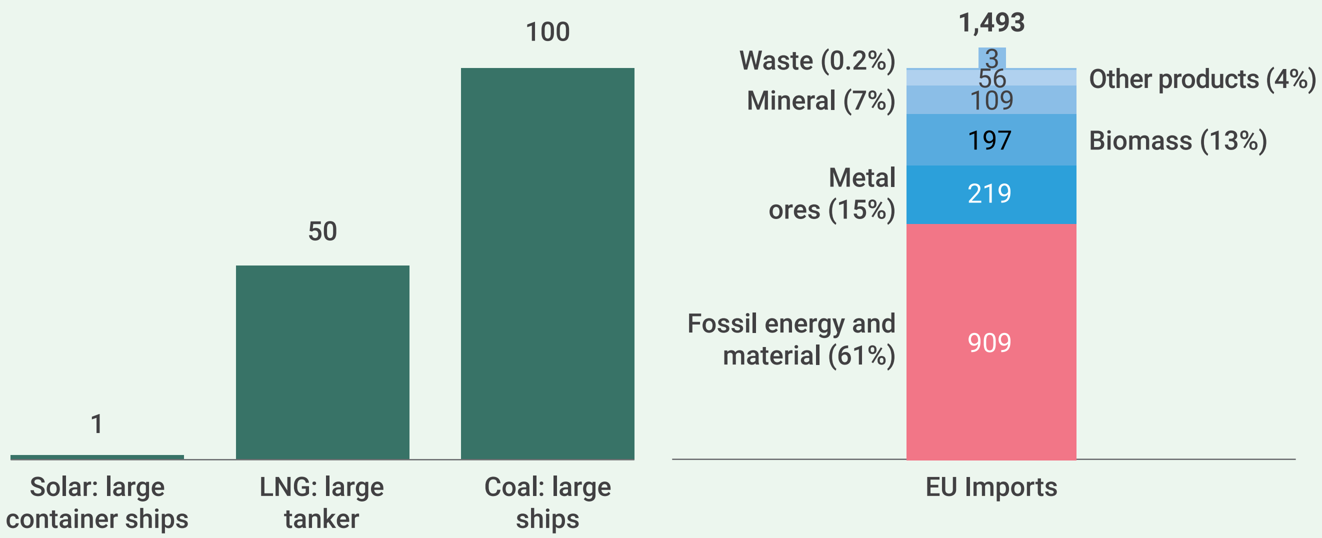
Energy resilience impact of solar

Solar PV requires significantly less transport compared to fossil energy...

... which could impact the 61% of fossil imports to EU

Number of ships to deliver equivalent electricity

Million tonnes, 2024



Source: IEA, Energy Technology Perspectives 2024, Eurostat, Circular Economy Material Flows (EU27, 2024)

Affordability: the price instability of the legacy energy system

The affordability challenge of today's fossil-fuel driven energy system is felt directly in the budgets of households and the competitiveness of industries, and ties closely to challenges with security. Exposure to volatile global fossil-fuel markets, amplified by geopolitical shocks, has made energy costs a structural vulnerability for both families and firms.

Energy-intensive businesses have been particularly exposed. Petrochemicals, which use natural gas as a feedstock and heat source, have seen a profound change in competitiveness. Petrochemical products compete on a global market, and European petrochemicals have been significantly more expensive since February 2022. This has been exacerbated by sanctioned Russian oil and gas being sold to Chinese and Indian players at a discount.

As a result, over 4 Mt of European ethylene cracker capacity has been closed to date and up to 40% of all capacity is at risk of closure.[16] Global petrochemical players, including Sabic and LyondellBasell, are in strategic retreat from Europe, selling infrastructure to distressed asset investors as further production cuts and job losses are expected.

Households are also affected. The energy bill of a typical dual-fuel UK household has increased 54% since February 2022, with both heating costs and electricity bills increased.[17] The structural marginal unit pricing is insidious in this case: though natural gas accounts for only 40% of UK electricity generation, it sets the price 98% of the time.[18] Only a minority portion of produced electricity has become more expensive but marginal unit pricing means the entire market has to pay a higher price.

Figure 06
Increasing cost of fossil energy in Europe (Natural gas TTF price from 2018 to 2026)

European gas prices soared as a direct consequence of Russian geopolitics

Gas price in Europe over time,
Dutch TTF Natural Gas Futures Historical Data, EUR/MWh

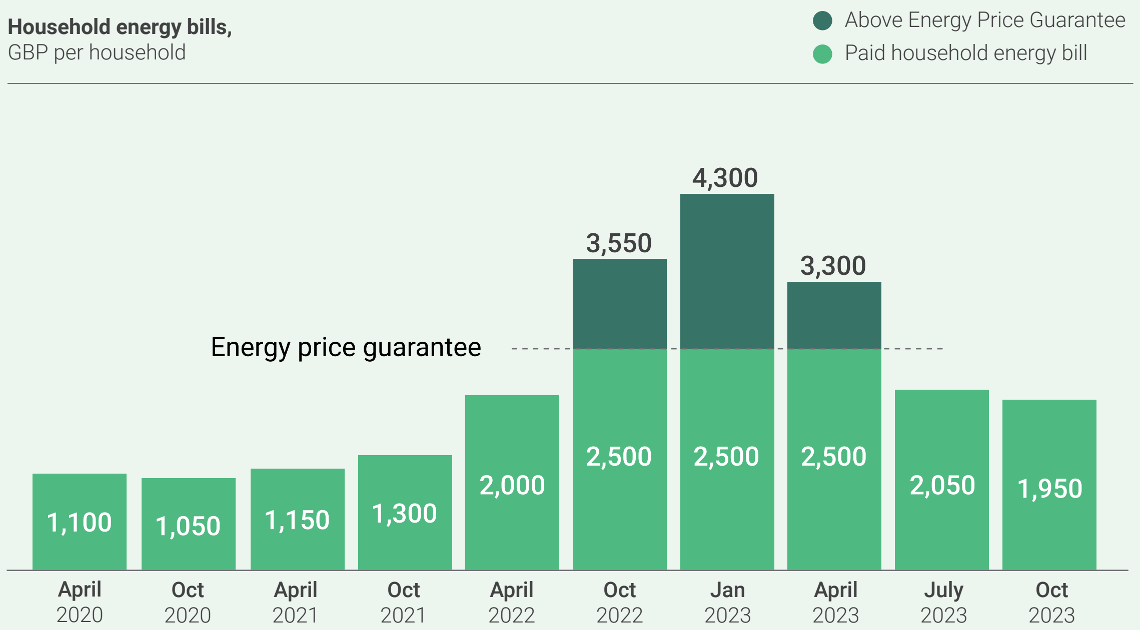
1 Statement from Alexander Novak, Deputy Prime Minister.

Source: "Dutch TTF Gas Futures Technical Analysis." Investing.com, www.investing.com/commodities/dutch-ttf-gas-c-futures-technical. Accessed 21 Jan 2026

16. ICIS, "European Ethylene: Crackers Under Pressure"; Wood Mackenzie "Petrochemicals in peril" (2025)
17. UK House of Commons Library, "Gas and electricity prices during the 'energy crisis' and beyond,"
18. Ember, "Electricity Data Explorer" (UK);

Figure 07
Increase in cost of UK household energy bills

Household energy bills rose sharply after Russia's invasion of Ukraine and have not dropped back to pre-invasion levels



Note: For a typical household on a price-capped, dual-fuel tariff paying by direct debit
Source: Ofgem

Planetary boundaries: the systemic overshoot of the legacy energy system

The combustion of fossil fuels for energy is the dominant driver of anthropogenic climate change, accounting for roughly 75% of global greenhouse gas emissions.[19] The resulting accumulation of CO_2, methane, and nitrous oxide in the atmosphere has driven nearly 1.5°C of warming above pre-industrial levels, with documented consequences including accelerating sea level rise, increased frequency and intensity of extreme weather events, ocean acidification, and disruption of ecosystems at scale.[20] The trajectory under current policy commitments points toward 2.5-3°C of warming by 2100, a range associated with severe and potentially irreversible systemic risks.[21]

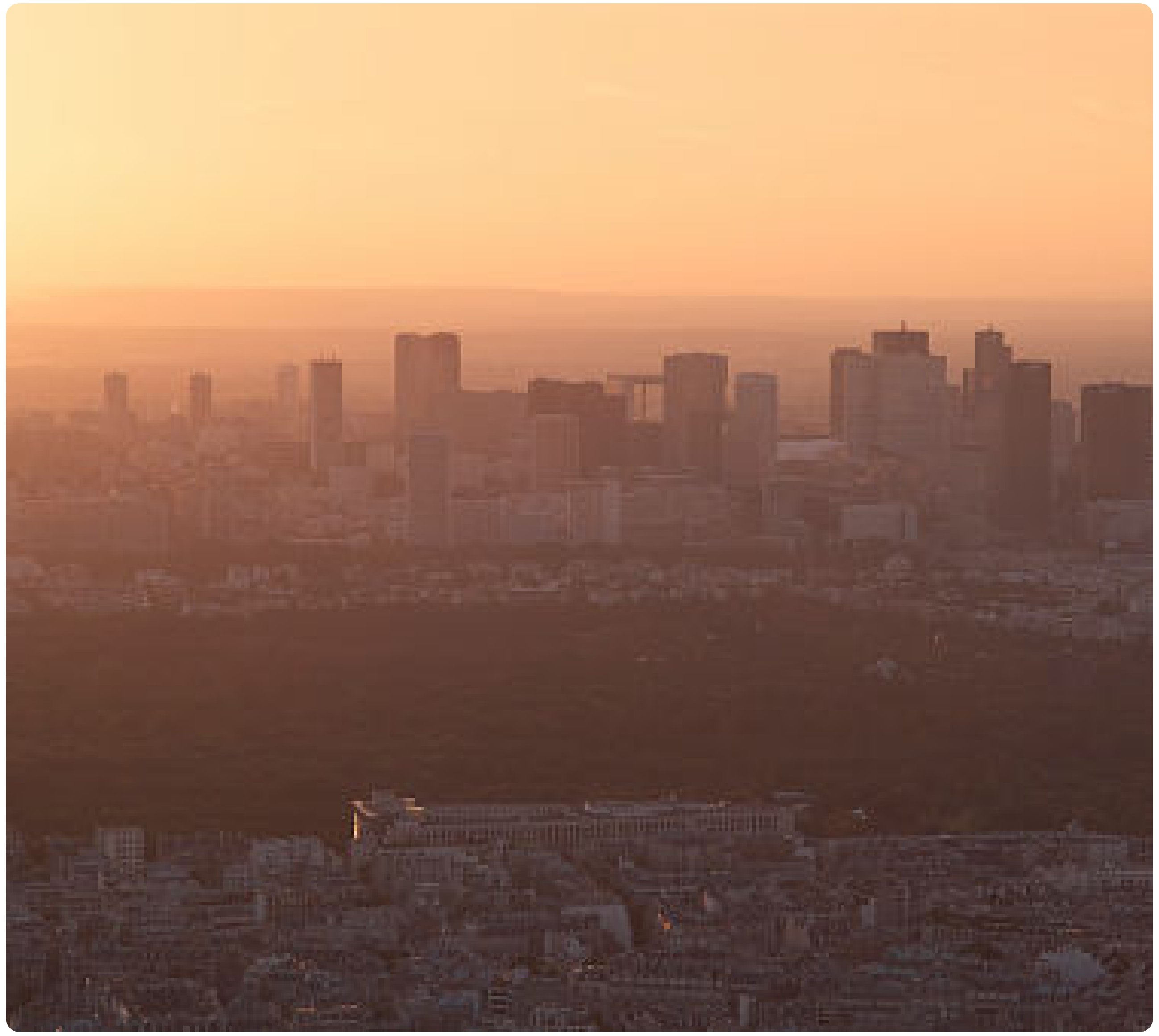
Climate, however, is only one dimension of impact. Water systems face contamination risks from extraction activities including hydraulic fracturing and coal ash disposal, while oil spills and pipeline leaks impose discrete but recurring ecological damage. Land use for extraction, refining, and infrastructure fragments habitats and displaces communities, impacts that fall disproportionately on lower-income populations and indigenous communities with limited political recourse. These harms are not incidental; they are structurally embedded in how the legacy system operates.

The Planetary Boundary framework underscores the scale of the challenge. The latest Planetary Health Check (2025) has assessed that we have gone beyond safe operating boundaries in seven of nine key "Earth system processes", with the additional two at risk.[22] The fossil-based energy system is deeply connected to each of these boundaries. The box below provides a detailed perspective on how the legacy and future energy systems contribute to these earth systems.

The human health, security, and environmental issues of the legacy energy system have a common cause: the combustion of fossil fuels for the purpose of creating energy. In the following chapter, we outline how an electric and fossil-free energy system can address these problems.

19. IPCC, "Climate Change 2021: The Physical Science Basis"
20. Copernicus Climate Change Service
21. UNEP, "Emissions Gap Report 2024"
22. Potsdam Institute for Climate Impact Research (PIK), "Planetary Health Check 2025"

Fossil fuel combustion for energy accounts for roughly 75% of global greenhouse gas emissions, while current policy commitments still point toward 2.5-3°C of warming by 2100.



How the energy system impacts planetary boundaries

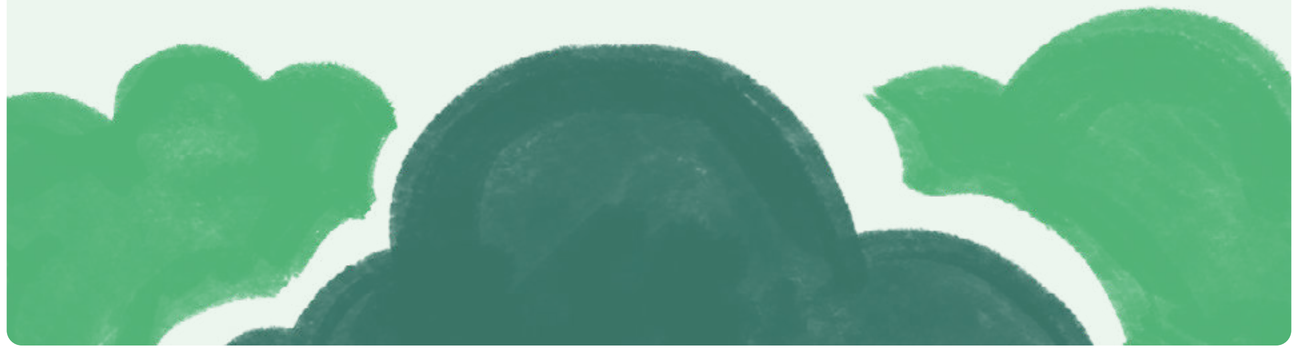
The Stockholm Resilience Centre has defined nine planetary boundaries that define the environmental limits within which humanity can operate safely. These earth system processes regulate the stability and resilience of the planet. When boundary thresholds are exceeded, the risk of abrupt, nonlinear, or irreversible environmental change increases.

Recent assessment shows we have gone beyond safe operating boundaries in seven of these systems, with the additional two at risk. This signals not isolated environmental pressures, but systemic imbalance across interlinked ecological processes. If left unaddressed, this imbalance threatens the biophysical foundations upon which human societies depend, including stable climate systems, reliable freshwater availability, fertile soils, healthy oceans and biodiversity. It also negatively impacts the predictable seasonal patterns that underpin food production, public health, economic stability, and geopolitical security. Undermining these foundations constrains long-term prosperity and reduces humanity's ability to thrive.

The energy system is embedded within nearly every sector of human activity and therefore influences multiple planetary boundaries simultaneously.

7 of 9

Recent assessment shows humanity has gone beyond safe operating boundaries in seven of nine Earth system processes, with the remaining two also at risk.



Climate change: Climate change is driven by greenhouse gases, largely CO_2, in the atmosphere trapping excess warmth. The energy system is the primary contributor to climate change, with 75% of greenhouse gas emissions stemming from the combustion of fossil fuels. This earth system has entered a negative spiral, with increasing global temperatures leading to increased power use for cooling and thus increased emissions. Recent estimates suggest the entire 2024 to 2025 increase in emissions from the power sector relates to weather changes.

