Together makes progress

# AI for energy systems

## Unlocking sustainable AI for a resilient energy transformation

**November 2025**

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# Foreword

Energy systems around the globe stand at an inflection point. Many leaders in the energy sector are navigating a transformation of scale and complexity, as they balance surging demand, environmental considerations, and the imperative to strengthen the resilience of their operations in an uncertain environment. These converging challenges present an opportunity: to reimagine the future of energy enabled by the responsible and strategic application of artificial intelligence (AI).

AI is rapidly becoming a catalyst for measurable progress in energy systems. Leaders across the sector are deploying AI-driven solutions to optimize their operations, strengthen reliability, and unlock substantial economic and environmental gains. From automated methane leak detection that saves billions while reducing emissions, to AI-powered demand forecasting that delivers both cost savings and grid flexibility, the evidence shows that AI is already helping energy stakeholders to achieve more, and to do so sustainably.

The potential impact of AI on energy systems is vast—by 2030, strategically leveraging AI could enable energy savings that far exceed the technology's energy consumption, deliver hundreds of billions in annual cost reductions, and help avoid emissions. These benefits, however, are not automatic. Realizing them may require action across the energy ecosystem. Energy producers and manufacturers, technology companies, financial services, and policymakers each have an important role to play.

Additionally, as AI becomes increasingly embedded in critical infrastructure, it's important that leaders work to uphold principles of sovereignty, transparency, and accountability. Fostering local capacity, governance, and ethical AI practices can help lay the foundation for AI to serve as a trusted enabler of security and resilience.

This report provides a timely and actionable roadmap for leaders to harness AI to help drive efficiency, sustainability, and long-term resilience in energy systems. Explore these insights, learn how other leading organizations have applied these AI-enabled solutions, and consider how you and your organization can help shape a sustainable, and AI-empowered energy future.

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# Executive summary

Energy systems face mounting challenges, notably demand, environmental concerns and the need for enhanced resilience.[1] Artificial Intelligence (AI), with its vast transformative potential, can offer a unique opportunity to help optimize operations, strengthen reliability and unlock substantial economic and environmental benefits.[2,3] It already provides energy systems with significant gains in efficiency, reliability and sustainability, and its full potential has yet to be unlocked.[4]

**AI applications in energy systems can be grouped into three categories, each containing three sub-categories with numerous applications:[5]**

1

**System optimization and control**

- Enhancing real-time network operations
- Optimizing and forecasting supply and demand
- Strengthening market and trade operations

2

**Asset lifecycle management**

- Planning and decision-making support
- Improving operations and maintenance
- Accelerating design, discovery, and innovation

3

**End-use efficiency and management**

- Improving energy management in buildings
- Enhancing transport management
- Optimizing industrial processes

It is important to recognize that system optimization, asset lifecycle management and end-use efficiency and management often overlap and reinforce each other in practice, as many successful AI applications integrate functionalities across different domains, creating powerful feedback loops. For example, demand forecasting supports grid optimization and also informs building management and investment decision-making, demonstrating the interconnected value of AI.[6,7]

Several real-world case studies illustrate the tangible economic and environmental benefits of AI-driven solutions. Automated methane leakage detection, for example, leverages advanced machine learning and remote sensing to continuously monitor networks, resulting in annual global savings of nearly US$6 billion by reducing emissions and operational costs and enabling faster repairs (see Box 1). Additionally, Emerald AI's Conductor platform can enable AI data centers to dynamically reduce power consumption in response to grid stress. In a field trial, these systems reduced power use by 25% over three hours during a peak-demand event (see Box 2). Meanwhile, AI-assisted permitting systems, digital platforms and automated review tools have achieved up to 50% reductions in review times and costs (see Box 3).

The deployment of AI solutions across energy systems can help deliver scalable value from the outset, reaching significant levels of energy savings, cost reductions and avoided emissions in the long run. Deloitte Global analysis reveals that:

- By 2030, AI-enabled energy savings may reach more than 3,700 terawatt hours (TWh), largely exceeding the technology's projected energy consumption.[8,9] By 2050, anticipated savings range from 9,500 TWh to 12,000 TWh, representing more than 10% of final energy consumption in a net-zero scenario.[9,10]
- AI can deliver more than US$200 billion of annual cost savings by 2030 and almost US$500 billion by 2050. Depending on the scenario, this represents US$11 trillion in cumulative savings through 2050.[9]
- AI-driven emission reductions can reach up to 660 megatons of carbon dioxide equivalent ($MtCO_{2eq}$) in 2030[9]—a significant contribution to global greenhouse gas (GHG) mitigation efforts.[11] However, by sustainably reducing the emissions associated with both end-uses and energy production across the system, these reductions follow a compounding pattern, falling to approximately 100 $MtCO_{2eq}$ by 2050.[9]

As AI becomes more embedded in critical infrastructure, questions of sovereignty—control over data, algorithms, and decision-making—are increasingly salient.[12] Sovereign AI principles emphasize transparency, accountability, local capacity-building, and safeguarding sensitive data to ensure that AI systems remain trustworthy and aligned with public interests. Conversely, AI itself can also be a powerful enabler of sovereignty. By reducing reliance on energy imports—it can strengthen the reliability and security of energy infrastructure[13] and empower countries to operate their energy systems more independently.

Integrating AI into energy systems has the potential to help businesses drive efficiency, support sustainability and build long-term resilience, resulting in tangible economic gains.

- **Energy and industrial manufacturing companies** are the main drivers of AI deployment as the end-users and owners of operational data. By investing in scalable applications such as AI-driven asset optimization, predictive maintenance and real-time system balancing, they can help generate rapid returns and resilience. By prioritizing high-quality standardized data, robust cybersecurity and effective data governance, they can impel reliable implementation, with an eye toward leveraging cloud and edge computing to help further unlock AI's potential. Lastly, through collaboration and data sharing with public sector organizations and technology companies, they can promote development of sector-specific AI solutions and regulatory alignment.
- **Technology companies** are among the engines of innovation in the field of AI, and they are key to tailoring AI to the needs of the energy sector. By investing in complementary technologies like the Internet of Things (IoT) and digital twins, technology companies can provide advanced solutions for important challenges in the energy sector such as grid stability, demand forecasting and predictive maintenance. They can help ensure their solutions are fit-for-purpose through close collaboration and direct engagement with energy and industrial manufacturing companies. To further their contribution to sustainability and resilience, technology providers can focus on several key areas: prioritizing procurement of cost-effective and low-carbon electricity and implementing demand-side management strategies for data centers, and embedding principles of sovereign AI—such as explainability, ethics, and open-source integration—into their solutions.
- **Financial services providers** are important for scaling sustainable and resilient AI-driven innovation. By deploying innovative financing instruments, such as green and sustainability-linked bonds, concessional loans, and mezzanine financing mechanisms, they can support deployment of sustainable sovereign AI in the energy sector, such as projects that adopt leading energy efficiency standards and flexible grid integration. As end-users themselves, they can leverage AI to help enhance key aspects of their operations including risk assessments, financial workflows and asset evaluation.
- **Governments and policymakers** can play an important role in creating the conditions for responsible and sovereign AI adoption in energy systems. By establishing standards, harmonizing secure data-sharing frameworks and investing in high-quality, interoperable datasets, governments and policymakers can accelerate collaborative AI innovation and optimize regional energy systems. Different policy approaches have been observed globally. For many jurisdictions, economic incentives—such as subsidies, tax credits and grants—are important for reducing the risks of AI adoption and supporting innovation, and some jurisdictions have adopted more streamlined regulatory approaches to achieve these priorities. Governments and policymakers can also help to address the growing AI talent gap in the energy sector by building local capacity through education, training and public-private partnerships (PPPs). Lastly, flexible regulatory frameworks, informed by evolving technologies and industry input, can help ensure that AI governance remains effective and adaptive as AI technologies mature.

AI can help to revolutionize energy systems, delivering greater resilience, efficiency and sustainability. To fulfill this potential, public and private stakeholders may work together to overcome barriers related to data access, skills, infrastructure and governance. This way, the benefits of AI can be realized, helping to ensure a secure, inclusive and sustainable energy future.

# 1. Introduction

Energy systems face complex and competing priorities due to geopolitical, financial and environmental pressures.[1] These challenges often require robust and efficient approaches for planning and operations, underpinned by high-quality data and advanced analytics.

As the demand for energy rises—particularly with greater electrification and efforts to expand access to secure and affordable sources—energy systems are undergoing rapid transformation. Global energy demand has increased by about 15% in the last decade.[14] Energy systems are becoming more electrified and increasingly incorporate distributed energy resources such as solar, wind, and battery storage.[15] The uptake of grid-connected devices—such as electric vehicles, rooftop solar and smart appliances—often requires energy systems to manage bi-directional power flows and real-time information exchange, automation, and coordination. Renewables are projected to represent 71% of global primary energy supply and almost 90% of electricity generation by 2050.[14] It is also anticipated that electrification will reach significant levels, representing 53% of final energy consumption and accounting for a majority of energy consumption in most sectors. In road transport, for example, electricity is expected to represent three quarters of final energy demand in 2050.[10]

At the same time, AI is emerging as a transformative force across the global economy, enabling automation, advanced analytics and rapid decision-making in sectors ranging from healthcare and finance to manufacturing and transport.[2] AI is transforming many aspects of daily life, from automating simple tasks to enabling complex problem-solving, mimicking aspects of human reasoning but at greater speed and scale.[3] AI systems can excel at processing large and complex datasets, recognizing patterns and making predictions. In the energy sector, AI is rapidly transforming planning and operations, with significant progress in efficiency, reliability and sustainability.[4]

The growing adoption of AI can also introduce new challenges. The electricity demand from data centers—which are central to digital infrastructure supporting cloud computing and advanced analytics—could rise substantially, with estimates suggesting levels as high as 3,500 TWh by 2050.[8] This growth may create additional costs and, if not matched by clean energy sourcing, further environmental burdens. Nonetheless, responsible deployment of AI, particularly through efficiency improvements and system optimization can help offset these impacts.[3,4]

Other challenges relate to data privacy since AI systems often require large amounts of data for training. Security is also a concern due to the potential for increased reliance on energy and technology imports.[3] The concept of sovereign AI seeks to help address these matters by strengthening domestic AI capabilities, and securing access to important technologies and resources.[1] Such an approach can help safeguard national interests, manage supply chain risks and reinforce energy sovereignty.[12]

This report explores the transformative potential of AI in supporting a reliable and sustainable energy future. Using a data-driven, model-based approach and presenting real-world examples and case studies, the analysis demonstrates how AI integration can enhance the planning and operation of energy systems, delivering measurable economic gains, environmental benefits and energy savings. The findings provide a balanced, evidence-based perspective on the potential application and impact of AI across the energy sector.

# 2. AI in energy systems

The growing complexity of modern energy systems—driven by integration of renewable energy with existing energy sources, widespread electrification and greater interconnectedness across sectors—can require more sophisticated approaches to system management and control.[4] AI's ability to rapidly process large volumes of data, detect patterns, and generate reliable, accurate forecasts offers significant opportunities to help address these needs.[2,4]

# 2.1. Key applications of AI in energy systems

Use of AI in the energy sector covers three main categories (Figure 1): system optimization and control, asset lifecycle management, and end-use efficiency and management.

Each of these categories contain numerous applications that are already providing considerable economic and environmental benefits by driving performance across the value chain.[4]

**Figure 1. AI applications in energy systems**

| | Applications | Examples demonstrating benefits |
|---|---|---|
| **System optimization and control** | Enhance real-time network operations | **Automated methane leakage detection**<br>Can realize net savings of about US$5.8 billion globally due to reduced methane emissions, and lower inspection and repair costs (see Box 1).[4,16,17,18] |
| | | **Dynamic line rating**<br>Reduced transmission congestion costs on a single power transmission line by approximately US$65 million in the US.[19] |
| | Optimize and forecast energy supply and demand | **Peak shaving in data centers**<br>Emerald AI's Conductor platform enabled AI data centers to reduce power use during peak demand by 25% over three hours.[20,21] |
| | Strengthen market and trading operations | **AI-aided optimal market participation**<br>Can entail up to 1% fuel cost reduction and 5% efficiency gain due to more accurate calculations and more timely market participation.[22] |
| **Asset lifecycle management** | Support planning and decision making | **AI-enabled streamlined permitting processes**<br>Reduced permit processing time, supporting energy capacity increase.[23] |
| | | **Digital twins for robust energy system planning**<br>Enabled up to 80% improvement in site identification in sub-Saharan Africa.[24] |
| | Improve operations and maintenance across processes | **AI-enhanced pyro processes for cement manufacturing**<br>Reduced fuel costs by 4.1%, and plant energy consumption by 2.2% in Czechia in 2024.[25] |
| | Enhance design, accelerate discoveries and foster innovation | **Autonomous material discovery in solid-state batteries**[26]<br>Can realize net savings of approximately US$11 billion per year in avoided energy losses due to more efficient batteries by 2030.[27] |
| **End-use efficiency and management** | Improve building management | **Demand forecasting for a tertiary building in South Korea**<br>Achieved 98% forecasting accuracy and lowered monthly electricity costs by 8-19% due to reduced centralized power demand.[28] |
| | Enhance transport management | **AI-embedded battery management system**<br>Can realize a 20% reduction in maintenance costs, and 12% improvement in energy efficiency for an electric vehicle (EV) in the US.[29] |
| | Optimize industrial processes | **AI-based fault detection and predictive maintenance for wind power conversion systems**<br>Can entail a 60% reduction in fault detection time, and a 10% improvement in precision.[30] |

Source: Deloitte Global analysis based on the sources mentioned in the table

### 2.1.1. System optimization and control

AI can support system optimization and control in the energy sector by enabling smarter, more responsive management across the grid. Through advanced forecasting, AI can improve the accuracy of supply and demand predictions, allowing operators to balance resources in real time and integrate variable renewable generation. Real-time network monitoring and control, powered by AI, can enhance grid stability and resilience, making it possible to quickly detect and address disruptions. In addition, AI-driven tools can optimize market operations by supporting more efficient trading, pricing and resource allocation, ultimately leading to a more flexible, reliable, and cost-effective energy system.

**Real-time network operations and flexibility**
AI can support real-time network operations and flexibility by continuously processing vast streams of live data from millions of sensors across energy networks. This allows for rapid detection of anomalies, precise forecasting and mitigation of system imbalances, and proactive congestion management to help maintain grid stability. AI-driven automation can also support sector coupling—coordinating electricity, heating, transport, and industry—to optimize energy flows and enhance system-wide flexibility. Grid operators are already leveraging AI for real-time forecasting and rapid response to grid imbalances.[31] Similarly, advanced platforms like Nostradamus[32] and GridFM[33] can improve load and renewable-generation forecasts, outage prediction, and power flow optimization. Importantly, these AI capabilities extend beyond electricity networks to other types of energy systems. For example, real-time data analytics can help detect and mitigate methane leakage in gas networks (see Box 1). By enabling more accurate and autonomous decision-making, AI can bolster integration of new energy facilities and reduce operational strain on conventional infrastructure across interconnected energy systems.

**Box 1. Case study: Automated methane leakage detection and mitigation**

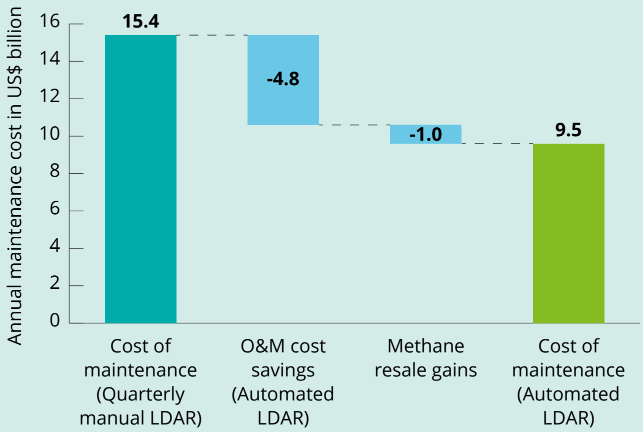
Methane is a highly potent greenhouse gas (GHG) that has a global warming potential about 80 times greater than $CO_2$ over the next 20 years.[34,35] Each year, about 140 megatons (Mt) of methane, accounting for 3.6 gigatons of carbon dioxide equivalent (Gt $CO_{2eq}$), is emitted globally as a result of producing and using oil, gas, and coal.[4]

Traditional leak detection relies on periodic manual inspections, which can be labor-intensive, costly, and often slow to identify seepage.[36] In contrast, AI-powered optical gas imaging (OGI) systems use fixed cameras, drones, or satellites to provide autonomous, continuous monitoring. Advanced models, such as convolutional neural networks trained on extensive datasets, can enable real-time leak detection, with systems such as GasNet achieving over 95% accuracy across a range of conditions and up to 97% accuracy for large, nearby leaks.[16]

Adopting continuous, AI-enabled leak detection and repair (LDAR) can offer substantial benefits:

- Reduce annual methane emissions by 2 Mt, lowering total leakage from around 145 Mt under traditional LDAR to 143 Mt.[4,37]
- Generate additional annual revenues of approximately US$1.05 billion based on the 2024 average global natural gas price of US$11.3/ Million British Thermal Units (MMBtu).[17]
- Decrease inspection and repair costs by 30% to approximately US$1.6/MMBtu versus US$2.3/MMBtu for traditional processes,[4] producing estimated annual savings of US$4.8 billion by applying the reduced inspection and repair costs to the total methane leakage.[38]

**Maintenance cost of methane leakage detection system**




Source: Deloitte Global analysis based on the aforementioned assumptions

Together, reduced emissions, lower operating costs and recovered methane sales at the 2024 average price of US$11.3/MMBtu represent total annual savings of almost US$6 billion globally.[18]

### Supply and demand forecasting and optimization

AI is increasingly being used to help automate exploration and production activities in extractive industries, including drilling or mining for non-renewable energy sources and critical minerals like lithium and rare-earth elements. In mineral exploration, machine learning can help accelerate target identification by analyzing geological and geophysical data.[39,40] In oil and gas extraction, AI-driven automation can enhance drilling precision and minimize losses.[41] AI models trained on geophysical and geologic data can also be particularly effective in reducing operating costs and enhancing the productivity of geothermal power plants.[42]

Above ground, AI can enable more accurate supply and demand forecasting by analyzing weather, satellite and consumption data, which can lead to more effective use of generation capacities. For instance, an AI-powered hydrology forecasting model by Entek Elektrik has enabled hydropower plants in Türkiye to maintain higher reservoir levels, preventing water loss and optimizing electricity generation—while increasing the forecast accuracy and time significantly.[43] Beyond more precise forecasting and planning,[44] AI models can optimize both generation and demand by adjusting power plant levels and resource allocation (see Box 2).