Ocean acidification: This is the decreased pH of the Earth's oceans, caused primarily by the absorption of excess CO_2 from the atmosphere. To repeat, the energy system is the primary contributor to excess CO_2 in the atmosphere. This planetary boundary was identified as being transgressed for the first time in 2025.

Biosphere integrity: This boundary describes biodiversity loss and functional integrity: maintaining the Earth's web of life to be able to deliver ecosystem services. The energy system impacts the biosphere largely in the harvesting of materials to use for energy leading to the destruction of habitats, and the related biodiversity loss. This can be, for example, direct deforestation for biofuel crops or habitats disrupted for the mining of coal, drilling for oil or gas, or use of land for solar or wind. 80% of all mining in the world by weight is for coal, and mining is the major source of habitat loss after agriculture.

Land-system change: Relates to how land is used. This can include deforestation and similar changes from fuel extraction and can also include the land used specifically for the energy system: the power plants and transmission lines that allow power to be produced and transported. This is particularly relevant as solar and wind power become more prevalent, as they require new land in new places, up to 20-50x more than nuclear per MWh. However, when compared to the land needed for the extraction of fossil fuels, this delta shrinks considerably.

Freshwater use: Water is used liberally in the energy system, including in the cooling of thermoelectric power plants. Hydropower is fundamentally a choice to change river flow to maximize power production and drastically change both local hydrological conditions, by forming dams and flooding valleys, and downstream access to water.

Biogeochemical flows*:* The relevant earth systems are the natural cycles of nutrients nitrogen and phosphorus. These fertilizers are used in the production of biofuel crops, which then can runoff and pollute local and distant waterways and coasts. Combustion of fuels also releases nitrogen oxides.

Atmospheric aerosol loading: This refers to the release of small particles that affect cloud formation, precipitation, and health. Combusting fuels is a major source of aerosols, such as sulfate and sulfur dioxide, which have historically had two primary effects. First is major impacts on health, including lung disease, and second is a cooling effect on climate that "masks" the warming of greenhouse gases. As aerosols are reduced, scientists expect accelerated warming, requiring even more rapid drawdowns of fossil fuels to keep within the boundary on climate change.

Stratospheric ozone depletion: The ozone layer protects the Earth's inhabitants from harmful radiation, and ozone-depleting substances dramatically affected this layer, though this has largely been stemmed by international agreements. Uniquely, this is largely isolated from the energy system.

Novel entities: The release of chemicals and other pollutants into the environment, particularly those which are understudied in their long-term effects on human and environmental health. Many of these substances, such as petrochemicals, require significant energy to create while others, including radioactive waste for nuclear plants, are a product of the energy system.

The future we envision

The future energy system we envision performs in balance with the Earth's systems and thriving communities. It provides sustainable, reliable, affordable and secure electricity, in abundance.

The energy system of the future must address the structural shortcomings of the legacy model while enabling durable economic growth. It must deliver reliable, affordable, and secure energy without compromising public health or pushing planetary systems beyond safe limits.

This future system will be electric, powered by low- and no-carbon sources and supported by storage, digital technologies, and optimization strategies. It will underpin competitiveness across industries, strengthen social resilience, and accelerate transport electrification. We believe this transition is both necessary and achievable, and that it represents one of the most significant long-term investment opportunities of our time.

A blueprint for tomorrow's energy system: sustainable, reliable, affordable, secure electricity in abundance

We need a fundamental structural redesign of how energy is produced, distributed, and consumed. Electrification, supported by sustainable generation, storage, expanded grid infrastructure, and flexible demand, forms the backbone of such a system. When combined with efficiency gains and digital optimization, this architecture enables both economic growth and planetary stability.

The opportunity is not simply to replace fuels, but to upgrade the underlying system, making it more efficient, more secure, and more aligned with long-term prosperity.

The five pillars of the future energy system

To meet these objectives, the future energy system must be clean(er), reliable, affordable, secure, and abundant. Only by combining all five attributes can it both resolve the structural weaknesses of the legacy system and provide a stable platform for long-term economic growth.

Sustainable: In the future, the energy system must operate within planetary boundaries and avoid harm to human health. In practical terms, this means shifting toward electricity generated primarily from low- and no-carbon sources, powering industry, transport, and households without driving up emissions, pollution, or ecological degradation.

Reliable: Energy must function as a critical public utility, consistently available and resilient to disruption. The system must be designed with sufficient generation capacity, storage, and grid infrastructure to meet demand under normal conditions and withstand external shocks such as extreme weather and lightning strikes, as well as internal failures including component breakdowns and technical malfunctions.

Investing in the energy system of the future

Figure 08
A comparison between the elements of the legacy and future energy systems

How the energy system works: Today and looking forward

The legacy system was designed around centralized combustion and one-way delivery.
The future system is distributed, digital, and bidirectional, with consumers as active participants.

	Legacy system	Future system
Generation	Large, centralized thermal plants located near fuel and cooling water. Output is controllable; spinning turbines provide both electricity and grid stability.	Distributed solar, wind, and storage deployed at all scales, from utility farms to rooftops. Near-zero marginal cost; no fuel required once assets are built.
Grid	One-way, high-voltage backbone planned outward from generation hubs. Distribution networks are largely analog, with limited visibility and no capacity for reverse flows.	Bidirectional flows managed by real-time sensors, dynamic line rating, and automated switching. Smart substations unlock latent capacity in existing infrastructure.
Demand	Passive consumers connected via one-way service drops and simple meters. Equipment draws power on its own schedule, with no communication back to the grid.	Active participants: electrified heat, transport, and industry create flexible load. Smart meters and behind-the-meter storage enable demand to respond to system needs.
Services	Stability provided as a byproduct of thermal generation. Market pricing anchored to fossil fuel costs. Governance standards assume large, dispatchable plants.	Inverters and batteries deliver grid stability as a dedicated function rather than a byproduct of generation. Demand response and virtual power plants aggregate distributed resources to balance supply in real time.

Affordable: Energy should be accessible at a cost that does not impose undue strain on households or erode industrial competitiveness. This includes the full value chain — generation, grid, demand, and services — and must support economic growth without dependence on sustained subsidies.

Secure: The future energy architecture must remain stable under geopolitical, economic, and technological uncertainty. This requires diversified and distributed generation, reduced reliance on imported fuels, robust grid infrastructure, and strong cyber and physical defenses to protect critical systems.

Abundant: The system must deliver sufficient energy where and when it is needed, enabling productivity, electrification, and improved quality of life across sectors and geographies.

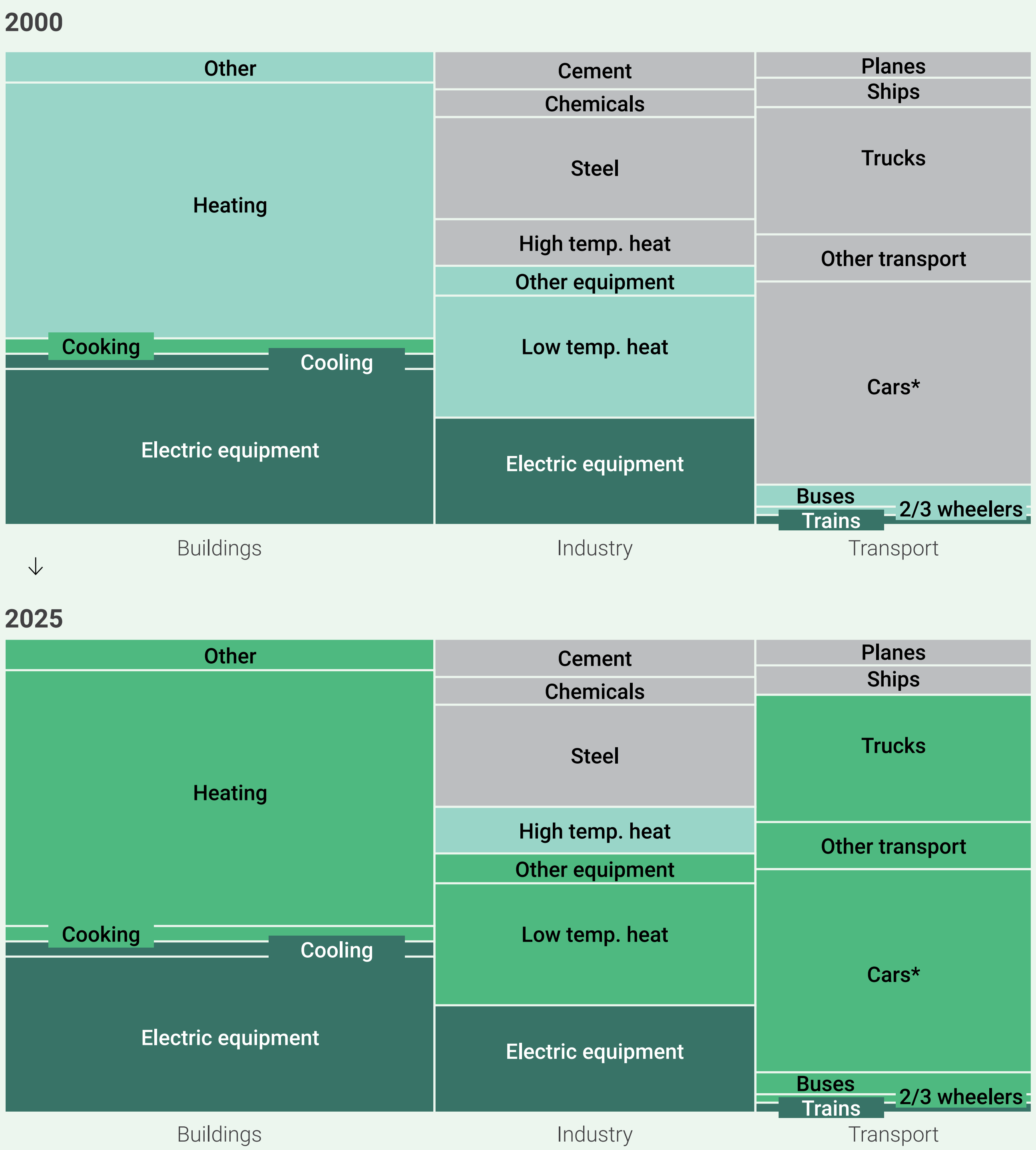
Figure 09
Significant progress has been made in electrification technologies for most end uses over the last 25 years

The electrification ceiling is high and rising

Over 75% of the global energy system can now be electrified

● Already (largely) electrified ● Can be electrified economically ● Can be electrified technically ● Still under development

Share of final energy demand by subsector and electrification potential (%)



Sources: IIASA; IEA; BNEF; Ember analysis • Note: excluding feedstock *Technologies available for subset of total end use with a clear path to expansion

The future energy system will be electric
The future we envision is mostly electric, for good reason. Electrification strengthens all five attributes of the future system: it is sustainable, reliable, affordable, secure, and abundant. It reduces dependence on imported fuels and price spikes, improves efficiency and performance across sectors, and improves health and comfort.

The electrification of housing, transport, and industry has already begun at pace as more efficient, lower operating cost electric alternatives begin to outcompete legacy fossil alternatives. Advances in electric technology, and corresponding cost decreases with deployment, show that we are able to electrify 75% of end use energy needs.[23] Even in the industrial and transport sector, often viewed as hard to abate, significant sectors are moving towards electrification. The progress made in the last 25 years gives us confidence that electric options will continue to develop.

Electrification will result in lower cost energy; the figure below shows how increasing electrification reinforces the economics. The cost of transmitting and distributing electricity is spread across the demand for it. As more end uses electrify and demand increases, the fixed cost of infrastructure is distributed to more users. Coupling this with the lower levelized cost of energy (LCOE) of renewable sources results in lower energy prices for all.

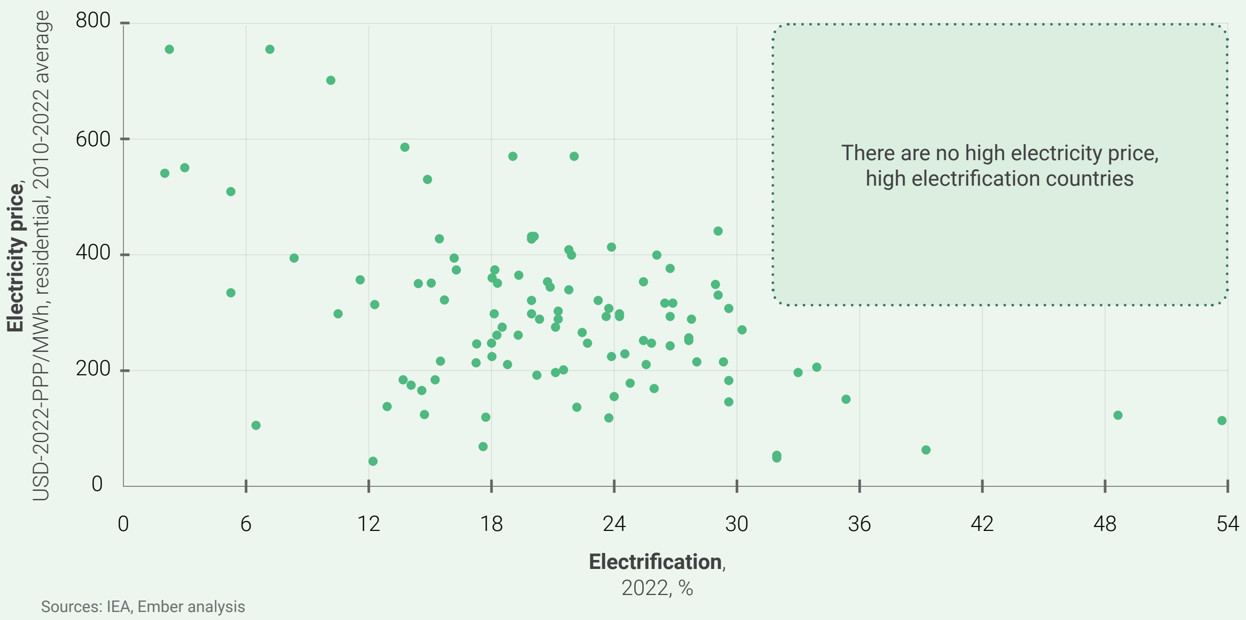
Achieving an electric energy system that is sustainable, reliable, affordable, secure, and abundant will require transforming every part of the electricity value chain. That entails generational shifts to low-carbon sources, consumption being largely electrified with consumers actively participating in the system, and new services maintaining reliability in real time.

The future system will be far more interconnected and dynamic, reflecting the increasingly electrified and digitized future. If we were designing the electric system with today's technologies, we would design a system that was local first and digitally coordinated, made up of microgrids with power electronics, software-controlled energy flows with open protocols, local buffering and storage, and markets that allowed interconnection between domains for resilience and reliability.

The future system will no longer operate in a linear fashion, moving electricity from generation to demand, but rather form a web where system functions are driven more by software than by physics. In Europe, the average size of generating units will move from over 600 MW to a comparatively small 30 MW, and interconnections will be at the distribution network level rather than the higher voltage transmission system.

Figure 10
Electrification and lower energy prices go hand-in-hand.