### Market optimization and trading

AI empowers organizations across the market with advanced price forecasting, risk assessments and automated trading, thus enhancing market efficiency and enabling more responsive energy systems. Machine learning models can accurately forecast electricity prices, supporting more robust trading and hedging strategies.[45,46] For instance, AI already offers real-time market simulation and forecasting. This enables dynamic demand response based on price signals, which helps market participants optimize operations while reducing exposure to price volatility.[47] AI's utility goes beyond forecasting and automated decision-making to complex problem-solving. For instance, it can help grid operators determine optimal power flow (OPF)[48] more quickly and accurately.[49] By accelerating complicated computations and analyzing the results, AI can help improve operational efficiency, lower fuel costs and boost overall system efficiency by up to 5%.[22]

**Box 2. Case study: Demand forecasting and response**

Managing peak electricity demand is a growing challenge for energy systems as high peaks can strain the grid, raising costs and increasing emissions—especially when non-renewable backup generation is needed. AI-powered peak-shaving strategies can help address these matters by accurately forecasting short-term demand, identifying demand types and clusters and coordinating real-time energy reductions across consumers and data centers.

**Peak shaving in data centers**

Emerald AI's Conductor platform can enable AI data centers to dynamically reduce power consumption in response to grid stress. In a field trial in Phoenix, Arizona, the system orchestrated workloads on a cluster of 256 NVIDIA GPUs, reducing power use by 25% over three hours during a peak-demand event, without compromising compute service quality.[20,21] Emerald AI's software can help electric grid operators keep up with this rapidly growing demand by enabling data centers to use the existing grid more flexibly, unlocking up to 100 GW of untapped capacity.[21]

## 2.1.2. Asset lifecycle management

AI can deliver value across phases of an asset's lifecycle, with key applications spanning planning and decision-making support; operations, maintenance and cybersecurity; and design, discovery and innovation.

### Planning and decision-making

AI can help facilitate strategic planning and investment decision-making by modeling complex energy scenarios, evaluating long-term infrastructure needs and identifying patterns within large and heterogeneous datasets notably through solutions such as digital twins.[50] This capability can enable faster and more robust, adaptive and economically sound system planning. Through automation, AI can help accelerate administrative processes, which in turn can facilitate timely investments in energy infrastructure projects, such as renewable energy projects (see Box 3).

Digital twins are among the most widely used AI tools for planning and decision-making support.[51] They are virtual replicas of physical assets, systems, or processes that are continuously updated with real-time data to reflect actual conditions and performance. By simulating a wide range of scenarios, digital twins support robust decision-making and future planning without disrupting real-world operations. They are already being deployed in the energy sector to help manage distributed energy resources and plan future-ready infrastructures. Singapore's National Power Grid uses a digital twin to enhance grid planning and resilience by simulating asset conditions and network scenarios.[52] Deloitte Australia's Optimal Reality platform helps companies create digital replicas that enable strategic investment and operational decisions by modeling long-term infrastructure and supply chain scenarios.[53]

**Box 3. Case study: Streamlining regulatory processes with AI**

**AI-enabled streamlined permitting**

Permitting is an important part of energy capacity expansion to ensure projects meet certain regulatory standards and requirements. However, in many countries this process is protracted by complex and fragmented regulatory systems. In the European Union (EU), for example, permitting procedures can take seven to nine years, sometimes over a decade, causing delays that can raise total project costs by up to 35%.[54] These slowdowns can impede progress toward sustainable growth.

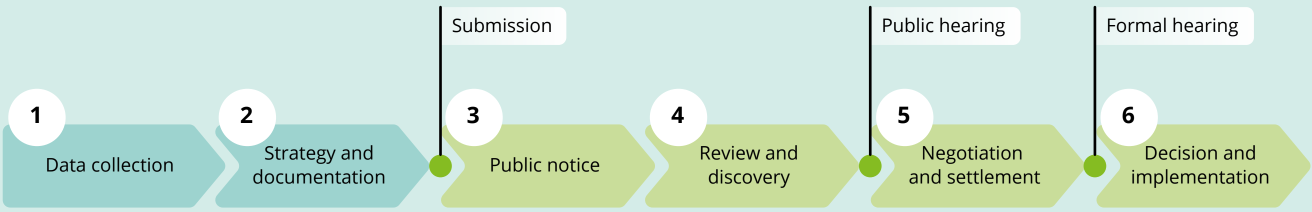
AI-powered permitting systems can help overcome these bottlenecks by automating administrative tasks, speeding up approvals and reducing manual efforts. The Danish Environmental Protection Agency (EPA) uses an AI-assisted digital platform to help streamline decision-making and coordination among multiple agencies and stakeholders. This system also reduces errors during permit reviews by leveraging historical data and advanced analytical tools. As a result, it has reduced permitting processing time by an estimated 50% for large-scale renewable energy projects such as offshore wind.[23]

Assuming a 50% acceleration in the installation rate of onshore wind and solar power due to faster permitting processes,[55] AI-assisted permitting could increase onshore wind capacity additions by up to 25% and boost solar installation by up to 13% by 2035, compared to traditional permitting methods.[56]

**Rate Case Assistant: an AI-powered solution**

Deloitte Consulting LLP's Rate Case Assistant is an AI-powered solution designed to help streamline the complex process of managing regulatory rate cases in the energy sector.[57] By automating data collection, document analysis and drafting, it can save time and reduce manual workloads for compliance and legal teams. The platform centralizes regulatory data for rapid access and enables data-driven peer analysis, boosting the accuracy of submissions and minimizing costly rework. It also supports strategy development by benchmarking filings and testimonials against historical and peer cases. These capabilities can enhance operational efficiency, strengthen investment justifications and accelerate digital transformation in regulatory compliance.

**Rate case filing process and the value brought by Rate Case Assistant**




**Pre – submission**

1. **Docket management:** Creates docket knowledge base for seamless chatbot experience and notifies user with a summary of new documents and recommended actions.
2. **Testimony drafting and strategy analysis:** Performs detailed analysis of historical documents and benchmarks specified aspects of a filing against past and peer cases.

**Post – submission**

3. **Stakeholder communication:** Efficiently assists in messaging a variety of external communications, customized to the audience (county/city officials and rate-payer advocate groups) and clearly provides all relevant information.
4. **Data request management:** Analyzes and categorizes data requests to automatically pull similar historic data, assigns a person to it to facilitate response preparation, and provides insight into which subjects need more support.
5. **Hearing preparation:** Provides a consolidated briefing document that synthesizes prior cases and hearing transcripts, plus current expert testimonies, data requests, and public comments.
6. **Final order summarization:** Provides a summary of the current filing order, highlighting important items and key takeaways.

Source: Deloitte Consulting LLP documentation of Rate Case Assistant

## Operations, maintenance and cybersecurity

AI-enabled platforms can help optimize industrial operations, improving fuel efficiency and product quality.[25] AI can quickly analyze processes and manuals, identify key operational constraints and provide quick support for the operation and maintenance of energy assets. This can take the form of simple chatbots and assistants, similar to generative pre-trained transformer (GPT)-based platforms (Box 4), or advanced tools such as predictive maintenance systems. AI-powered predictive maintenance can enhance operational efficiency by reducing unplanned outages, extending asset lifespans and lowering maintenance costs. A previous Deloitte Global study on AI's role in enhancing the resilience of infrastructure systems showed that using AI-enabled predictive maintenance for offshore wind turbines can reduce downtime by 15% and average repair cost by 20%, while increasing market revenues by 6%.[2] AI can also support cybersecurity by monitoring and detecting threats and responding to them automatically across networks.[58]

**Box 4. Case study: AI-assisted maintenance**

Maintenance and operations teams in industrial settings often rely on rapid, reliable access to technical information to keep equipment running smoothly and safely. AI-powered GPT platforms greatly enhance these processes by enabling staff to find procedures, manuals and troubleshooting guidance instantly through natural language queries.[59] This approach not only helps reduce downtime and human error, but also supports multilingual teams and drives operational efficiency.[60]

One example of such a platform is Entek's Maintenance Assistant, an AI-powered application utilizing advanced natural language processing technology.[61] Designed to transform turbine maintenance in natural gas power plants, the system enables instant access to thousands of maintenance manuals, delivering quick, relevant answers.[61] It has delivered a 62% increase in operational efficiency, reduced errors, and accelerated interventions, extending equipment lifetime and improving reliability.[61]

**Design, discovery and innovation**

AI can reshape the way in which new technologies and materials are designed and discovered, making these processes significantly faster and more efficient.[62] Energy sector applications are numerous, ranging from rapid analysis of aerodynamic interactions for better wind turbine design[63] to autonomous and accelerated materials discovery for solar cells, batteries, and carbon capture sorbents and membranes (see Box 5).

**Box 5. Case study: Autonomous material discovery**

Generative AI (GenAI) is revolutionizing materials discovery by analyzing large datasets from materials science, chemistry and physics and predicting the structural, physical and chemical properties of materials with high accuracy. Accordingly, AI-driven approaches can help drastically reduce the time and cost associated with traditional lab experiments and simulations. For instance:

- Perovskite solar cells (PSC) are emerging as cost-effective and practical alternatives to conventional photovoltaic technologies.[64] However, optimizing their performance remains challenging due to the complex interplay of material compositions and processing conditions, which traditionally requires time-intensive and often unpredictable experimentation.[65] AI models can accelerate this process by systematically adjusting manufacturing parameters, such as precursor concentrations and temperatures, using experimental data. For example, by testing only 0.36% of possible material combinations, researchers achieved a power conversion efficiency of 21.4%, surpassing the efficiency of the combinations found manually (20.5%) and improving reproducibility.[66]
- Solid-state batteries (SSBs) can store more energy and operate more efficiently than widely used lithium-ion batteries,[67] but the slow discovery of suitable solid electrolytes has hindered their large-scale adoption.[68] A new AI-guided approach addressed this constraint by combining advanced simulations with cloud computing to screen over 32 million materials in less than 80 hours.[26] This accelerated screening process identified 500,000 stable candidates and 18 promising solid electrolytes, enhancing the possibility of broad SSB adoption, which could prevent up to US$11 billion in energy losses annually by 2030.[26,27]
- Carbon Capture and Storage (CCS) involves capturing carbon dioxide from power production and industrial processes and storing it underground to prevent atmospheric release. AI techniques can help accelerate the discovery of high-performance solvents, membranes, and sorbents, often hastening material identification by up to five times and cutting research costs.[69]

These examples show that GenAI is accelerating the development of advanced materials, supporting breakthroughs in solar energy, batteries and carbon capture, and paving the way for more efficient, sustainable energy technologies.

## 2.1.3. End-use efficiency and management

AI can enable end users, such as businesses, households and industrial customers, to optimize their energy consumption with greater precision and flexibility.[4] By leveraging advanced analytics and real-time automation, it can enable smarter building management, streamline transportation and logistics, and optimize industrial operations. These applications, in turn, can help drive more sustainable and cost-effective energy consumption across sectors.

**Smart buildings and energy management**

AI-enabled smart building systems are redefining energy management through advanced heating, ventilation and air conditioning (HVAC), adaptive lighting, predictive control, and real-time load shifting and shedding.[70] Tested in Sweden, AI-enabled, optimized HVAC has been highly effective in reducing demand for both district heating and electricity, saving both costs and reducing emissions.[71]

**Transportation management**

AI in the transport sector can help optimize traffic flows, enhance route planning and real-time logistics, support autonomous mobility, and extend battery life and performance, which can help to reduce congestion and fuel consumption.[72] For example, major logistics companies are already deploying AI solutions to help optimize delivery routes, eliminating millions of unnecessary miles annually and significantly reducing fuel costs and $CO_2$ emissions.[73]

### Box 6. Case study: AI-embedded electric vehicle battery management system

A battery management system (BMS) is instrumental for the real-time control and safety of rechargeable battery packs in electric vehicles. A BMS monitors each cell's voltage, temperature and current, estimates key indicators like state of charge (SOC) and battery health, balances cell charging, manages thermal systems and automatically prevents dangerous evolutions.[74]

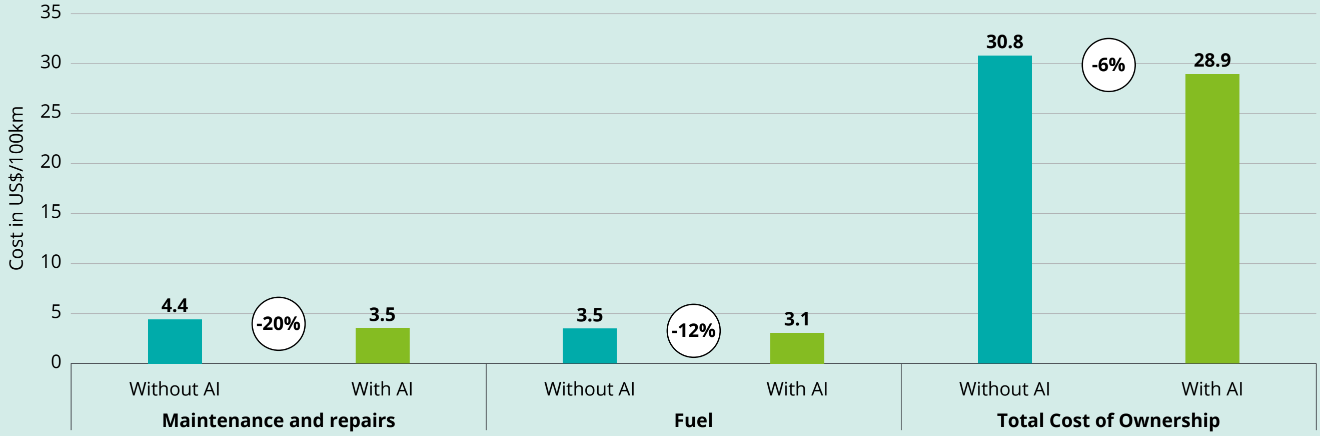
Traditional systems typically rely on fixed-rule approaches, which prioritize safety over efficiency and other benefits. Integrating AI into BMS design introduces machine learning algorithms that analyze historical and real-time data to produce:

- Up to 15% more accurate estimates of charge and health, increasing usable battery capacity[29]
- About 15% less battery degradation by detecting and mitigating harmful usage patterns[29]
- Approximately 12% greater energy efficiency through optimized thermal management and adaptive charging based on driving behavior and environmental conditions.[29]

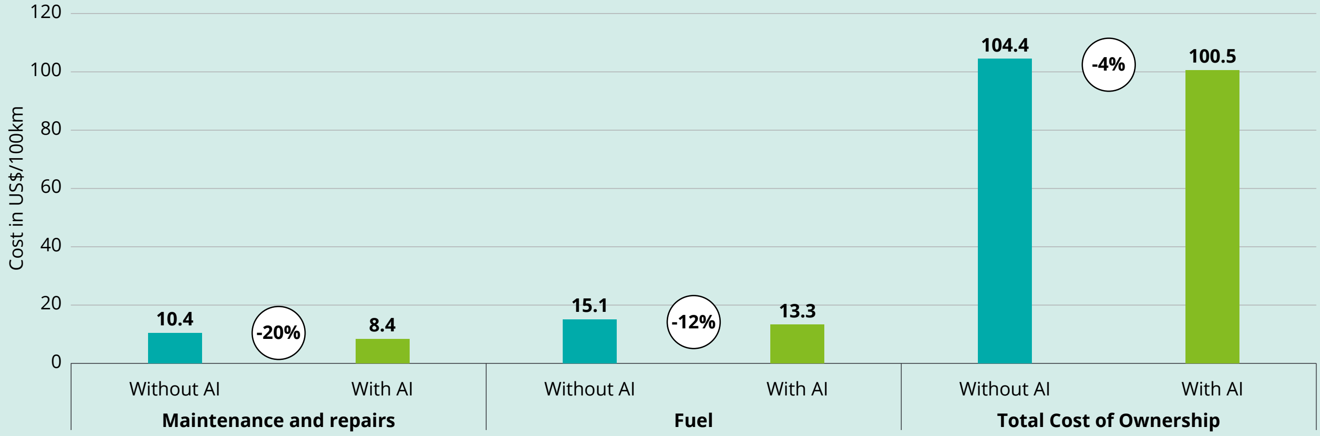
These technical improvements can lead to significant cost and energy savings as illustrated below.

**Average cost reduction with AI-embedded BMS**

a) For a sedan EV in the US




b) For a heavy-duty truck in the EU




Source: Deloitte Global analysis based on estimated cost reductions from Briggt and Johansson[29] and vehicle cost estimates of ICCT[75] and Atlas Public Policy[76]

### Industrial process optimization

AI is also actively being used across industrial sites to help streamline operations, reduce energy use and minimize waste.[77] For instance, applying AI for process control, combined with digital twins and smart cleaning systems, has proven highly effective in reducing material waste by nearly 50%, decreasing greenhouse gas emissions and enhancing energy efficiency.[78] In advanced manufacturing settings, AI-driven automation and predictive maintenance have contributed to lowering per-product electricity consumption by approximately 24% and cutting production waste by up to 48%.[3]

## 2.2. The interconnectedness of AI applications

The categories and sub-categories of AI applications in energy systems, as shown in Figure 1 and described above, serve as a framework for grouping diverse use cases. However, AI applications generally overlap and exhibit interdependencies across functions and domains. For example, real-time system optimization, such as electricity grid management, draws on robust data not only from asset lifecycle management (e.g., predictive maintenance and fault detection) but also from end-user behaviors and device-level insights, such as flexible demand data from buildings.[79,80]

Similarly, demand forecasting and dynamic pricing rely on accurate information from operational domains, supply forecasts and end-user activities, such as smart building control and process automation.[70] As a result, many successful AI deployments integrate functionalities across multiple domains, creating powerful feedback loops that continuously improve forecasting accuracy, operational coordination and overall system resilience.