Greater uptake results in lower prices

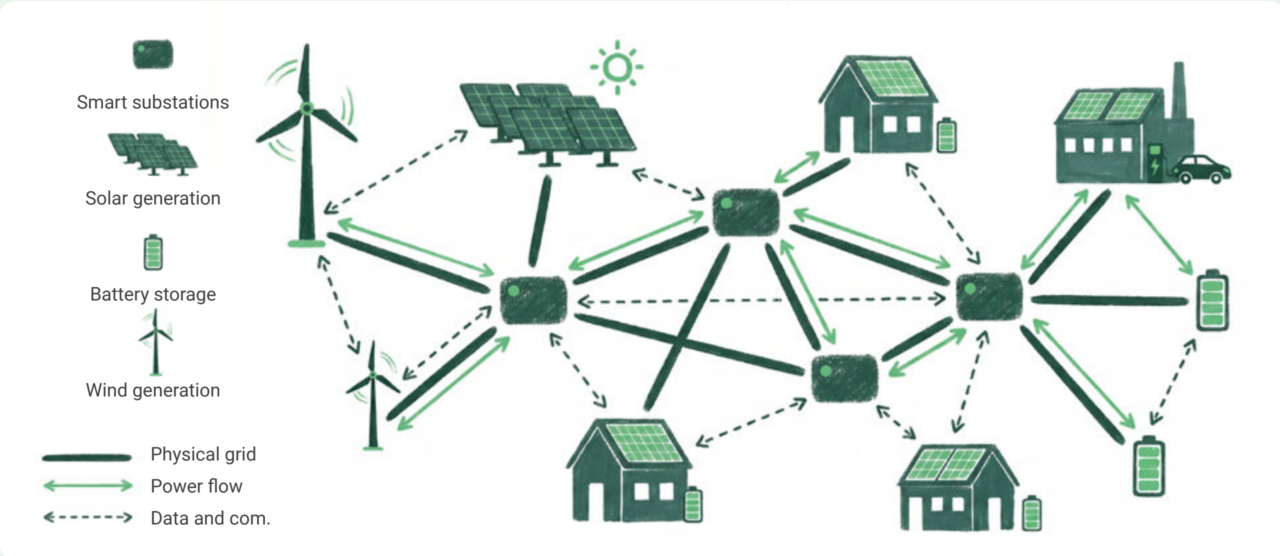


Sources: IEA, Ember analysis

23. IEA; BNEF; Ember Energy

How the future energy system will work

The future power system is an interconnected mesh: diverse, distributed generation and storage feed electricity bidirectionally through a digitally coordinated grid, while consumers actively participate in system balance. Services that were once embedded in thermal generation become dedicated, system-spanning functions.



Generation	Grid	Demand	Service
Distributed sustainable energy replaces centralized fossil fuel generation.	Digitally enhanced networks enable bidirectional power and data flows.	Consumers become active participants in the energy system.	Grid services become dedicated functions across the whole system.
Physical infrastructure			
Solar, wind, and storage are deployed at all scales. Hydro and nuclear remain, with no single asset type dominating. The portfolio provides resilience and low marginal cost generation.	Real time sensors, dynamic line rating, automated switching, and smart substations unlock capacity in existing lines and manage power and data flows digitally across voltage levels.	Electrified heat, transport, and industry create flexible loads. Smart meters and behind-the-meter storage allow consumption to respond to system needs.	Inverters, batteries, demand response, and virtual power plants provide stability, flexibility, and real time balancing that were previously bundled with thermal generation.
Institutional design			
Distributed economics Modular assets with low marginal cost shift investment logic from fuel efficiency to system utilization and flexibility.	**Performance-based regulation** Regulation shifts from capital deployment to outcomes like reliability, utilization, and speed of connection.	**Dynamic pricing & participation** Real-time pricing and demand response give consumers visibility and incentives to help balance the system.	**Dedicated service markets** Stability, flexibility, and fast response are provided by multiple assets across the system, instead of by centralized thermal generation.

System operator: Digitally coordinated across the full value chain

Predictive balancing
AI driven forecasting, distributed storage, and automated dispatch provide the buffer the legacy system lacked. Balance is managed proactively, not only reactively.

Value based pricing
New market designs decouple electricity prices from fossil fuel costs. Prices reflect actual generation costs and reward flexibility, storage, and system services.

Adaptive governance
Standards evolve to accommodate inverter based resources, bidirectional flows, and demand side participation as legitimate sources of capacity and stability.

We see the following as the crucial characteristics of the future system across generation, services, grid and demand:

Renewables lead the way: Shifting to clean, secure electricity via renewables is key. Solar and wind are now among the cheapest sources of new power (see Figure 12 below), and can be deployed at scale in most regions, enhancing energy independence and reducing fuel price volatility.

Storage outpaces generation: Deploying storage, mostly in the form of batteries, and other firming assets to buffer intermittencies in renewable generation and provide frequency response and stabilization to enhance grid resilience, and to ensure a renewables-based system can meet demand. This blend of uses has driven 72% p.a. growth in installation of the past decade.[24]

End use electrification accelerates: The dual shocks of the Ukraine war and the conflict in the Middle East are pushing us to electrify everything we can – vehicles, heating, industrial processes – to improve efficiency and reduce reliance on fossil fuels. Electrification cuts emissions, shields economies from oil and gas price shocks by using increasingly cheap, locally-produced sustainable electricity, and improves energy efficiency. This last point is crucial in the affordability of the electric future: heat pumps are 3-4x more efficient than gas boilers and thus will be more cost-effective as long as the price of electricity is less than 2.5x that of gas.[25]

Flexibility and digital services move from auxiliary to core: Investment in and roll-out of flexibility services and smart grid technologies using high speed power electronics are growing fast, allowing the transition to proceed reliably and cost-effectively. Tools like demand response, smart EV charging, and virtual power plants (aggregating distributed resources), will match demand with variable and distributed supply and storage in real time.

However, there are alternatives to a system focused entirely on electricity, with some people proposing alternative fuels for combustion as a potential basis for a future energy system. Our view of alternative fuels and their role in the energy transition is described on the next page. In summary, we see the potential but believe that to date they have been constrained by issues of affordability and should be deployed in a targeted manner.

24. IEA
25. IEA

Spotlight: How we view the role of alternative fuels in the energy transition

The role of alternative fuels in the energy transition
Alternative fuels such as advanced biofuels and e-fuels play a role in decarbonizing sectors where direct electrification is technically challenging, including aviation and maritime. Their key advantage is compatibility with existing infrastructure, enabling emissions reductions without full system redesign.

Structural constraints limit scalability
Despite this potential, alternative fuels face material challenges. Production costs are often significantly higher than fossil-based fuel, scalability is constrained by limited sustainable feedstocks, and many technologies remain dependent on long-term subsidy frameworks. In addition, some feedstock sources raise concerns around land-use change, competition with food production, and broader planetary boundary impacts.

EU policy increasingly reflects these constraints. Under the Renewable Energy Directive (RED II/RED III), biofuels must meet strict sustainability criteria, including minimum greenhouse gas savings thresholds, traceability requirements, and safeguards against indirect land-use change (ILUC). The EU differentiates between conventional, food-based biofuels and advanced feedstocks (Annex IX), with policy increasingly prioritizing waste- and residue-based feedstocks while tightening limits on high ILUC-risk pathways.

Summa's investment lens
Our approach is technology-agnostic but thesis-driven. Any energy investment must support our vision of a system that is sustainable, reliable, affordable, secure, and abundant. We assess alternative fuels against these criteria and against evolving EU sustainability standards.

Technologies that rely on sustained, high subsidy regimes to remain competitive are generally outside our scope.

We exclude feedstocks that have a disproportionate negative effect on planetary boundaries, fail to meet robust EU sustainability criteria, or compete structurally with food systems.

Where fuels are derived from genuine waste streams, comply with EU sustainability frameworks, and support circular value creation, we see stronger alignment. In such cases, we may engage, particularly where valorization of limited feedstocks enhances resource efficiency within our Circularity theme.

Alternative fuels are therefore viewed as a niche enabler within a broader electrification-led transition, not a primary pathway for system-wide decarbonization.

The future system is feasible and necessary

Transformations of this magnitude inevitably attract scrutiny and resistance. Constructive debate is essential: it sharpens analysis, exposes weaknesses, and ultimately leads to better solutions. At the same time, some of the opposition reflects entrenched interests whose business models are closely tied to the legacy system.

At Summa, we actively engage in these discussions. Our confidence in the direction of travel is grounded in structural economics, technological progress, and the clear need to operate within planetary boundaries, not in optimism alone. We hold six fundamental beliefs that give us confidence in the future vision we present:

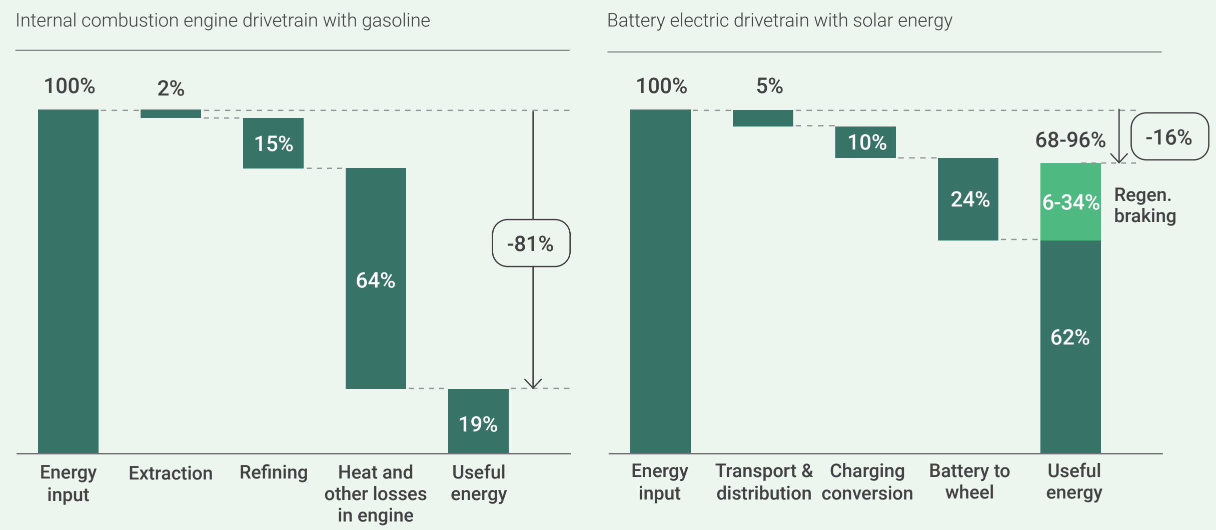
- We can build enough renewables to meet energy demand.
- We can afford the transition.
- The future system can be reliable.
- Dependency on China is significant, but the benefits outweigh the risks.
- The rise of AI and growth of data centers can provide an opportunity.
- The energy transition will create stable, well-paying jobs.

We can build enough renewables to meet energy demand
It is common to see renewable energy generation amounts compared to primary energy, but this is a false comparison as it ignores the inherent efficiency advantage of electricity. However, the current fossil energy system wastes nearly two-thirds of the energy contained within the fossil fuels as heat, a problem renewables avoid entirely. The wasted two-thirds do not need to be replaced by clean, renewable power sources.

In cars, for instance, a battery electric car with regenerative braking converts 68-96% of electricity to useful energy, compared to 19% for a typical combustion engine running petrol or diesel.[26]
A fully electrified economy would require only half of the primary energy of the fossil-based system. The renewables build out does not, therefore, need to match fossil phase-out GW for GW.

Figure 11
Energy loss comparison between ICE vehicles and BEV

Internal combustion engines are inefficient wasting more than 80% of energy – while BEVs are 3-5X more efficient depending on regenerative braking



Sources: US DoE; FuelEconomy.gov; GREET model; CEER Electricity Distribution Report; EPA; IEA;

26. US DoE, "All-Electric Vehicles,"

We can afford the transition

The status quo is not free, nor is it efficient; the US power system runs at a 50% utilization with the grid utilization lower still.[27] Moving to a new energy system requires investment, but so too does maintaining the existing system of generation and distribution.

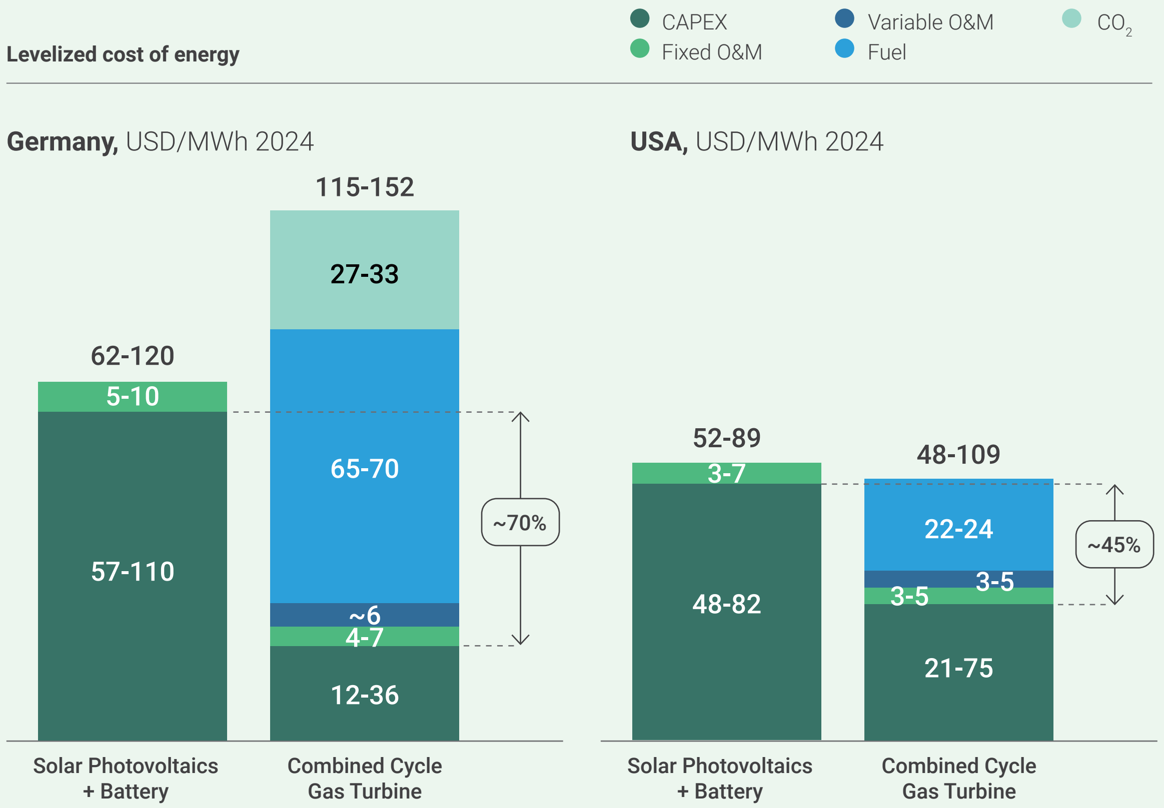
Replacing fossil generation with renewable amounts to a CAPEX-for-opex trade. A new combined cycle gas plant requires 45-70% less CAPEX per MWh than a solar + battery storage facility, but this is offset by the near-zero cost of operating solar versus the reoccurring cost of procuring gas to combust.

The specifics of this comparison depend on geography. Countries with no domestic gas supply and existing CO_2 pricing, such as Germany, are already largely tilting towards renewables, whereas countries such as the US are at roughly par. It is however instructive to see that even the US, with the best possible conditions for gas, is seeing increasing penetrations of renewable, attributable simply to the fundamental economic advantages of avoiding combustion. The following case study describes the experience of Texas.

Renewables and storage are expected to outperform fossil fuels in almost all geographies, as learning rates continue to drive costs down. In contrast, fossil fuel extraction costs continue to rise as more difficult to access sources are discovered.

Figure 12
Renewables have a higher initial capital cost compared to gas power, but a near-zero operating cost

Renewables are 45-70% more expensive upfront in EU and US on average, but higher fuel and CO_2 costs in EU mean TCO is more favorable



Assumptions
- EU gas price = 38 EUR/MWh
- CO_2 price = 75-90 EUR/t CO_2e

Assumptions
- US gas price = 3.45-3.5 USD/MMBTu
- CO_2 price = 0 USD/t CO_2e

Sources: Fraunhofer ISE (2024), Lazard LCOE+ (2025)

27. The Brattle Group, "The Untapped Grid (March 2026)", prepared for GridLab and the Utilize Coalition

Low-cost renewable energy in Texas

CASE STUDY

Texas offers a clear, market-driven example of how wind, solar, and batteries are outcompeting fossil fuels, even in a state with no clean energy mandates. Texas operates one of the most open electricity markets in the world: developers can build almost anything. And when barriers like permitting are low, the system consistently builds what is cheapest and fastest. The open market, coupled with abundant renewable resources, makes Texas a national leader in renewable energy deployment. From 2022-2025, Texas added six to eight times more solar, wind, and batteries than natural gas, and retired some coal generation. This happened despite active subsidies for natural gas through low-cost capital from the Texas Energy Fund, favorable property tax agreements, and free pollution externalities. Wind, solar, and batteries continue to win on cost and deployment speed.