Importantly, the interconnected nature of AI applications often compounds the potential benefits, thus strengthening the business case. For instance, advanced demand forecasting, often classified under system optimization and control, also supports end-use efficiency and management, as well as planning and investment decision-making.[6,7]

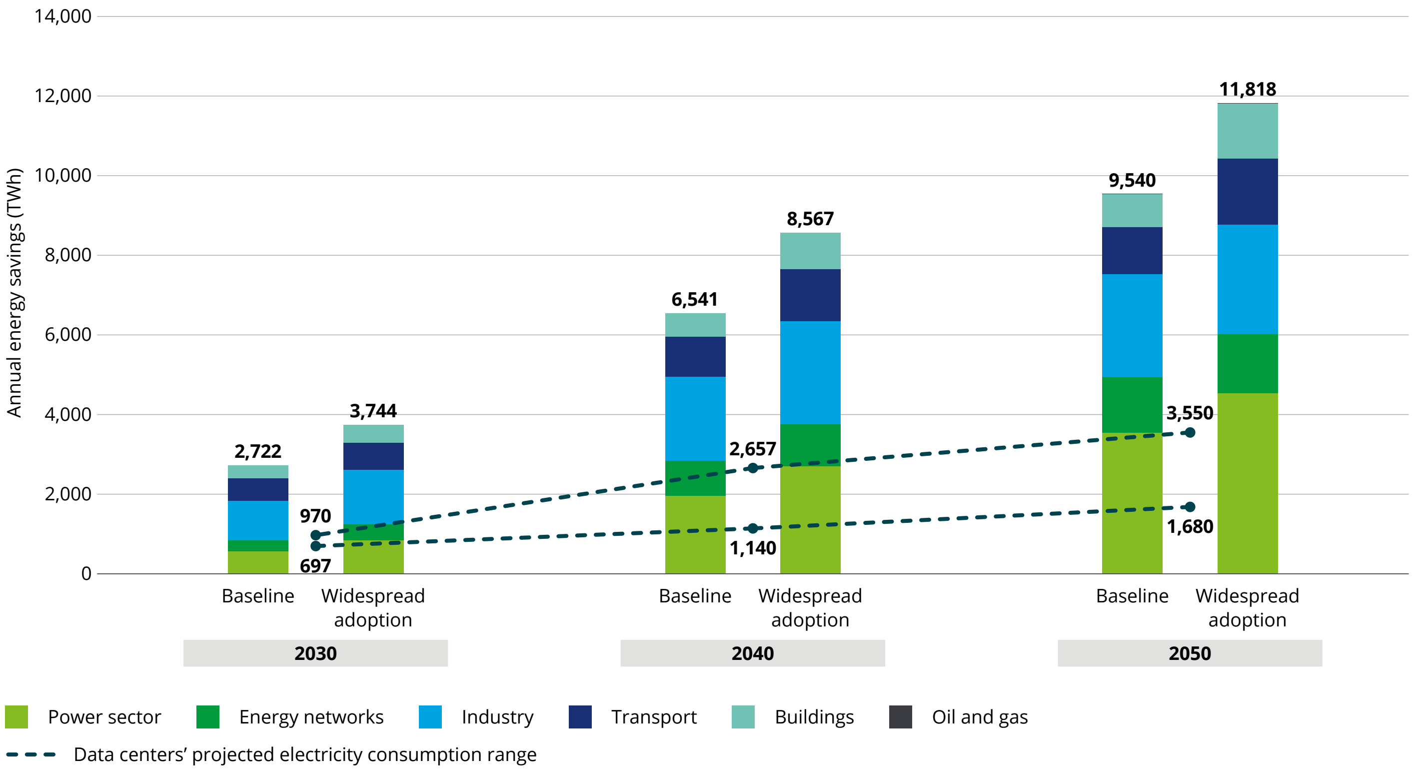
## 2.3. Measuring the impact of AI

The case studies in Section 2.1 illustrate the tangible value AI can bring to energy systems through specific applications and projects. This value can be quantified as energy efficiency gains from optimized resource utilization, decreased losses and better demand-side management; cost reductions from operational savings and extended asset lifespans; and emission reductions from lower non-renewable energy source consumption, increased renewable integration and decreased demand.

To assess the potential global impact of AI, two potential futures were explored: a baseline scenario that follows current trends and a widespread-adoption scenario that envisions AI being embraced at scale around the globe.[81] In the baseline scenario, advanced economies face no explicit barriers to AI adoption, while other markets encounter constraints. The widespread-adoption scenario assumes higher levels of AI preparedness in emerging markets and low-income countries through international support.[81] Further details on the methodology can be found in Appendix 1, including a detailed description of the AI adoption index, which reflects varying levels of AI preparedness, access and exposure across regions.

Both the baseline and widespread-adoption scenarios suggest that AI can save more energy than it consumes from the outset, saving approximately 2,720 TWh to 3,740 TWh by 2030 (Figure 2),[9] well above AI's projected energy consumption of just under 1,000 TWh,[4,8] though they remain small compared to current global energy supply (about 1-2% of the energy supply in 2023).[14] The mid- to long-term benefits are even higher, with energy savings set to significantly outpace AI's energy consumption[8] varying between about 6,540 TWh and 8,570 TWh in the baseline and widespread adoption scenarios respectively.[9] These savings could reach almost 12,000 TWh by 2050 in the widespread-adoption scenario and roughly 9,500 TWh in the baseline scenario (Figure 2),[9] substantially outweighing AI's energy consumption, which is expected to peak at about 3,550 TWh.[8] While these levels remain around 5% of total energy supply of recent years, they correspond to 10-12% of projected world energy consumption (and 6-7% of primary energy supply) in a net-zero scenario in 2050.[14]

**Figure 2. Energy savings enabled by AI along the energy value chain**




Source: Deloitte Global analysis based on Appendix 1 for AI's energy savings and Deloitte's "Powering AI" for AI's energy consumption

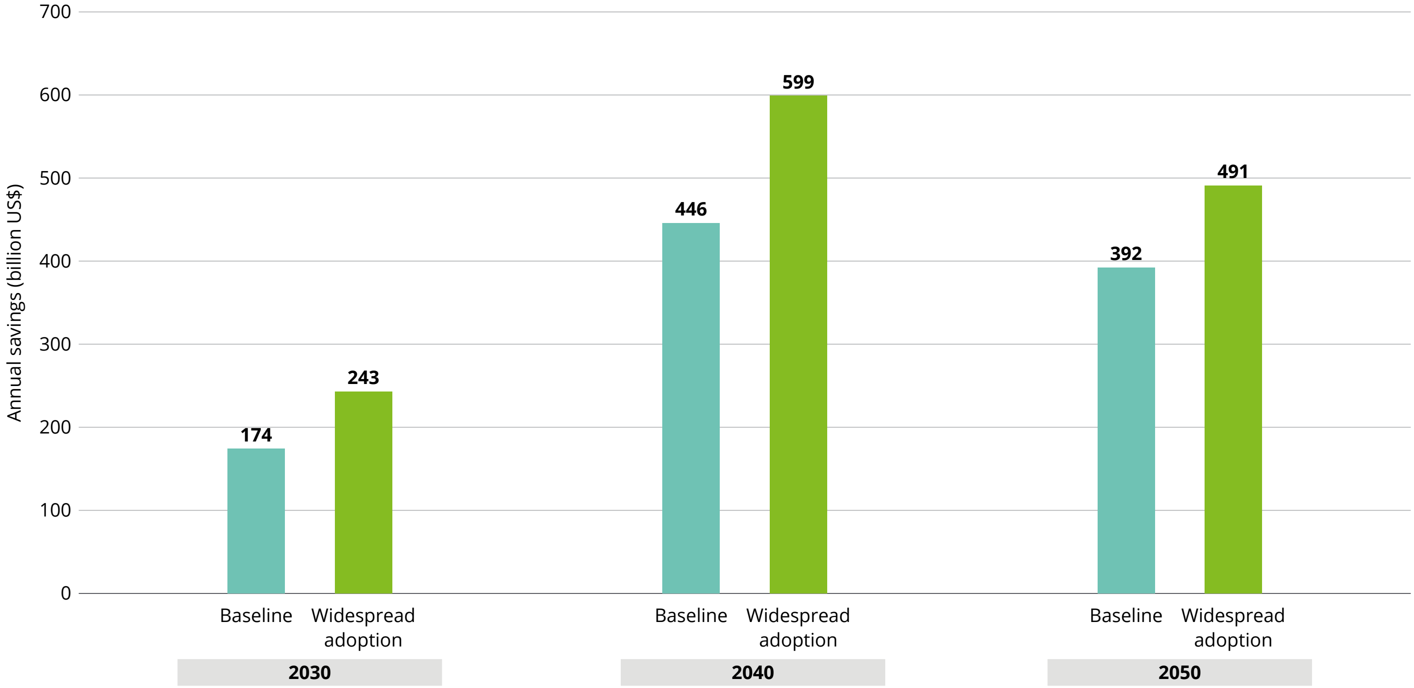
In the short term, most of these energy savings are expected to originate from industry and the power sector, together accounting for 1,550 TWh to 2,210 TWh (Figure 2)—or about 60% of total savings—in 2030. In the longer term, while energy savings from industry, transport and buildings grow significantly, the power sector takes the lead—notably due to improvements in material efficiency, demand-side management, power plant design, resource management and uptime. By 2050, energy savings from the power sector are expected to reach 3,540 TWh in the baseline scenario and 4,530 TWh in the widespread-adoption scenario (Figure 2), representing 37% and 38% of total energy savings respectively.

Integrating AI into energy planning and operations can also deliver substantial economic benefits. Annual savings could surpass US$200 billion by 2030 and reach almost US$500 billion by 2050 (see Figure 3). These values, while representing a small proportion of overall AI investments needed, are significantly higher than the projected energy-related investments needed for data centers (in the order of US$50 billion by 2030).[4] Therefore, the economic benefits of AI, even in the short run (2030), still show a net gain over the energy investments needed to power them.[4] Cumulatively, summing the savings shown in Figure 3, the economic benefits from AI could total between US$8.3 trillion and US$11 trillion from 2030 to 2050. This could reduce the overall cost of the energy transition, estimated at nearly US$200 trillion,[82] by up to 5%.

In the widespread-adoption scenario, cost savings are projected to decrease slightly from approximately US$600 billion in 2040 to about US$490 billion in 2050. This decline anticipates reduced power sector investments after 2040, reflecting both lower unit costs and a slowdown in new capacity additions, i.e., 9 TW of expected additions between 2040 and 2050 compared to 15 TW between 2030 and 2040.[14] Additionally, as AI adoption nears saturation in the energy sector, incremental savings can diminish, leading to smaller annual improvements beyond 2040.