While electricity prices have risen everywhere in the US, Texas prices have increased less than in regions more exposed to fuel oil or natural gas price volatility, largely because Texas keeps adding new renewable generating capacity. In the first nine months of 2025, solar and wind met 36% of the state's electricity demand, with solar increasing by 50% and wind by 4% over the same period in 2024. Where Texas does see cost pressure, it is driven not by generation but by long-neglected transmission and distribution infrastructure.

Winter storm Uri, in February 2021, is often cited as proof that an electric system too reliant on renewables cannot perform in extreme weather conditions. However, the causes of power outages in Texas during that storm were shown to be more attributable to the failure of improperly weatherized fossil fuel systems.

In January of 2026, winter storm Fern again brought extreme cold to Texas and much of the eastern US. In contrast to 2021, the power stayed on in Texas, and the cost to customers for additional power was much lower than for residents of the eastern US, where less battery storage was on the system. At the time of the storm, Texas had 17 GW of batteries connected to the ERCOT system, while PJM, the Regional Transmission Operator for the mid-Atlantic US, had only 1 GW. Electricity prices were between two and ten times higher than in Texas, and the US Department of Energy had to order data center diesel generators to operate and support the PJM grid.

Overall, Texas demonstrates that when markets are allowed to function and projects can be built quickly, renewable energy technologies consistently outcompete fossil fuels on cost, speed, price stability, and now reliability, even in a state that is a global powerhouse of fossil fuel production and is politically skeptical about climate policy.

The future system can be reliable

As currently used, renewables lack the dispatchability and flexibility of fossil power. Without supporting assets and services, like battery energy storage, to provide stability to the grid, the power system could be subject to fluctuations in frequency and voltage like those that caused the Iberian blackout in April 2025. In that incident, the system failure was primarily due to inadequate voltage control and response capability. This was not a failure of renewables, but rather a lack of markets to procure grid support services, exacerbated by limited interconnections to the rest of European system that could have provided the necessary services to stabilize the system.[28]

A renewable system cannot be built in isolation. It requires regulators and operators to incentivize and build stability into the system. In this way, the Iberian blackout closely resembles the 2016 South Australian blackout, in which storm damage to transmission lines caused wind farms to trip offline due to inadequate ride-through settings, overloading a single interconnector and collapsing the entire state grid.[29] The vulnerability lay not in the wind generation itself but in the system's lack of frequency and voltage support services, and its limited interconnection capacity. Critically, the South Australian response also shows how quickly these gaps can be closed. The Hornsdale Power Reserve, commissioned just fourteen months after the blackout, reduced frequency control costs by 90% and has since become the first large-scale battery to provide synthetic inertia services to the grid.[30]

Dependency on China is significant, but the benefits outweigh the risks

China has a dominant position in the production of many key renewable technologies, including solar PV and batteries, as well as the supply chain of raw materials needed to build them. Unfortunately, the US and Europe fell behind in developing the technologies, and in producing them cost effectively. There are important risks with China's dominant position in the market including supply chain risks, cyber security, and human rights violations. Cyber security is an increasing concern, requiring vigilance and the adoption of US and European technology in critical areas to counteract threats. These must be weighed against a fossil-based system, where geopolitical vulnerabilities and instability are increasing. Where energy is generated from solar and wind, there are no reoccurring purchases of fuel; once the technology is procured, it can continue to operate without additional purchases.

Additionally, as electricity costs decrease with the continued transition, European and US manufacturers can regain some competitiveness with lower energy costs. Recycling presents another significant opportunity to further reducing dependence on China by cutting the need to buy rare earth metals.

The rise of AI and growth of data centers can provide an opportunity

There is rapidly increasing energy demand from data centers as AI development accelerates, which is often raised as a major concern. Eventually, data centers are predicted to be at most 3% of total global electricity demand, with industry, transportation, and building heating/cooling dwarfing them. In the US and Europe, the current effect of data center growth is greater, driving up electricity demand over 10% today. While data centers are posing a challenge today, they are merely exposing the fragile, outdated design of the electric system that has to be addressed.

A benefit of the data center boom coming first is that the hyperscalers have the money and political support to force the system changes that are needed. In the US, several states, including New York and Virginia, are enacting legislation to rapidly increase or free-up capacity in the existing electric system. And as AI develops, it will be a tremendous asset in more efficient operation of the electricity system from meter and sensor data analytics to grid optimization and battery life longevity.

The energy transition will create stable, well-paying jobs

The energy transition is an economic engine that has already begun creating well-paying jobs at scale, and we believe this job creation will continue to accelerate throughout the transition.

Renewable energy employment reached 1.6 million jobs in the EU alone in 2022. Most of these roles are local and hands-on, including electricians, heat pumps installers, EV-charging technicians, and grid specialists.[31] These roles demand skilled labor on the ground and cannot be offshored. As such, tend to pay well even at an early tenure, in the region of EUR 50,000-80,000 p.a. Projections suggest an additional 1 million clean-energy jobs will be necessary in Europe by 2030, primarily within installation, maintenance, and technical services.[32] These jobs require skills that need to be developed in the workforce. In the UK, the Electricity Networks Sector Growth Plan is creating a strategic pathway to match training with the needs of the domestic supply chain and to allow for electric growth.

28. ENTSO-E, "Interim Report on the Iberian Peninsula Disturbance of 28 April 2025"
29. AEMO, "Black System South Australia 28 September 2016 — Final Report"
30. Aurecon, "Hornsdale Power Reserve: Year 1 Technical and Market Impact Case Study"
31. IRENA & ILO, "Renewable Energy and Jobs: Annual Review 2024"
32. Amoria Bond, "1 Million Energy Jobs by 2030: Key Skills Gaps Shaping Europe's Workforce" (2024)

Investing in the energy system of the future

North America is seeing a parallel trajectory. Clean energy jobs climbed by 142,000 in 2023, more than half of all new energy-sector employment and double the growth of the economy as a whole.[33] The Inflation Reduction Act was expected to generate 900,000 additional clean energy jobs and, while the current administration is likely to enact policies that slow this growth, we still expect hundreds of thousands of new, stable, and well-paying jobs from clean energy over the coming decade. The energy transition will undoubtedly cause disruption, with 40,000 people currently employed as coal miners, and an additional 100,000 employed in coal more broadly, in the US alone.[34] However, we believe the opportunities created by the transition will greatly outweigh the negative disruption, and that policies can ease the transition and create opportunity for those affected.

Fossil fuels vs. renewables: pressure on Earth's systems

The planetary boundaries framework makes the trade-offs explicit: no energy system is impact-free. But fossil fuels are structurally misaligned with a safe operating space. In the legacy system, pressures are high where it matters most — climate change, ocean acidification, and air pollution — because extraction and combustion continuously add greenhouse gases and toxic pollutants to the atmosphere and oceans.

A future system built around renewables materially reduces those systemic pressures. As Figure 13 shows, renewables shift climate, ocean acidification, and air pollution from high to low pressure, removing the core "always-on" harms that define fossil energy.

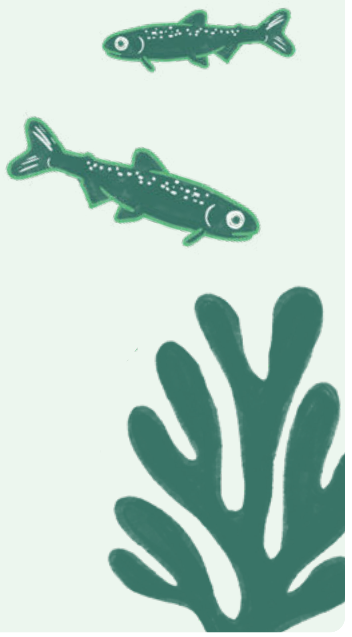
That does not mean zero impact. Other boundaries remain medium, including chemical pollution, freshwater withdrawal, and biodiversity loss, reflecting the footprint of mining, materials, land use, and infrastructure. And land conversion can increase from low to medium as solar and wind scale, making siting, permitting, and grid design critical to avoid pushing development into high-biosphere value areas.

The takeaway is clear. Renewables are not perfect, but they are decisively better on the boundaries that drive systemic instability. The task now is to build the renewable system in a way that keeps the remaining pressures contained, through better materials stewardship, circularity, careful land-use planning, and smarter grids.

33. US DoE, "United States Energy & Employment Report"
34. US EIA, "Annual Coal Report" (2024),

Figure 13
The energy transition can notably reduce pressures on three of the stressed earth systems

Earth system	Pressure in legacy energy system	Pressure in future energy system
Climate change	High	Low
Ocean acidification	High	Low
Chemical pollution	Medium	Medium
Biogeochemical flows	Low	Low
Freshwater withdrawal	Medium	Medium
Land conversion	Low	Medium
Biodiversity loss	Medium	Medium
Air pollution	High	Low
Ozone layer depletion	Low	Low



What this means in practice: the example of offshore wind

Offshore wind illustrates how renewable technology can materially reduce pressure on the most systemically critical planetary boundaries, while still requiring disciplined development.

From a climate and air pollution perspective, offshore wind represents a structural improvement. Once installed, turbines generate electricity without combustion, eliminating operational greenhouse gas emissions and particulate pollution. This directly lowers pressure on three boundaries where the legacy system exerts high stress: climate change and ocean acidification through reduced CO_2 accumulation, and air quality.

Offshore wind is not impact-free. Construction requires steel, copper, rare earth elements, and subsea infrastructure, all contributing to chemical pollution and upstream extraction pressures. Installation can temporarily disturb marine ecosystems through seabed preparation and noise during pile driving. In ecologically sensitive regions, such as enclosed fjord systems with limited water exchange and high biodiversity value, large-scale offshore wind may create disproportionate trade-offs. Siting decisions therefore matter: projects must avoid sensitive habitats and key migratory routes. While concerns about bird mortality are often overstated in public debate, credible studies show that collision risks are generally far lower than the broader biodiversity impacts driven by climate change. At the same time, turbine foundations can function as artificial reefs, and exclusion zones can act as de facto marine reserves, increasing local marine biomass when properly managed.

Investing in the energy system of the future

Land-use pressure is relatively limited compared to onshore renewables, but grid connection and port infrastructure expansion can introduce localized impacts. Lifecycle design, including turbine recyclability and circular material flows, becomes increasingly important as fleets age.

In practice, offshore wind demonstrates the broader transition principle: materially reducing high-impact fossil pressures while actively managing and minimizing secondary environmental effects. Done well, it shifts the system from chronic planetary overshoot to controlled, declining environmental intensity.

The outcome of the energy transition is predictable. There are simply too many robust tailwinds behind a renewable, electric future to stop the transition completely. Even when one tailwind is removed, for example due to political shifts, there are enough others to carry momentum forward. Our next section dives deeper into how this system is taking shape and what opportunities are available.

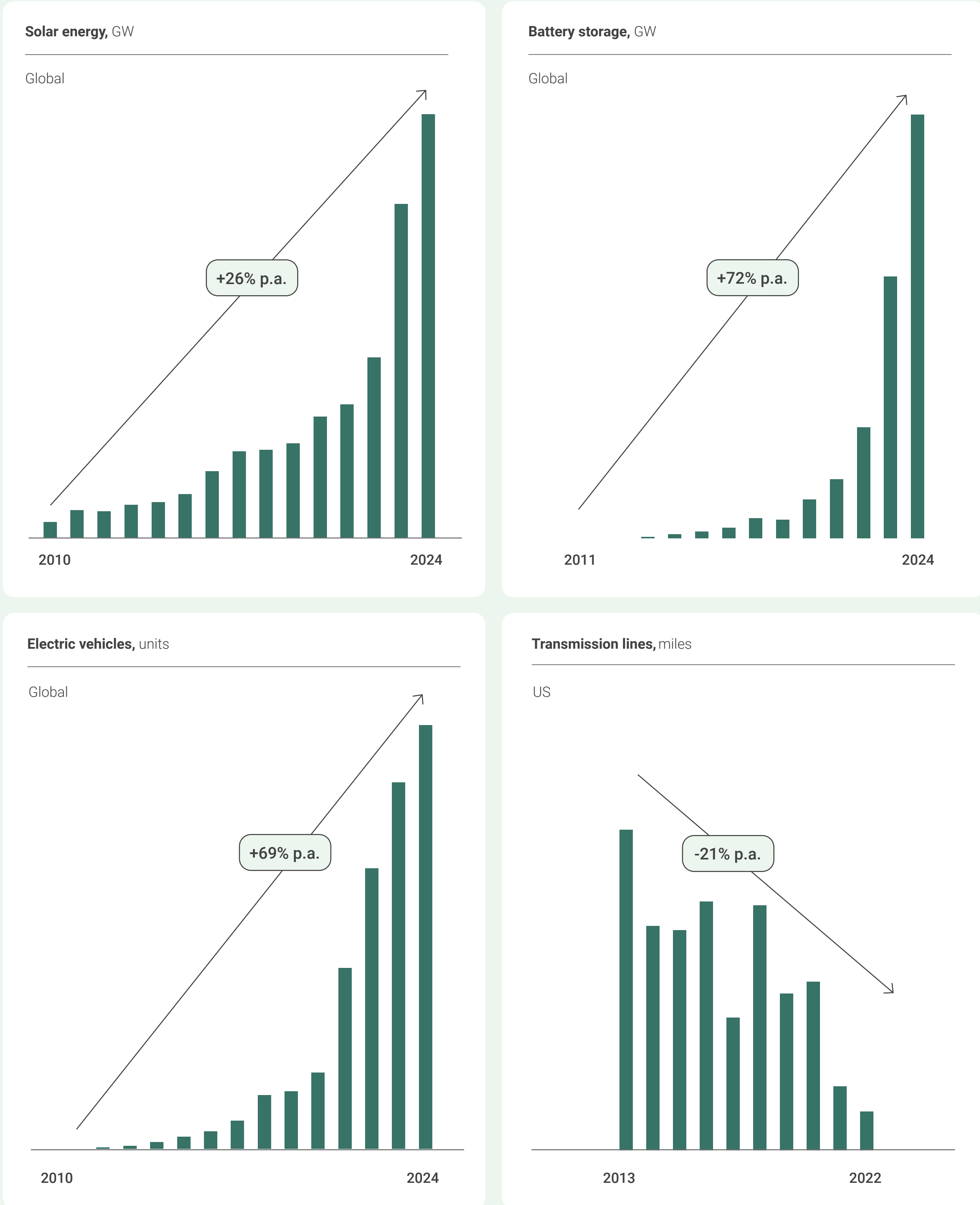
The transition opportunity

The energy system we envision is already on its way. Key technologies are becoming mainstream but system level change is moving too slowly and requires focused investments in the solutions best able to accelerate the transition.

Getting to the future we envision requires rethinking, redesigning, and redeploying assets and capital. We are transitioning an essential system while it is in full operation, increasingly exposed to extreme weather events, geopolitical shocks, and facing a scale and pace of change it has never experienced. In this transition lies tremendous opportunity – economic, social, and environmental – that forms the foundation for the modern energy system.

The future system has fundamental advantages over the legacy system, leading to a transition already in progress. However, the existing infrastructure, incentives, and processes of the legacy energy system are hampering the speed of transition, particularly in the build out of the grid. Overcoming these hurdles will require rapid deployment of key technologies that can leverage existing infrastructure to accelerate the transition.

Yearly incremental capacity additions. Up- and downstream investment are accelerating – but midstream infrastructure isn't keeping up[35]



35. IRENA; IEA, BNEF; Ember Energy; Our World in Data; Energy Transitions Committee

The energy transition is inevitable and already well progressed

The transition, and the dominance of electricity, is a question of when and not if. The transformation of the energy system starts at the source. Replacing fossil combustion with electricity generated from sustainable sources is the foundational shift that enables improvements in health, security, affordability, and planetary stability. Solar and wind are now among the cheapest sources of new power generation in most regions. They can be deployed at scale, enhance energy independence, and materially reduce exposure to fuel price shocks.

Investment in renewables has grown rapidly over the past 15 years, with solar averaging 25% p.a. growth in installed capacity. This has outpaced almost every major projection system, including those of the IEA whose World Energy Outlook (WEO) has continually missed actual growth despite increasing the forecast year-over-year.[36]

Energy storage is growing at an even higher rate than renewables. Storage investment is growing at 30% p.a., driven largely by China, and the significant decrease in cost and increase in battery efficiency in recent years.[37] The predominant technology is lithium-ion batteries, which are now capable of providing cost effective storage for over four hours, moving towards 8-12 hours. This allows them to effectively cover hourly variations in renewables and provide the necessary grid services to make renewable power reliable and abundant.

Renewables have reached a tipping point

The explosive growth of renewables and storage is not simply due to decarbonization pledges by rich nations. Their growth, and our conviction about their ability to continue to grow, is the result of renewable technologies becoming the most economical way to generate power. Depending on geography, renewables are able to deliver power for USD 40–80 /MWh, on par or less than the least expensive fossil options. And they remain competitive even when adding storage, which provides firmer and dispatchable power.[38]

Renewables have higher CAPEX but lower opex than fossil fuel-based power. The Levelized Cost of Energy (LCOE) calculation takes the average cost of producing one MWh over a power plant's lifetime, including all building, operating, and fuel expenses, and divided by the total energy it generates. The numbers in Figure 16 are very clear. Because of this cost advantage, renewables now make up over 90% of new generation capacity.[39]

In addition to competitive LCOE, a critical factor for renewable energy and battery storage reaching the tipping point is the speed at which these projects can be built. Even a large-scale renewable energy project can be online within two to three years of the investment decision, while natural gas generation is averaging five or more years, and nuclear power can easily take more than 10 years.[40] Smaller scale systems can be in operation within a matter of months.

This speed is especially important as demand for power increases, and the geopolitical threats to fossil fuel continue. In geographies like Europe and North America, demand growth was flat for most of the first two decades of the 21st century as efficiency gains offset population and economic growth. This is no longer the case; transitioning transport, buildings, and industry will increase global demand by 15,000 TWh by 2040.[41]

The inevitability of the future energy system is a function of this demand growth and the fundamental advantages of renewable energy. The most competitive industries, the most efficient households, and the cheapest modes of transport will be electric. This will require more electricity generation, and the fundamental advantages of renewable energy and storage will drive a more sustainable system for all.

Where the transition is lagging

A transition of this scale, like previous transitions such as the industrial revolution or the ongoing digital transition, are full of challenges and structural incompatibilities. The energy transition has the added pressure of having very little time to avoid and reverse catastrophic impacts on the Earth's systems.

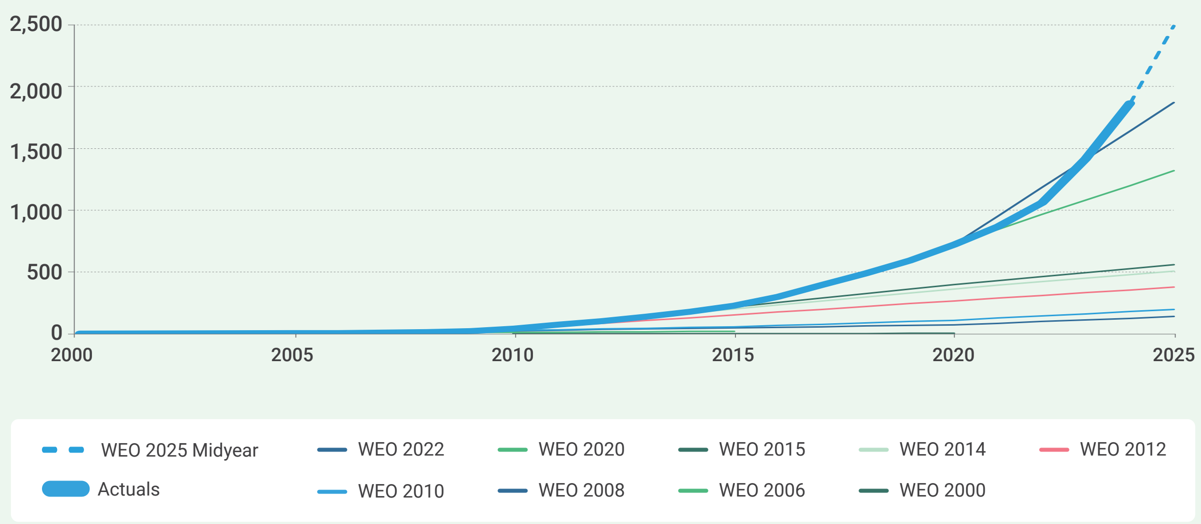
The comparison with the digital/communications transition is particularly relevant. Thomas Edison built the first commercial power station over 140 years ago, barely five years after Alexander Graham Bell patented the telephone. Consider if both men traveled to the present day. Graham Bell would have no frame of reference for what an iPhone was, or how it works. Edison could almost certainly walk into a power station and understand what was happening, because the technology hasn't changed meaningfully since what he built.

36. IEA World Energy Outlook
37. IEA World Energy Investment
38. Lazard LCOE version 18
39. IEA; Ember Energy
40. IEA World Energy Outlook; US EIA "Capital Cost and Performance Characteristics for Utility Scale Electric Power Generating Technologies" (2024)
41. IEA

Investing in the energy system of the future

Figure 14
The pace of the transition has consistently outperformed expectations

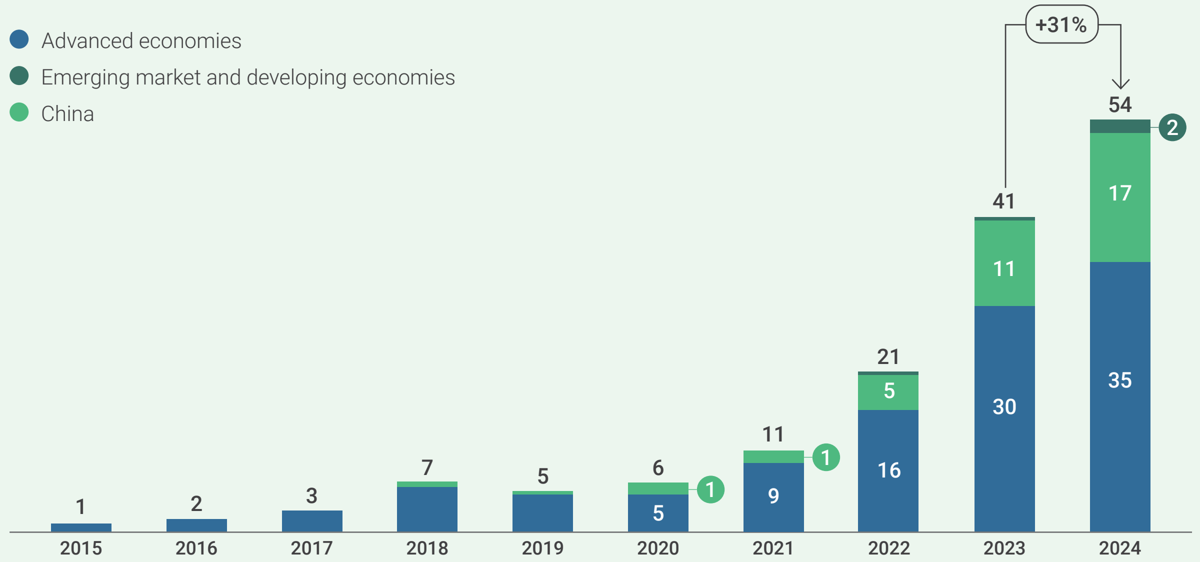
Solar photovoltaics capacity, global, actuals vs. IEA World Energy Outlook, GW, MER



1. 2025 forecast from Ember midyear insights 2025
Source: IEA World Energy Outlook; Ember

Figure 15
Energy storage investments have already begun to accelerate globally

Energy storage investments, billion USD, 2015-2024, MER

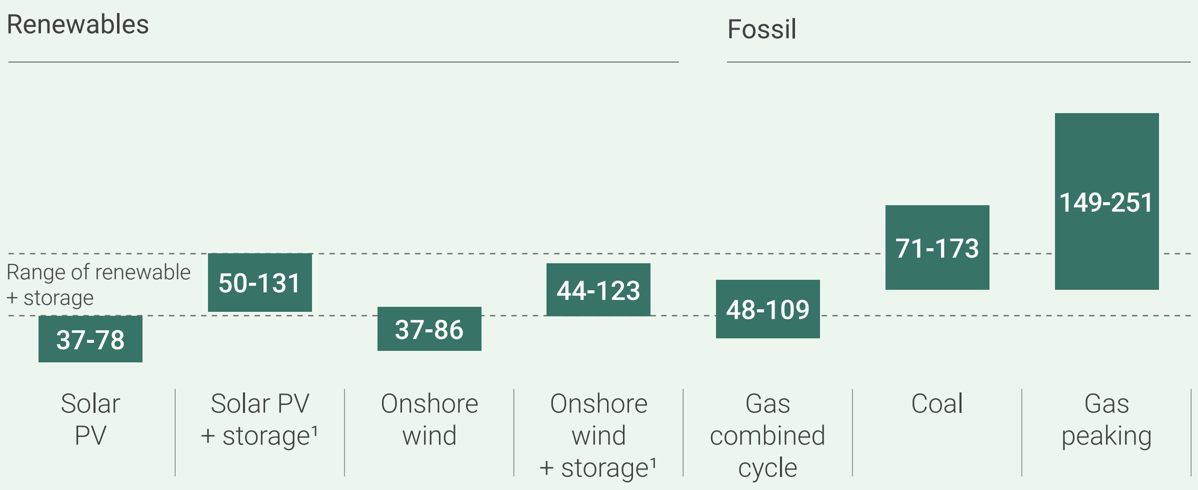


Source: IEA, World Energy Investment 2024 Datafile, IEA, Paris https://www.iea.org/data-and-statistics/data-product/world-energy-investment-2024-datafile

Figure 16
Renewable energy, even when coupled with storage, is competitive with fossil fuel energy on an LCOE basis

LCOE of renewables now lower than fossil generation, with renewable + storage regionally competitive

Levelized cost of energy comparison, USD/MWh, USA



1. Reflects the LCOE for a system composed of standalone generation plus standalone storage less the combined system-level synergies (assumed to be 10% of storage capital costs and 25% of inverter costs). The synergies capture potential cost reductions or efficiency gains from integrating generation and storage, such as shared interconnection infrastructure, improved energy dispatch, enhanced capacity utilization and operational efficiencies.

Source: Lazard's Levelized Cost of Energy Analysis - version 18.0

The grid is the limiting factor in the transition today
To date, the limiting factor of the energy transition has been the grid and the systems which keep the legacy grid stable. Many of the physical and operational characteristics of the grid are either incompatible or non-optimal for an energy system powered by renewables with dynamic demand in the form of modern industry, electric vehicles, and AI data centers, all of which use power electronics. Compounding the issue is the age of the North American and European T&D grids, which have suffered from a lack of investment due largely to flat demand, customer push-back on rate increases, and slow adoption of new technologies within the electric utility sector. The result is an electric grid unprepared for the energy transition and unable to support the functions required.

Current investment lags net zero pace by over USD 300 billion per year, preventing more rapid electrification of the economy, leading to continued high emissions and unnecessarily expensive power.[42] These investment gaps are based on the continued operation of the grid in a similar fashion to the past, an approach that is unaffordable and too slow.

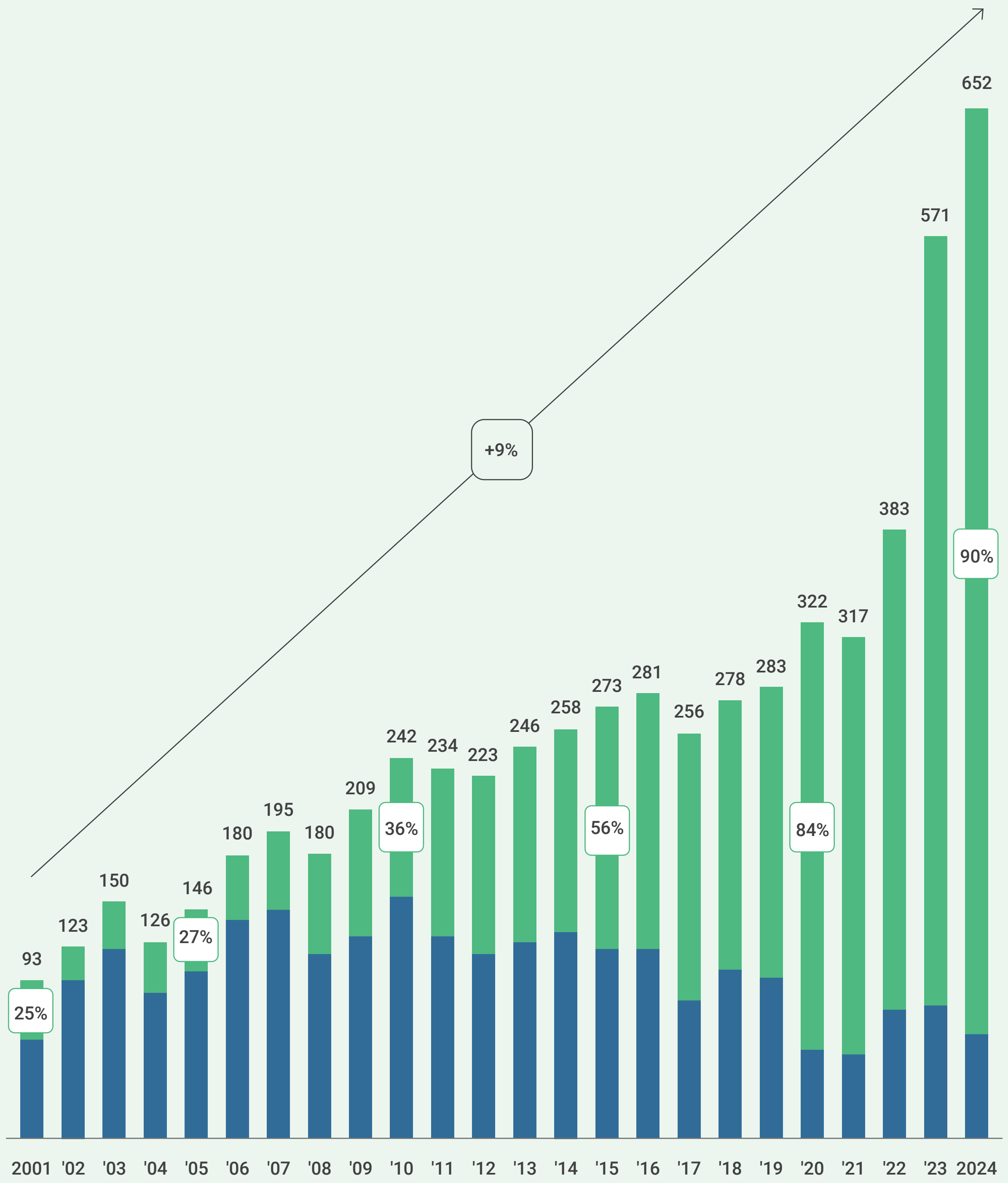
In the US, the pace of grid installation has even slowed drastically (-21% p.a.) over the past five years, despite estimates that total installed wires required will need to nearly double by 2050.[43] This is not the case elsewhere. Over the same period, India's rapid acceleration has seen its installed capacity more than double. The EU has set ambitious grid interconnection targets to make the continents' power system more robust, but current projections suggest that 80% of the EU will miss these targets.[44]

42. IEA
43. US DoE; Energy Transition Commission; IEA
44. ACER, "Monitoring Report on the Implementation of Electricity Market Regulation" (2024); European Commission, "State of the Energy Union" (COM(2024) 634).