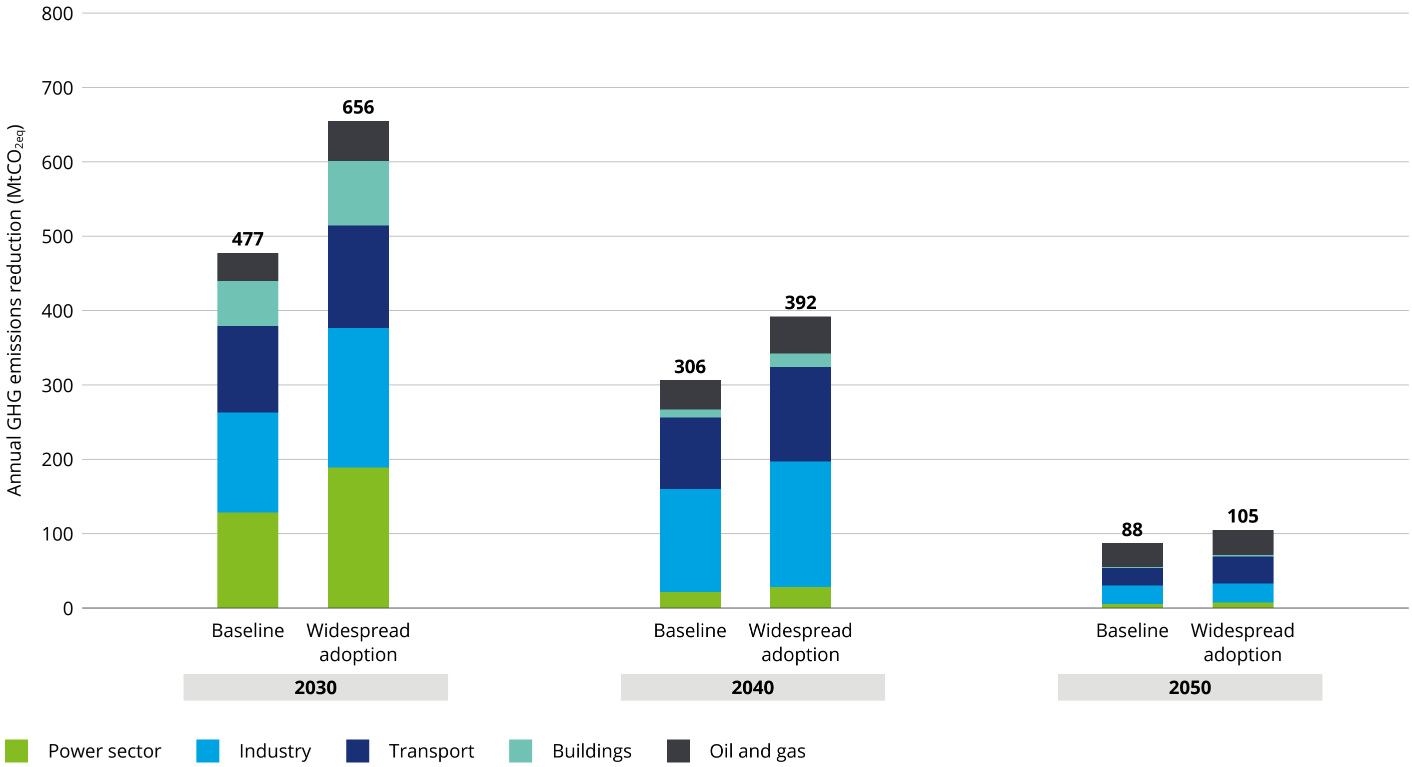
Energy savings achieved through AI adoption can directly translate into substantial emission reductions, reaching nearly 660 $MtCO_{2eq}$ by 2030 (Figure 4)—a level comparable to the annual greenhouse gas (GHG) emissions of highly industrialized countries.[11] However, as energy systems become increasingly more efficient and low carbon, the additional impact of AI on emission reductions is expected to gradually decline, with avoided emissions projected to fall below 400 $MtCO_{2eq}$ by 2040 and to level off at approximately 100 $MtCO_{2eq}$ by 2050 (Figure 4).

**Figure 3. Economic benefits of AI applications across energy supply, transport and consumption**




Source: Deloitte Global analysis based on the methodology described in Appendix 1

**Figure 4. Environmental benefits of AI use in the energy value chain**




Source: Deloitte Global analysis based on the methodology described in Appendix 1

# 3. Sovereignty and AI

Through sovereign AI, countries and regions can gain autonomy over their AI infrastructures and decision-making processes.

# 3.1. Sovereign AI considerations in energy systems

Sovereign AI refers to the design, deployment and governance of intelligent computing systems within a specific nation or region. The goal of this approach is to help ensure that AI technologies reflect local values, comply with national and/or regional regulations, and maintain data securely within jurisdictional boundaries.[83] Through sovereign AI, countries and regions can gain autonomy over their AI infrastructures and decision-making processes. This may reduce dependence on foreign technologies and help protect sensitive data.[84]

In energy systems, sovereign AI is grounded in four core principles: security and resilience, data and technological independence, local capacity and innovation, and ethical and legal compliance (see Figure 5):

**Figure 5. Achieving sovereign AI principles for sustainable, reliable and secure AI-driven energy systems**

| Principle | Overview | System optimization and control | Asset lifecycle management | End-use efficiency and management |
|---|---|---|---|---|
| 1 Security and resilience | Deploy locally-controlled, secure AI systems with robust cybersecurity and data governance to protect important energy operations. | • Can help ensure continuous, sovereign control over critical energy operations. | • Can limit foreign interference and enhance the resilience of national energy assets. | • Can help protect sensitive data from unauthorized access and reinforces national oversight. |
| 2 Data and technological independence | Develop and operate AI solutions using domestic data, infrastructure, and technologies to retain full national control and autonomy. | • Can enhance energy system autonomy and prevent bias in real-time decision making. | • Contributes to ensuring that vital knowledge and technology stay under national jurisdiction. | • Supports independent policy development based on domestic insights, not foreign platforms. |
| 3 Local capacity and innovation | Invest in local workforce, research and development, and relationships to create and adapt AI solutions tailored to national energy needs. | • Helps foster innovation ecosystems given evolving national energy needs. | • Can foster local technology and reduce dependence on foreign providers. | • Can drive national industrial growth and competitiveness in AI exports. |
| 4 Ethical and legal compliance | Ensure all AI applications adhere to national ethics, data privacy, and legal standards, with transparent and auditable processes. | • Can help AI operations to comply with competition laws and support auditability by regulators. | • Supports fairness and transparency in investment decisions. | • Assists in building public trust and protecting consumer rights and national sovereignty. |

Source: Deloitte Global analysis based on World Economic Forum,[12] Oracle,[83] NVIDIA[84] and Shrier et al. (2025)[85]

- **Security and resilience:** The rise of powerful, accessible AI has heightened the sophistication and scale of cybercrime and fraud. Cyberattacks on the power sector have doubled from 2020 to 2022, with 48 attacks reported in Europe alone in 2022.[86] This makes sound cyber defenses important for energy security. As GenAI amplifies new threats, nations and international bodies should consider strengthening and better coordinating their cybersecurity strategies to safeguard energy infrastructure.[85]
- **Data and technological independence:** Sovereign AI requires advanced digital infrastructure, such as modern data centers and data localization policies, to keep data processing and storage within jurisdictional boundaries. National and/or jurisdictional control over AI infrastructure is important for maintaining strategic autonomy, as it minimizes reliance on foreign technologies and reduces vulnerability to external influences. By prioritizing domestic development, countries can help protect sensitive data and align their AI policies with national and/or regional interests and values.[83]
- **Local capacity and innovation:** AI adoption can help increase global GDP while improving local economies. GenAI alone can add about US$7 trillion to the global economy over the upcoming decade.[87] Realizing this potential, countries can foster their own domestic AI industries, which could create jobs, attract investment and strengthen existing and new sectors, boosting both local economic growth and national competitiveness.
- **Ethical and legal compliance:** AI systems may also create privacy or other risks by exposing sensitive personal data to unauthorized users or enable misuse. Investing in sovereign AI allows countries to create and train AI systems with local data, priorities and values.

While sovereignty is important, it is also important to recognize that the quality and robustness of AI systems often depend on the heterogeneity and scale of the data used for training the models.[2] High-quality AI outputs benefit from access to large and varied datasets, which may require collaboration beyond national borders. Cross-border cooperation can help provide access to richer datasets and encourage sharing of leading practices.[2] However, participants in any cooperative endeavor should comply with regional data residency requirements, adhere to data privacy standards, and use the appropriate amount of data, retaining only what is needed.[88]

## 3.2. Resilience gains from AI in energy systems

AI can also enable resilience and autonomy. As discussed in Section 2.1, AI-powered systems can assist in managing external risks such as equipment failures, supply disruptions or cyber threats through accurate forecasts and real-time detection. Furthermore, AI-driven improvements in energy efficiency can help reduce overall demand, while AI-powered grid management and system optimization can foster integration of additional energy sources. These advances can reduce reliance on energy imports thereby reinforcing energy security and economic independence.[13] These capabilities can help strengthen the reliability and security of energy infrastructure as well as empower countries to operate their systems more independently and efficiently, directly supporting the goal of sovereignty in important sectors.