Figure 17
The share of new generation that is renewable is growing rapidly

Renewables now make up 90% of newly installed generation capacity

Global installed capacity additions per year by generation type, GW — Fossil, Nuclear, Renewable



Source: Ember electricity data

Iberian Blackout

CASE STUDY

On April 28th 2025, Spain and Portugal suffered Europe's worst blackout in over 20 years, cutting power to 50 million people for 12–16 hours. A rapid voltage spike in Spain triggered a cascade of generator disconnections, severing the Iberian grid from the rest of Europe in seconds.

Three market and policy failures explain why:

1. The market priced out what the grid needed most. Day-ahead prices were near zero, so synchronous generators, which provide the inertia and reactive power essential for grid stability, had no incentive to run. No minimum dispatch requirements existed to keep them online.

2. Ancillary services frameworks weren't fit for purpose. Renewable generators operated at fixed power factors, unresponsive to voltage swings. The only reactive power device online had just 150 MW of capacity. Protective controls were being switched manually rather than automatically.

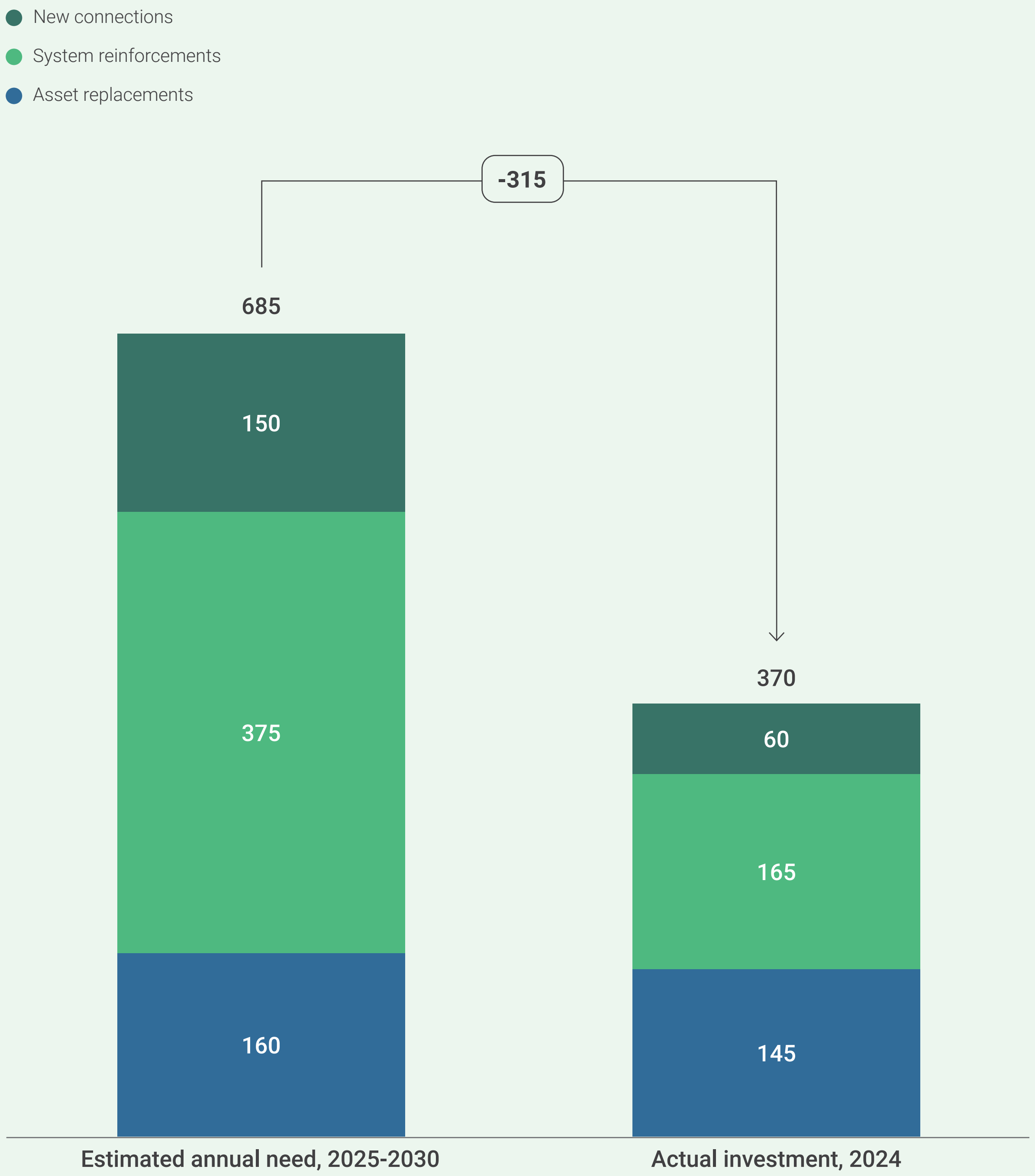
3. Flexible resources couldn't respond in time. When operators spotted the risk and called for a gas plant with stabilizing capability, it needed 90 minutes to start when the situation required something with a response time of under 13 minutes.

The blackout was not the result of operator error, and the system did exactly what it was designed to do. The problem is that this design dates from an era of large synchronous plants and predictable demand, and it doesn't fit in the current Iberian reality. Fixing it requires quantifying the full range of services a high-renewables grid needs, building transparent markets to procure them, and attaching incentives strong enough to attract investment in the right places.

Figure 18
Investment in the grid to date has fallen far short of the projected need through 2030

Grid investment is lagging behind the pace necessary to support the energy transition

Annual investment into global transmission and distribution grid, USD billion per year

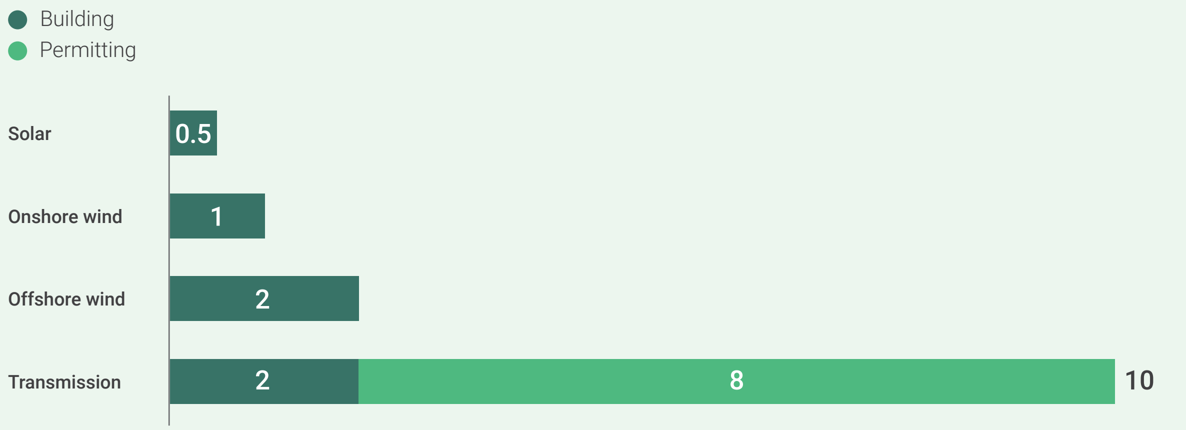


Source: ETC "Building Grids Faster" (2024) based on Systemiq analysis of BNEF (2024) New Energy Outlook

Figure 19
New transmission lines can't get past regulatory barriers

Lack of generation capacity is hamstringing new electrification - and new capacity can't get connected

Construction times for clean energy infrastructure projects, Global average, Years to delivery



Source: Systemiq analysis for the ETC; ETC (2023), Streamlining planning and permitting to accelerate wind and solar deployment

The implications are stark. No matter how much sustainable energy is produced, the future energy system will not be achieved if that energy cannot reliably and affordably reach end consumers. Without belief, and assurance, that this energy is available, industry, households, and transport cannot comfortably invest in the electrified assets that will reduce their costs and reduce energy externalities.

Lagging grid investment boils down to organizational and regulatory hurdles: they are organized from the bottom-up, consisting of numerous entities that must cross myriad local hurdles to be able to build. Each effort to build out the grid requires multiple permits across multiple jurisdictions, opposition from impacted property owners, as well as opposition from consumer advocacy groups worried about cost, and often political pressure from climate change naysayers. Getting past these hurdles takes time, with some estimates suggesting it takes an average of 10 years to get a new transmission line built, with eight of those spent on permitting and permissions.[45]

Furthermore, grid infrastructure is capital-intensive. There are many benefits of a robust and agile grid, often shared by the entire economy. But the requirement for timing, sizing, and location may be dictated by one large load, such as a new data center. For a utility and grid operator, highly regulated cost-recovery mechanisms designed to treat all customers fairly and equally can cause significant delays and require extensive stakeholder engagement. Solving the investment gridlock requires a combination of better utilizing assets already built, reducing the total grid investment need, and designing markets for performance-based investment.

45. Systemiq analysis for the Energy Transmission Commission

Investing in the energy system of the future

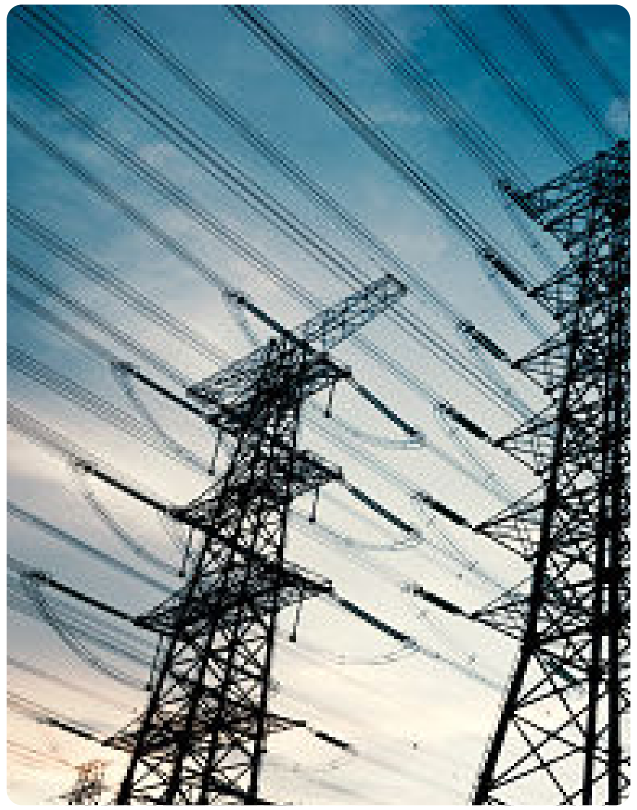
UK Great Grid Upgrade

CASE STUDY

The UK's Great Grid Upgrade, launched in 2023 and now moving through phased regulatory approvals and construction, is the largest expansion of the country's electricity transmission network in decades. The Upgrade involves tens of billions of pounds of investment in new high-voltage lines, subsea HVDC cables, and substations to connect large volumes of offshore wind to demand centers in England. The upgrade is a response to a grid overmatched for the future of energy: grid connection queues have stretched to 10–15 years, with over 700 GW of projects in the pipeline, far exceeding near-term system capacity.

Network constraints are already costly, with the UK spending over GBP 1–2 billion per year on constraint payments, which included paying wind farms to turn down. The Upgrade, however, is critical to meeting the UK's target of 50 GW of offshore wind by 2030, as well as reducing curtailment, and enabling cheaper renewable energy to flow across the system.

More fundamentally, the Great Grid Upgrade is representative of the proactive, system-wide planning model needed to align the grid for a more flexible future. Instead of connecting generation sequentially and upgrading the grid in response to bottlenecks, the UK is now planning and building network capacity ahead of need, coordinated across offshore and onshore systems. This approach shortens queues, reduces wasted development spending, avoids inefficient upgrades, and enables a more reliable grid that delivers abundant power.



700 GW

The UK grid connection queue has stretched to 10-15 years, with more than 700 GW of projects in the pipeline and GBP 1-2 billion spent each year on constraint payments.

New systems are needed to bridge the legacy system with the future

The electricity system requires more than an increase in generation and grid assets to reliably deliver abundant energy. Services today are designed for the legacy power system, the large, centralized, baseload-focused system described in the first chapter. Innovation in system features such as grid controls, storage, and market design must, at a minimum, keep pace with the structural changes of decentralized generation, dispatchability, and two-way power flows. Demand side flexibility and response needs to be fully incorporated as a resource, and controlled and compensated in a way that it becomes dependable for grid capacity and reliability. Today, the gaps are evident thanks to events such as the Iberian blackout of April 2025, which present the urgency of solution deployment.

Virginia and the Future Grid

CASE STUDY

In spring 2026, Virginia passed America's first grid utilization legislation, SB 621, with the aim of maximizing the potential of the existing grid. SB 621 empowers the State Corporation Commission and utilities to work collaboratively to identify the best, lowest-cost solutions to drive down the cost of electricity, rather than mandating specific technologies. It establishes grid utilization metrics at the feeder and substation level, and incorporates those metrics directly into the Integrated Resource Plan (IRP) process for the first time.

By embedding utilization metrics into planning, SB 621 helps utilities maximize existing infrastructure before turning to expensive new construction, thereby reducing congestion, smoothing peak demand, and improving overall system load factors. This means lower stranded asset risk, better alignment between load growth and infrastructure investment, and more disciplined capital deployment. Over time, this shift from "build for peak" to "optimize system-wide utilization" can contain transmission and distribution cost growth, improve reliability through smarter asset use, and save customers billions of dollars.

This legislation is particularly notable as Virginia is one of the states most heavily impacted by data center construction with its proximity to US Federal Government agencies. SB 621 has, in large part, been driven by the projected growth in Virginia's data center capacity: it is set to grow by two to three times in the next ten years, from ~10 GW to as much as ~30 GW. Virginia simply cannot build enough new transmission and distribution to support operating the grid as it has in the past, and SB 621 is a first step in future-proofing demand for this reality.

As the system changes, the following capabilities need to be addressed to guarantee reliable and abundant energy provision:

Grid stability

The decision to standardize on alternating current 140 years ago means the legacy system is dependent on the inertia of high mass rotating machines, which naturally synchronize frequency leading to stable power. As increasing levels of renewable energy are connected, mostly based on power electronics, greater adoption of direct current or new sources of stabilization are needed. Power electronics also pose a challenge to voltage regulation, another key element of maintaining a stable grid.

Dispatchability

Fossil fuel plants are both predictable and dispatchable: the power produced can be controlled through regulating the fuel consumed. Solar and wind resources do not have this ability and must be supplemented with sources of dispatchable power, such as stored power in batteries or flexible hydro, to compensate for short- and long-term variations in energy production to provide reliable and abundant energy. The good news is that as more renewables are connected, they begin to compensate for each other through geographic dispersion. For example, cloud cover variation effects different solar power plants at different times.

Market reform

Power markets in many regions are struggling to reflect and support the transitioning electricity system. Renewable energy generation has near-zero marginal cost of production when the sun is shining or wind is blowing. This has led to large periods of negative pricing during oversupply of solar and wind, which discourages investment. In some cases, renewable energy producers are even forced to turn off their generation. Conversely, there have been periods where consumer prices are set by expensive fossil generation despite the majority of energy being provided by low-cost renewables.

New pricing models with better locational, time, and service bases, will improve energy affordability, while still incentivizing investment in the necessary power generation and infrastructure. Australia's National Electricity Market, for example, moved from 30-minute to 5-minute price settlement in 2021, aligning wholesale price signals with the actual dispatch interval, so fast-responding assets like batteries can capture the real-time value of balancing renewable variability.

Flexibility

The most efficient power system is one where system assets, such as storage and end-consumers, participate dynamically, adjusting their consumption and charge/discharge to best suit the system as a whole. Batteries, hybrid plants, and industrial loads provide stability and monetize their flexibility across time and location, turning volatility into revenue sources. This dynamism can replicate the stability, flexibility, and dispatchability provided by fossil production in a legacy system.

Adaptation

The energy system, and in particular the electrical grid, is significantly impacted by the increase in extreme weather events. US electricity customers experienced nearly double the amount of power outage hours in 2024 than in 2014, with hurricanes accounting for 80% of the increase.[46] Additionally, utility equipment has been directly or indirectly responsible for numerous major fire events in the last decade.

Adapting to these conditions is a high priority for the electrical industry, requiring strategies ranging from basic vegetation management to advanced weather forecasting. In California, the three investor-owned utilities now spend approximately USD 7-9 billion per year on wildfire mitigation CAPEX, which includes undergrounding, advanced line sensors, dynamic line rating, and vegetation management. PG&E alone has increased its annual wildfire mitigation spend from USD 3.8 billion in 2019 to USD 6.2 billion in 2024. This category of CAPEX barely existed a decade ago.

The repercussions of non-adaptation are significant. The January 2025 Los Angeles wildfires alone contributed enough CO_2 into the atmosphere to undo the benefits of 225 MW of solar energy produced over 20 years,[47] which is enough to power San Francisco for a year.

46. US EIA, "Annual Electric Power Industry Report" and System Average Interruption Duration Index
47. Copernicus Atmosphere Monitoring Service (CAMS)

These challenges are material but not impossible to overcome. They all stem from a similar place: the energy transition to date has focused primarily on increasing generating capacity, and secondly on electrification of demand. While necessary, this is not sufficient. Reaching the energy future we envision requires building out the connective tissue of the system: the infrastructure, systems, and services required to make sure that sustainable, abundant and secure energy can be delivered reliably and affordably.

Technologies that enhance existing infrastructure will accelerate the transition

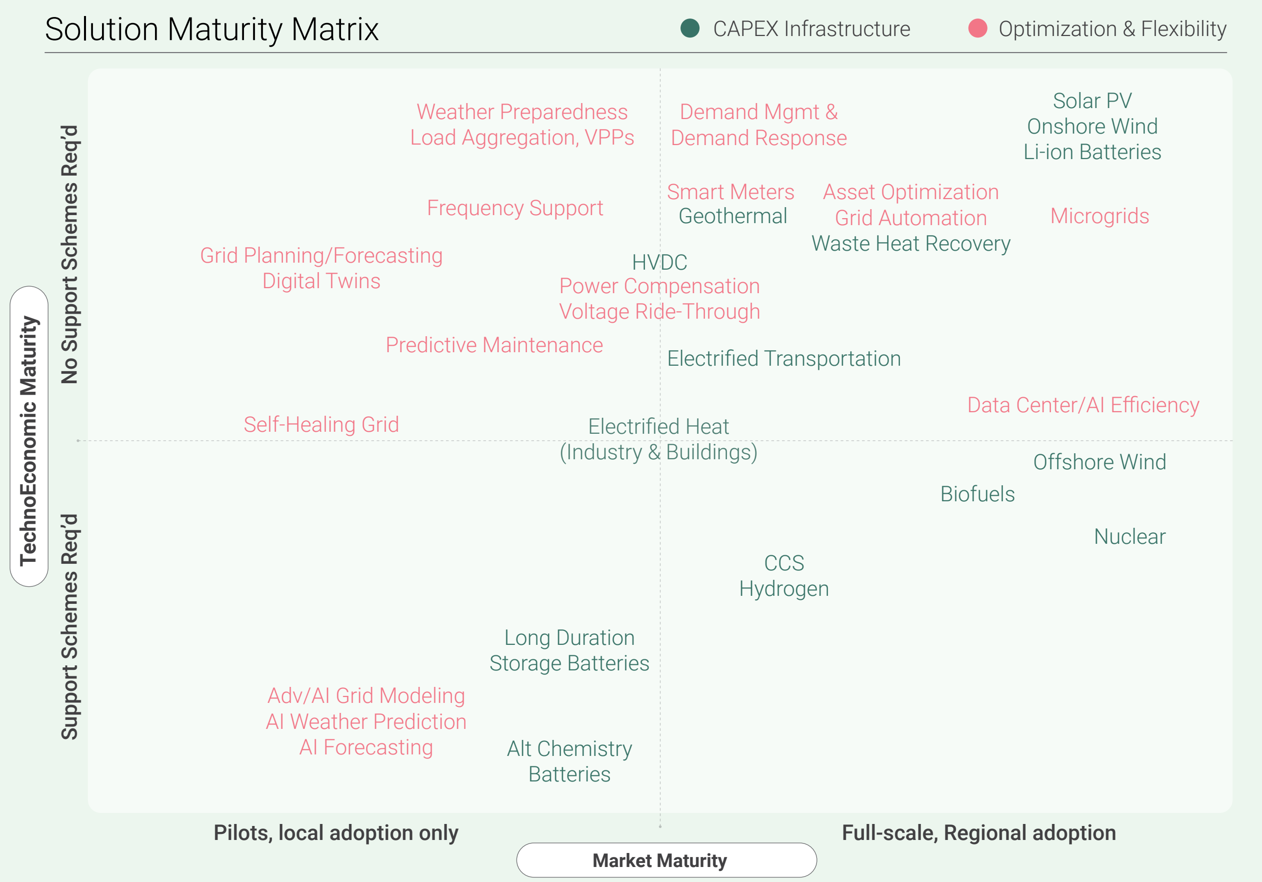
The future energy system does not necessitate discarding the existing infrastructure. While new assets will always be part of the long-term picture, a major share of near-term progress will come from technologies that improve how today's infrastructure functions. These solutions can make the transition faster, more reliable, and more affordable, by unlocking efficiencies from the existing system.

To date, much of the transition has been driven by large, capital-intensive additions to generation capacity, such as utility-scale solar and wind. Future pathways often emphasize similar expansions, including major grid build-outs. These investments, of course, remain essential. However, there is substantial additional potential in technologies that enhance, optimize, or extend the assets we already have. These are solutions that can accelerate renewable grid connections, increase the utilization and effective capacity of the existing grid, provide essential system stability services, and refurbish or repower existing generation assets.

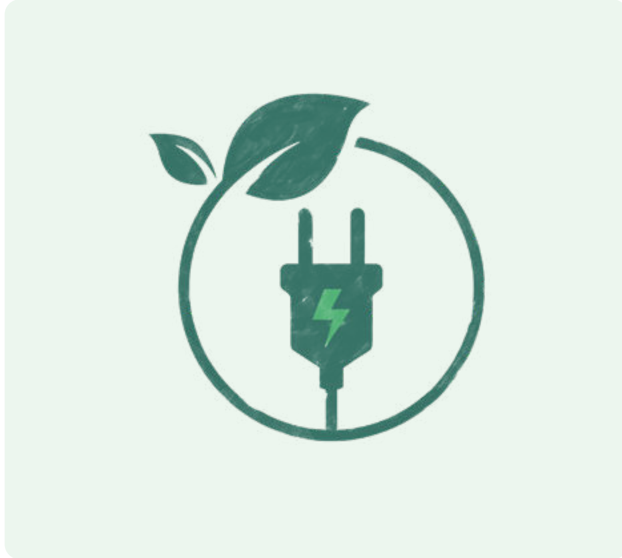
The chart below maps some of the existing and new technologies that are part of the energy system of the future, and their relative position in TechnoEconomic and market maturity.

In this context, a high TechnoEconomic maturity refers to technologies and solutions that are operating at a technical readiness level (TRL) of nine, and that do not require support schemes for adoption.

Figure 20
Relative maturity of technology solutions that are part of the future energy system



Progress will come from technologies that improve how today's infrastructure functions making the transition faster, more reliable, and affordable.



Importantly, this does not mean that support schemes do not exist, such as investment tax credits for solar energy, but rather they are not required for the technology to be cost effective.

Market maturity refers to how widespread the adoption is within the US and Europe, which is often affected by regulatory schemes. Electrified heat for both industry and buildings is in all four quadrants because it is heavily dependent on the specific technology, sector, location, and capital cycle of the existing assets.

The technologies and solutions are split between physical infrastructure, and optimization and flexibility technologies. The capital-intensive physical infrastructure solutions are largely on the right, market mature, side of the chart, a function of their wide-spread adoption and of existing market mechanism that promote their use. By contrast, the newer optimization, flexibility, and efficiency solutions are generally less mature but are poised to take advantage of the changing markets and regulatory constructs, such as those highlighted previously in Texas, Virginia, and the EU. Many of them have high TechnoEconomic maturity and can quickly be deployed as customers increasingly understand the benefits and market impediments fall.

Innovations in grid technology span hardware (HVDC, advanced transformers), software (system modeling, digital twins, forecasting), and operational services (predictive maintenance, grid optimization).

These solutions aim to increase utilization of existing grid assets, reduce congestion and curtailment, and streamline planning and operations. Despite promising results where they have been implemented, and the clear need, solutions like self-healing grids and advanced grid modeling have been slow to develop, in part because grid digitalization and automation have suffered from under-investment.

Technology that enables flexibility, such as smart meters, demand-response platforms, and efficiency analytics, are well established. Others, such as load aggregation and Virtual Power Plants (VPPs), face market hurdles, although there are examples of very successful adoption in some utility service areas.

Due to the impacts of extreme weather, AI-based technologies for advanced weather forecasting, preparedness such as vegetation management and advanced lightning detection, and prevention such as targeted public safety power shutoffs, are developing rapidly. Undoubtedly the assessment of TechnoEconomic maturity of this class of technologies will be out-of-date the day this report is published.

The transition relies on a diverse mix of technologies, each addressing specific system challenges. A structured approach is required to determine where interventions can create the greatest impact. The next chapter outlines how our Theory of Change helps identify these leverage points and focus efforts where they matter most.

The Summa theory of change

The figure below charts our specific Theory of Change for the energy transition. When we invest in one of the investment themes, such as in EA Technology in 2024, we work directly with the portfolio company to define output metrics to track. EA is a grid-enhancing technology company within our "Enhanced grids" theme, with novel and efficient solutions for monitoring the electrical grids and assets tightly tied to our impact theme of reliability. With this in mind, we work with EA to track number of homes and businesses they monitor, as well as the reduction in minutes of power outages for consumers. These are the metrics we believe correlate most closely with our impact mission.

These outputs lead to important outcomes. For example, monitoring houses and businesses provides detailed data on network quality and capacity, enabling grid operators to increase capacity without additional CAPEX, reducing total system costs and increasing availability of power.

These are target outcomes for our "affordable" and "reliable" impact themes. Reducing power outages is itself directly tied to another "reliable" outcome: faster system recovery after disruptions. We will continue to work with EA to ensure that together we develop output metrics that are in line with their business, and that they have the support they need to continually improve performance against these metrics.

Theory of change: connecting systems change to investment opportunities and impact

Input
Direct impact

Summa's inputs are our investments in resilient, high-performing companies that solve global challenges. We deploy capital, cutting-edge expertise, and active ownership to scale innovative portfolio companies at the forefront of the energy transition.

Our team comprises leading energy experts including Andrew Marino, Gisle Glück Evensen, Annika Moman, Gustav Lindberg, and Sundeep Singh. Their knowledge and experience are instrumental in shaping our sourcing, investment decisions, and portfolio support.

Our Via Summa team provides hands-on operational guidance to our growing network of portfolio companies. We regularly convene forums that bring together industry leaders, researchers, and stakeholders to spark innovation and share best practices. This helps our companies anticipate emerging risks, align with regulatory expectations, and contribute to systems change.

Activity
Direct impact

We invest in portfolio companies operating across four investment themes, described in detail in the following chapter. Summa's energy strategy spans the full value chain. In aggregate, these companies address critical leverage points for building a future-proof energy system. Together, they represent the next frontier of high-impact, high-growth investment opportunities in energy. Investing in these areas unlocks both significant financial returns and meaningful systemic change.

- Sustainable Generation
- Enhanced Grids
- Electrified Demand
- System Services & Flexibility

The investment opportunity:
Read more about the investment opportunity across these four themes in the next chapter.

The Future We Envision: Future We Envision: Read more about the impact we aim to enable in the chapter about the future we envision.

Impact
Indirect impact

Impact represents the long-term, systemic change that results from sustained outcomes, moving beyond immediate results to deliver broad societal and environmental benefits aligned with Summa's mission. For our Energy Transition theme, this means realizing the future energy system we aim to enable. Achieving this vision demands collaboration across industry, academia, regulators, and communities, as no single actor can drive this transformation alone.

- Sustainable
- Reliable
- Secure
- Affordable
- Abundant

Output
Direct impact, examples

Our portfolio companies deliver products and services that generate specific, measurable results within each investment theme. Summa works closely with each portfolio company to define and track the metrics that best capture their distinct contributions. At the company level, key metrics include:

Sustainable generation:
MW of repowered renewable assets MW/MWh
of hybrid renewable + storage system added
MWh of firm clean energy delivered

Enhanced Grids:
MW of additional transfer capacity unlocked
Share of grid with real-time visibility
# of homes/business covered with sensors
Reduction in outage minutes from congestion

Electrified demand:
MW of flexible demand enrolled # assets with
smart monitoring MW of heat electrified
Total MWh shifted from peak periods

System services & flexibility:
Technicians and specialists trained
Clean energy projects delivered on time
Reduction in outage duration post-severe weather

Outcome
Indirect impact, examples

These outputs contribute to the system-level outcomes necessary to drive the energy transition, capturing the broader progress achieved when multiple interventions align across sectors.

Sustainable:
Decline in combustion related pollutants
(NOx, PM2.5, etc.)
Lower total GHG emissions from energy sector

Reliable:
Increased grid stability with fewer frequency/
voltage deviations
Faster system recovery after disruptions

Secure:
Reduced dependency on imported fuels
Stronger physical and cyber resistance of
grid and distribution

Affordable:
Reduction in total system cost
Lower and more predictable prices for
households and businesses
Reduced exposure to fossil fuel price shocks

Abundant:
Increase in total clean energy available
Local availability of clean electricity across system

The investment opportunity

The energy transition is already considered the investment opportunity of this generation. Our core investment themes support an addressable market of EUR 1.2 trillion which creates EUR 5 trillion of investor value, alongside creating an additional EUR 800 billion of ecological value for the planet.

The fundamentals of the transition are strong, with economic tailwinds pointing towards continued electrification. The constraints, and opportunities, lie in the system: an outdated architecture and operating model unable to meet both today's needs and provide the future energy system we envision. Solutions that unlock more rapid electrification create significant value for the system, and this value can be shared by the products and services that do the unlocking. We have organized our investments into four themes, that align with the four elements of the energy system and represent the solutions with the greatest ability to accelerate the transition. They are Sustainable Generation, Enhanced Grids, Electrified Demand, and System Services & Flexibility.

Across Europe and North America, we estimate these transition-enabling activities represent EUR 1.2 trillion in annual addressable market by 2030 and can unlock EUR 5 trillion in investor value alongside an additional EUR 800 billion in ecological value for the planet. The addressable market comes from investment in the four key themes in the IEA Net Zero Emissions by 2050 Scenario.

The value created by the companies providing the solutions includes the market valuation of their contribution to accelerated electrification and avoided capital expenditure, especially in the grid. Throughout this report, we have described the inefficiencies in the grid that are constraining electrification, and investments in system solutions that unlock capacity and create flexibility drive tremendous value that can be captured by the companies providing it.

This is where Summa's Theory of Change differs from other approaches. We aren't focused on deploying capital solely through building more, but rather on using that capital to get more out of what we have already built, and to enable a faster transition.

A consistent requirement for sound investments is system-level affordability. The solution should drive down the LCOE for the whole system. Occasionally, a subsidy or contract-for-difference is required for a particular technology to improve the overall system. Summa is not opposed to support schemes. However, we do not invest in technologies based solely on these schemes and only see them as relevant when the technology being supported has a clear line-of-sight to unsupported cost competitiveness.

Investment themes

Below we have outlined the relative opportunity within each theme, as well as examples of subthemes, covering the greatest opportunities for Summa's investment profile. While the themes are an effective way to communicate priorities, the most promising investments will span multiple themes and deliver systemic benefits.