Regions and countries that are highly dependent on energy imports can help improve their energy independence by adopting AI-enabled measures. Consider the EU:[89] if the potential of AI applications had been deployed across the energy sector in 2023, European oil and gas consumption could have been reduced by approximately 226 TWh and 230 TWh respectively (see Appendix 1). These levels correspond to approximately 7% and 5% of the European natural gas and oil imports in 2023.[90] In addition to spending less on non-renewables, this drop in consumption could have also decreased exposure to external supply disruptions and price volatility, reinforcing the EU's pursuit of energy security and economic resilience, which has been a top priority since the beginning of the Russia-Ukraine war in February 2022.[91]

# 4. Unlocking sustainable sovereign AI

Coordinated and decisive effort across stakeholders is important for unlocking the transformative power of sovereign sustainable AI for the energy sector.

AI has the potential to be a game-changer for the energy sector in driving efficiency, sustainability and resilience across the energy value chain. From optimizing grid operations and energy trading in real-time, enhancing asset management throughout the lifecycle (including planning, maintenance, and design innovation), and improving end-use efficiency in buildings, transport, and industry, AI offers transformative opportunities.

While AI itself requires significant electricity input, the resulting energy savings are projected to be far greater, potentially reaching almost 12,000 TWh by 2050 (see Figure 2). This represents up to 12% of the total energy demand in a net-zero world, along with substantial cost reductions of up to nearly US$500 billion annually by 2050 and US$11 trillion cumulatively through the period to 2050 (see section 2.3). These advances also reinforce energy sovereignty, with AI-driven efficiencies expected to reduce energy imports.

To realize these benefits without compromising resilience, AI development should adhere to key sovereign AI principles: security and resilience, data and technological independence, local capacity and innovation, and ethical and legal compliance.

# 4.1. Key considerations

The integration of AI—particularly sustainable sovereign AI—offers significant potential to help drive efficiency, accelerate sustainable growth and build long-term resilience, resulting in tangible economic gains. Realizing this potential can require coordinated, cross-sectoral collaboration among key stakeholder groups, each playing a distinct and important role:

**Energy companies and industrial manufacturers** are at the forefront of operationalizing AI solutions, leveraging their assets, data, and skills to help drive system-wide transformation and value creation by:

- **Investing in high-quality data infrastructure and prioritizing the collection, curation and integration of accurate, high-quality operational and market data.** To help enable effective AI model training and deployment, energy and industrial companies will likely need to establish standardized data formats that are interoperable across assets and business units. These formats should be accompanied by robust cybersecurity measures and data governance policies to help ensure continuous operation, protection of sensitive data, and compliance with evolving standards.
- **Developing AI talent and upskilling the workforce by investing in AI literacy and specialized training programs for employees at all levels.** Between 2018 and 2024, the share of AI talent in energy and mining was among the lowest across sectors, and 40% on average lower than in education, financial services, professional services, and technology, information and media.[4] The energy sector is expected to encounter competition from other sectors in developing and maintaining a skilled AI workforce.[92] Building internal capabilities helps to ensure that teams can effectively interpret AI outputs, manage AI systems and drive continuous improvement.
- **Starting with high-impact applications that offer quick, measurable benefits and that can be scaled across the organization.** Proven applications include predictive maintenance, efficiency improvements,[93] advanced forecasting, and grid optimization—which can be deployed across multiple assets to deliver cumulative economic benefits.[92]
- **Leveraging cloud and edge computing to enhance utilization of AI capabilities, while respecting data security.** Cloud platforms can process large datasets and train sophisticated AI models, enabling robust information analysis across operations.[94] At the same time, deploying AI at the edge—closer to devices like sensors or substations—can allow for real-time analytics and faster decision-making.[4] This can also help to reduce data transmission lags, enhance efficiency with on-device processors, and distribute energy use over many devices.[8] Combining cloud and edge computing can help companies extract strategic insights and respond rapidly to operational challenges, while minimizing energy consumption.
- **Fostering cross-disciplinary and cross-sector collaboration through research and technology cooperation, PPPs and sector-wide data sharing practices.** This can give companies access to cutting-edge AI techniques, customized deployment and development capabilities, and support with regulatory alignment, while using accurate, robust and anonymized data to help address data privacy requirements.

**Technology companies** play an important role as enablers and innovators, bridging the gap between cutting-edge AI capabilities and the unique operational requirements of the energy sector. They are distinctly capable of:

- **Leading research and development and innovation in AI technologies tailored to help address energy sector challenges such as grid stability, demand forecasting and predictive maintenance.** Technology leaders can identify and evaluate AI use cases in specific sectors, such as energy and industrials. Continued investment in research, especially at the intersection of AI and complementary technologies such as IoT, digital twins and cloud computing, is important for continuous improvement and for driving adoption within the sector. This often involves creating sector-optimized models, scalable platforms, and reference architectures.
- **Proactively engaging with energy stakeholders to improve data sharing and devise sector-specific solutions.** This includes providing transparent, timely information on data-center operations and co-developing robust methodologies

for forecasting electricity demand. Through this collaboration, energy providers can better prepare to meet the growing power demands of AI, and technology providers can help energy leaders to plan infrastructure more effectively, support grid reliability, and accelerate innovation in resilient operations and clean energy integration.

- **Adopting advanced, regionally tailored, clean-energy procurement strategies for data centers.** Technology providers can lead by example in managing the rapidly growing energy consumption of data centers by prioritizing procurement of reliable, cost-effective and low-carbon electricity. This includes greater use of long-term power purchase agreements (PPAs),[4] and co-locating data centers with clean energy assets.[8] These actions can help advance corporate sustainability goals and also improve local grid resilience.
- **Ensuring responsible AI, notably by embedding explainability, ethics and robust compliance into AI.** This may include providing transparent algorithms, data sovereignty, and clear documentation to help enable trustworthy and transparent AI decision-making.[12] Frameworks such as Deloitte's Trustworthy AI™ can be effective in developing such responsible and secure AI models and assets.[95] Additionally, open-source tools and knowledge-sharing initiatives can help enable seamless integration with existing infrastructure and diverse data sources, fostering industry-wide participation and reducing barriers for smaller players. Such tools and initiatives are already being supported by some governments as illustrated by America's AI Action Plan.[96]

**Financial services providers** including lenders, equity investors and insurers have an important role to play in supporting and scaling AI-driven innovation in the energy sector. Not only as financial enablers, but also as users of AI, they can help by:

- **Prioritizing and supporting investments in AI-driven energy and digital infrastructure projects that demonstrate potential benefits in sustainability, flexibility and resilience.** This could include deploying innovative financing instruments such as sustainability-linked bonds, concessional loans and mezzanine financing mechanisms[82] to support data centers, grid upgrades and integration of more energy sources.
- **Developing and implementing appropriate risk assessment frameworks tailored to the specific opportunities and challenges posed by AI in the energy sector, including cybersecurity, regulatory changes and operational resilience.** Insurers should consider developing new coverage models that help address AI-specific risks[97] and to incentivize resilience improvements via insurance pricing and product innovation.[2] Additionally, financial institutions can leverage AI to help enhance their internal risk identification and credit scoring processes, automate their financial workflows including due diligence, and improve asset evaluations.[98] AI-based financial models such as pay-as-you-go can also provide tailored financing solutions to increase capital flow into renewable projects.[99]
- **Proactively collaborating with policymakers, technology firms, utilities and energy operators to identify priority areas for investment, such as flexibility incentives for data centers and standardized reporting.** By participating in PPPs, financial service providers can help de-risk early-stage AI projects and lay the groundwork for a robust, responsible and innovative AI-enabled energy ecosystem.

**Governments and policymakers** are important for the adoption of AI across energy systems. Their influence can help lay the foundation for sustainable sovereign AI by:

- **Establishing standards and informing definitions for AI transparency and accountability in infrastructure projects or removing barriers to AI.**
- **Harmonizing secure, cross-sector and cross-border data-sharing frameworks to help enable robust, collaborative development of AI models and optimization of regional energy systems.** Sustained public investment in high-quality, interoperable scientific datasets is important for advancing collaborative AI-driven innovation across sectors and borders.[4] The EU's Enershare platform offers a case in point: this popular data-sharing framework fosters a unified space for efficient and secure cross-sectoral data exchange.[100]
- **Providing targeted economic and financial support such as subsidies, tax incentives, grants and other mechanisms to help reduce the financial risk associated with AI innovation and adoption.** Despite a rise in government investment in AI research, development and innovation, current data indicate that AI applications within the energy sector are still comparatively limited.[4] This likely requires widespread development of support mechanisms such as the Dutch Wet Bevordering Speuren Ontwikkelingswerk (WBSO) tax credit, which partially compensates companies for R&D-related investments in AI-based predictive maintenance, intelligent transport systems and energy optimization.[101]
- **Investing in local capacity and fostering domestic AI talent through education, training, regional innovation hubs and collaboration between academia, industry and the public sector.** AI is being used more in the workplace[102] against a backdrop of an AI talent gap that is poised to widen.[103] Government-supported training with inputs from industrial specialists can be important to overcoming talent constraints and meeting the growing demand for new skills, in-house. Some governments are beginning to address the increasing need for upskilling and reskilling through various initiatives such as AI literacy programs spawned by the EU AI Act[104] and grants from the US Workforce Innovation and Opportunity Act designed to promote AI literacy within the public sector.[105]

- **Promoting flexible policy approaches that can evolve with the rapid development of AI technologies and the dynamic needs of energy markets.** Given the speed of AI advancement, which often outpaces the capacity of different stakeholders to keep up, adaptive policy approaches can help minimize the risk of regulatory obsolescence and allow for calibrated evolution of AI governance.[2]

# 4.2. Creating an inclusive AI future

Artificial intelligence has the potential for tackling important global matters such as sustainable development and healthcare access, but it may only be successful if many countries and communities can access, adapt and shape AI solutions to their unique needs. This may require targeted support for infrastructure development, investment in local capacity building, and the creation of robust, interoperable data ecosystems that respect sovereignty and privacy.[12] Therefore, governments and multilateral institutions should consider prioritizing funding and technical assistance for digital and energy infrastructure in underserved regions, including those within countries, while fostering the conditions for local innovation and participation in global AI research networks.[106]

PPPs can serve as a powerful lever for closing these gaps. By combining the regulatory insight and convening power of the public sector with the technical skills and innovation capacity of the private sector, PPPs can help accelerate the deployment of inclusive AI solutions.[107] Successful collaboration actively involves civil society and local communities, integrating different perspectives and ensuring that AI design and deployment reflect social, ethical and cultural priorities. Singapore's National AI Strategy 2.0 (NAIS 2.0) offers a case in point. Explicitly designed with inclusivity and ethics in mind, it includes initiatives to help make AI energy management tools accessible to both large and small utilities, and to train a broad segment of the workforce in AI literacy and application.[108]

Furthermore, inclusive AI development should address bias and promote fair access.[99] This means investing in multilingual AI models and building datasets that reflect local realities.[84,99] Ongoing monitoring, auditing, and transparent reporting are important for building and maintaining trust and accountability.