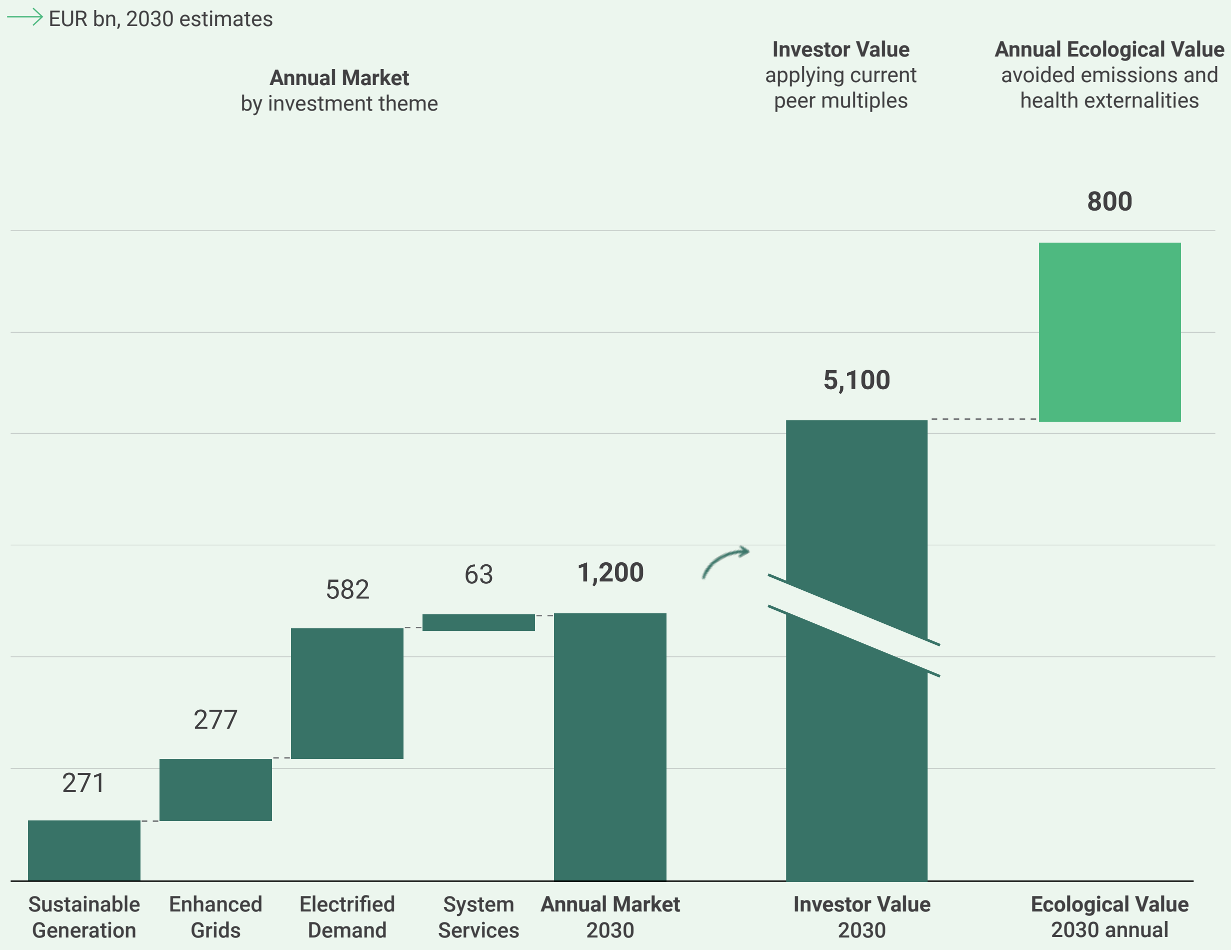
Sustainable generation

Value pool: EUR 271 billion

The transition will require significant amounts of additional sustainable generation, distributed at all levels of the system and interconnected as quickly as it can be built. That electricity needs to reach consumers when and where they need it, without artificial curtailment or outdated market constraints. The intermittency associated with solar and wind generation needs to be coupled with energy storage assets to provide the match between supply and demand.

Figure 21
The energy transition investment opportunity in Europe and North America

Summa's role in the future energy system: a EUR 1.2 tn annual market by 2030, unlocking 5tn in investor value and EUR 800 bn in annual ecological value



Investable activities in this area include:

Optimization of existing generation
Optimization and advanced asset management lifts output and improves operations at grid connection points already in place. This is one of the fastest ways to increase practical renewable supply because it avoids new transmission permitting, shortens time to impact, and increases capacity factors on infrastructure that already exists.

Hybrid plants: renewables and storage
Co-locating storage with wind or solar upgrades variable generation into a resource capable of providing the stability and peak-shaping once supplied by thermal units. This directly reduces curtailment and improves system efficiency by matching renewable production with periods of system need. This can include greenfield hybrid plants or investing in storage at existing wind or solar parks.

Local/distributed generation
In areas where the bulk transmission grid is congested, placing smaller scale generation, storage, or a combination, close to load centers bypasses constrained corridors, improves local reliability, and reduces losses. This approach becomes increasingly important as transportation electrifies, and commercial and industrial loads grow faster than grid expansions can serve them.

Enhanced grids

Value pool: EUR 277 billion

The grid is the most significant bottleneck in the transition. Despite progress in the transition, the grid's operational model still assumes centralized generation, one-directional flows, and stability services provided mechanically. Our investments are aimed at addressing the grid investment debt by unlocking more capacity within the existing infrastructure, and significantly increasing the speed at which new generation and demand can connect. Investable activities in these areas include:

Digitization, automation and smart grid technologies
The grid still lacks modern sensors and control systems in many areas, leaving operators with limited information, especially on the distribution systems where EVs, solar and batteries are being installed. Data and control systems, such as feeder monitoring and automated voltage management, give operators the visibility they currently lack and allow these assets to be connected safely.

There are a myriad smart grid technologies, such as dynamic line rating which increases the safe transfer capacity of existing lines by replacing conservative static calculations with real-time data. This also includes improved modeling using smart meter data, prediction analytics, and advanced weather models to better understand when and where power is being used.

Power compensation, voltage ride-through and frequency support
As synchronous machines retire, grids lose inertia and other stabilizing properties. Technologies such as grid-forming inverters, advanced relays, and dynamic voltage support fill these gaps, improving stability. They ensure the system can accommodate high shares of inverter-based generation and power electronics-based demand without risking reliability.

EA Technology

PORTFOLIO COMPANY

In 2024 Summa took a majority position in EA Technology, a global leader in electrical asset management and grid-edge solutions headquartered in the UK. EA's hardware and software provides grid-edge intelligence which allows owner and operators of the electrical network to build resilient and reliable networks. The ecosystem enables real-time monitoring and identification of issues such as capacity limitations, faults, pre-faults, power quality disturbances and more. These actionable insights mean engineers can target reinforcement where it is genuinely needed, de-risk flexible alternatives, and give customers clearer answers about what the network can accommodate and when.

Microgrids and remote power systems
Small- to medium-scale generation plus storage systems in homes, buildings, and commercial/industrial sites charge when power is abundant and can isolate, or island, from the grid when there are reliability or resilience events. This capability can keep critical local networks operating, reducing stress on the overall grid and providing reliable power where needed.

Electrified demand

Value pool: EUR 582 billion

Electrification of heat, transport, and industry is essential to reduce fossil fuel use, as well as improve the efficiency and cost competitiveness of the sectors. With the Ukraine war and the conflict in the Middle East, security and continuity of operations will increase the adoption of electrified demand.

Investable activities in this area are impacted by capital cycles, regulatory environments, and markets, but the opportunity space is significant:

Clean and efficient manufacturing
Energy is typically the second highest cost for industry, after labor costs. Solutions that reduce energy usage, and electrify it, are gaining in popularity and adoption. This opportunity sector ranges from all-electric steel production, to electricity-based fuels, and to electrically-derived hydrogen for chemical feedstock.

Thermal efficiency and storage
Heating, especially industrial heating, is a tremendous source of inefficiency in the energy system. As we move away from fossil fuels, efficient district heating systems are becoming increasingly important, as well as electrified heat where and when it is needed, with waste heat recovery wherever possible. Integrated controls and thermal storage shift demand across hours, making heating a flexible asset that can significantly contribute to system stability and asset optimization

Smart meters and meter data management
Investment in smart meters has been strong for several decades, with penetration rates at 82% in the US and 63% in Europe. However, the data they gather is significantly underutilized when it comes to providing useful information about electricity usage patterns to both customers and utilities. Leveraging this data provides opportunities for better system operations and capital investment decisions.

Pacific Steel Group

PORTFOLIO COMPANY

Summa invested in the Pacific Steel Group (PSG), an established rebar installation company in Southern California that is vertically integrating with an all-electric low emissions mill. PSG's advanced micro mill from Danieli eliminated natural gas and uses all electricity to melt, form and fabricate the rebar. It has several efficiency improvements including power management software that reduces power usage by nearly 10%, and a continuous casting and rolling system eliminating reheat. PSG is building onsite solar and battery storage which will supply nearly 40% of the energy needed, and working with the electric utility to define a rate structure that will allow them to provide additional flexibility in periods of high grid stress. Additionally, the mill is fitted with an emissions control system that meets one of the strictest air emissions requirements in the United States.

System services and flexibility

Value pool: EUR 63 billion

The energy transition requires a scale of deployment, servicing, and optimization beyond what is seen in the legacy system, requiring significant additional service providers, including professionals, technicians, scientists, and system operators. They will all have to design and operate a system with a new level of dynamism and flexibility. Without flexibility services across the system, electrification could sharpen peaks, exacerbate congestion, and increase reliance on expensive and polluting fossil fuel peaking plants.

We see most particular opportunity in:

Virtual power plants, demand management and demand response
Most users of energy are unaware of the strains on the electric system, nor when there is excess available power, outside of publicized extreme weather or reliability events. Without information or incentive, customers do not participate in the efficiency and reliability of the system, despite often having the ability to do so. Demand side technologies, and coordination through mechanisms like Virtual Power Plants (VPPs), allow customers to become active participants in the energy system, and benefit from the services they provide.

This opportunity includes industrial demand, much of which is operationally flexible. Processes such as cold storage, water pumping, air compression, and batch-based manufacturing can be scheduled or shifted within defined windows without affecting throughput or product quality. With appropriate controls, these loads can move consumption away from stressed hours to periods of lower cost, abundant power.

Resilience and adaptation technologies
Improving system resilience to extreme weather and manmade attacks is an increasingly important part of electrical system reliability. Technologies such as lightning detection and protection, early fault detection in urban-wilderness interfaces, and circuit specific public safety power shutoffs, are growing quickly in the face of increasing threats. With the rise of our digital economies, response and restoration following major weather events is hampered by the lack of data on existing systems. Making the necessary improvements can provide tremendous value.

Modeling, forecasting, planning, and settling
As the system complexity increases, so will the information models that support the full life-cycle and operations. Visibility and transparency are essential to the future energy system. Services that use existing meter data, AI-enabled pattern development and forecasting, smart planning of where to expand, upgrade and reinforce, and settle the actual performance between financial partners will become increasingly more sophisticated and essential.

Predictive maintenance and asset-management platforms
As renewable energy, storage, and grid assets grow, the uptime, performance, and lifetime extension become system-critical. Advanced monitoring and maintenance platforms ensure assets deliver their expected output, and remain reliable under stress, while allowing owners and operators to prioritize expenditures where needed most.

Workforce development
One of the most critical shortage areas in the energy transition is skilled labor, from lineman to electrical engineers to surveyors. Developing hundreds of thousands of highly skilled professionals will take time, even if the interest is there. Systems and tools like visualization, automated design, and drones are increasingly necessary to effectuate the energy transition with an increasingly strained workforce.

These four investment themes share common characteristics that make them attractive for impact investors. They all focus on large, near-term, underserved demand caused by structural bottlenecks. They share favorable economics driven by efficiency, avoided CAPEX, and learning curves. None require subsidies for competitiveness, and all have strong tailwinds.

A pathway forward in the energy transition

The energy transition requires contributions from across the economy. It requires a coordinated sequence of actions from a range of actors including governments, infrastructure investors, impact investors, corporates, and philanthropy all doing what they are structurally best suited to do, with each solving different parts of the problem.

Taken together, these actors determine the speed of the transition. Governments should clear the path, infrastructure investors should build the backbone, impact capital should accelerate enabling technologies, and philanthropy should nurture the next round of innovation. The transition succeeds when each plays its part, and where capital flows to bottlenecks rather than around them. Done well, this will lead to cleaner, cheaper, more secure, and more abundant energy system years before it would be otherwise.

Tibber

PORTFOLIO COMPANY

Summa is part owner in the company Tibber, a residential digital electricity platform that goes beyond traditional energy retail by combining an energy contract, smart home devices, and grid flexibility into a single integrated offering. The platform empowers European households to reduce consumption and shift it in response to real-time price signals, thereby lowering their costs. They do this by intelligently scheduling the energy usage of electric cars and heat pumps and the energy generation of solar and batteries. With such a large fleet of physical energy assets, Tibber trades capacity in energy balance and reserve markets, resulting in customers earning money by providing flexibility services to the grid through a VPP. This service helps defer costly grid infrastructure investments which would have resulted in increased bills for all energy consumers.

Governments should establish the direction of travel. Their task is to establish long-term policy stability through planning rules, market design, carbon pricing, and permitting, as well as building the shared infrastructure no private actor can deliver alone, including transmission corridors and interconnection. They should use targeted incentives only where they accelerate cost curves or unlock early adoption and avoid locking economies into the use of inefficient solutions due to excessive subsidy. Their job is not to pick winners but to remove friction by shortening grid connection queues, reducing uncertainty, and ensuring that markets reward flexibility, stability, and clean firm power.

Infrastructure investors then take over where conditions are predictable. They finance the long-lived, standardized assets that form the backbone of the energy system, including utility-scale renewables, transmission projects, storage farms, EV charging networks, and heat networks. Their large balance sheets, appetite for long-term contracted cash-flows, and ability to deliver standardized, proven assets at scale make them optimal at ensuring mature technologies get rolled out as widely and as cheaply as possible. By dint of their risk appetite, however, infrastructure investors are badly placed to solve the bottlenecks of the transition.

This is where **impact investors** play a distinct and catalytic role. The technologies to solve these bottlenecks require active ownership, sector expertise, commercial discipline, and growth capital. Impact investors should focus on scaling commercially proven solutions, professionalizing operations, helping teams enter new markets, and integrating them into the existing energy ecosystem.

Corporates shape the pace of transition through their own energy use. When large energy users electrify heat, transport, and industrial processes, they create the stable demand signals the system needs to scale. The road forward is clear: electrify earlier, procure clean power with long-term certainty, and participate in flexibility markets.

Philanthropy and **catalytic capital** bridge the earliest funding gaps on the most nascent technologies. Early funding shortens the path to inevitability and expands the geographies and technologies the transition can reach. The box below describes how the Summa Foundation works with catalytic capital.

Summa Foundation: Closing the gap where markets fall short

Many critical social and environmental challenges cannot yet be solved by markets alone. Promising solutions often exist, but they are too early-stage or too unproven and perceived as too risky to attract commercial capital, despite their potential for large-scale impact.

The Summa Foundation exists to bridge this gap. As an independent charitable foundation owning 10% of Summa Equity and its funds, it is structurally embedded in Summa's model.

Guided by its purpose to promote thriving societies and nature, the Summa Foundation's vision is to create a world that we want to pass on to the next generation. The Foundation pursues this vision through its mission to serve as an impact multiplier that addresses global challenges that markets alone cannot solve. While Summa Equity invests where impact and market-rate returns go hand in hand, the Foundation supports early-stage solutions and helps move innovations from proof-of-concept towards commercial scale.

The Foundation works closely with Summa Equity's teams, combining philanthropic capital with deep industry expertise, global networks, and long-term engagement. This partnership enables targeted support where it can unlock the greatest additional value, particularly within Summa's investment themes.

In the energy transition, there continue to be major opportunities to expand access to clean power. Africa provides a good example. Today, around half the continent's population lacks reliable electricity despite having 60% of the world's solar resources. Off-grid renewable solutions can drive economic growth, and improve health and education outcomes, especially when combined with local financing and skills development. Yet many of these solutions are not commercially ready and philanthropy must play an important role in proving models, building capacity, and preparing them for long-term scale and future investment.

SUMMA EQUITY | SUMMA FOUNDATION