Finally, advancing AI literacy and developing AI skills at each level of society is important. Governments, educational institutions, and industry can work together to design training initiatives and awareness campaigns, empowering people to understand, use and shape AI technologies.

By equipping the workforce and the wider public with important digital skills, broad participation in the AI-enabled energy economy can be secured.

Coordinated and decisive effort across stakeholders is important for unlocking the transformative power of sovereign sustainable AI for the energy sector. By working together, governments, private actors (including technology providers, energy companies, industrials and financial service providers), civil society and other organizations can leverage AI as a strategic tool—integrated across planning and operation of energy systems—and enable the energy sector not only to withstand future challenges, but also to lead the way toward a sustainable, equitable and resilient future.

# Appendices

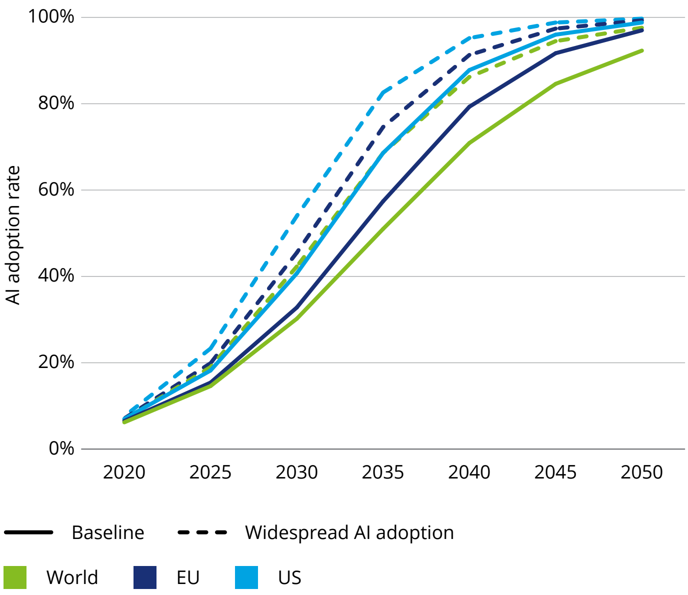
## Appendix 1.
## Calculation of the impact of AI applications in energy systems

Estimating the global impact of AI on the energy sector involves assessing how each AI application affects cost, energy consumption and emissions. This analysis is aligned with the projected evolution of the sector[14] and takes into account the unique characteristics of different regions. Countries have been grouped into the following regions: North America, Central and South America, Europe, Eurasia, Middle East and North Africa (MENA), Africa, China, India, Southeast Asia and other Asia Pacific (e.g., Australia, Japan, South Korea, etc.).

AI adoption rates can differ significantly across regions, primarily due to variations in socio-economic factors. Estimation of these adoption rates is based on GDP and GDP per capita,[109] investments in AI and additional indicators such as regional patent filings, where available.[110] Projections for these parameters extend to 2050, utilizing a combination of linear regressions and exponential trend functions, including macroeconomic studies on AI's potential impact by region,[81] and current and medium-term objectives set by specific regions such as Germany and the EU[111]. This approach is inspired by the International Monetary Fund's (IMF) AI adoption scenarios: Baseline, Limited Adoption and Enhanced Adoption. Each scenario is defined by parameters such as access to AI technologies, data restrictions, geopolitical matters, availability of advanced processors and infrastructure, and is applied to various regional groupings including advanced economies, emerging markets and low-income countries. The impact of AI can be more pronounced in the United States, China, Europe and other advanced economies, as indicated by a relatively small difference between the Baseline and Enhanced Adoption scenarios; in both cases, the AI-induced shock to GDP after 10 years is estimated at around 4.5%. In contrast, emerging markets and low-income countries are expected to experience a more modest overall impact of AI on GDP.[81] However, these regions display a greater disparity between the two scenarios, with the average deviation of GDP from the steady state after 10 years ranging from 2.8% in the Baseline scenario to 3.3% in the Enhanced Adoption scenario.[81]

In this report, two primary scenarios are defined: a baseline scenario reflecting current levels of AI use within the energy sector and a widespread-adoption scenario assuming higher rates of AI uptake. A logistic function (i.e., S-curve) is used to model the spread of AI adoption over time (see Figure 6). This approach reflects the typical trajectory of new technology adoption, consisting of a rapid initial growth followed by a plateau as saturation is reached. For example, the global adoption of the internet displayed a similar S-curve pattern.

**Figure 6. AI adoption curves under different scenarios**




Source: Deloitte Global assumptions inspired by IEA and IMF

The benefits of AI vary depending on the specific application and the sector in which it is used. Potential energy savings are considered across power generation, transport (including road, rail, shipping and aviation), industries (grouped as iron and steel, chemicals, cement, and other) and buildings (both residential and tertiary). Relevant AI applications that are identified in section 2.1 of the report are prioritized by their widespread adoption level, technological maturity and data availability. Figure 7 shows examples of the selected AI applications per sector and the energy saved by each.

**Figure 7. Energy savings due to AI adoption in select applications**

| Sector | AI applications | Impact on energy savings |
|---|---|---|
| Power | AI-driven aerodynamics improvements in onshore wind[112,113] | Above 10% |
| Power | Material discovery for solar PV and batteries[26] | 5% to 10% |
| Power | PV array detection through computer vision technology[114] | 5% to 10% |
| Power | Dynamic line rating[4] | 5% to 10% |
| Power | Predictive maintenance[4] | 5% to 10% |
| Power | AI-aided AC optimal power flow calculation[48,49] | Less than 5% |
| Transport | Battery management system[29] | Above 10% |
| Transport | Route optimization[4,115] | Above 10% |
| Transport | Autonomous trains[4] | Above 10% |
| Transport | Autonomous navigation[116] | 5% to 10% |
| Transport | Optimized flights[117] | 5% to 10% |
| Industry | Process optimization in iron and steel[118] | 5% to 10% |
| Industry | Process optimization in cement production[4,119] | 5% to 10% |
| Buildings | AI-based space conditioning[4,120] | Above 10% |
| Buildings | Smart demand shedding and peak shaving[28] | Above 10% |

**Impact level:** Less than 5% 5% to 10% Above 10%

Source: Deloitte Global analysis based on the sources in the examples within the figure

The impacts of these applications, combined with regional AI adoption rates, are applied directly to net-zero outlook data and supplemented with additional sources for further regional and sectoral precision where necessary.[121,122,123] Input data includes the evolution of energy production by source, energy consumption by sub-sector, and technology and commodity costs. For example, in the power sector, improved wake steering and blade optimization in onshore wind farms can increase energy production by up to 12%.[113] This efficiency gain is applied to newly added capacities calculated based on various regional outlooks,[14,122] with adjustments made according to the AI adoption rate specific to each region. In the maritime transport sector, the adoption of autonomous navigation technologies is expected to impact both new and existing fleets, resulting in an estimated reduction in fuel consumption of approximately 5%.[116] The regional adoption rates of autonomous navigation are refined based on industry projections, with low and high automation scenarios for 2040 ranging between 17% and 50%.[124,125] Yearly energy savings are subsequently calculated following this equation:

$$Energy\ savings_{y,r} = AI\ adoption\ rate_{y,r,s} \times Energy\ consumption_{y,r,s} \times AI\ impact_{app,s}$$

With:

- $Energy\ savings_{y,r}$ yearly energy savings from using AI in gigawatt hours (GWh). If the AI application affects newly added capacities, the energy savings of the previous period is added to the energy savings of the year calculated.
- $AI\ adoption\ rate_{y,r}$ yearly adoption rate by region in percentage and calculated based on the methodology described in the Appendix 1.
- $Energy\ consumption_{y,r}$ yearly energy consumption in GWh of existing capacities or newly added capacities depending on the AI application. This variable is extracted from regional outlooks.[14,122]
- $AI\ impact_{app}$ the impact of the AI application in percentage form.
- $y$ the year in which the equation is applied.
- $r$ the region on which the equation is applied.
- $s$ sector in which the equation is applied.
- $app$ the AI application.

Concerning the economic assessment, energy savings may be translated into cost reductions in different ways depending on the AI application:

- Fuel cost savings by direct reduction in fuel consumption (e.g., route optimization and autonomous navigation). These savings are calculated based on the amount of fuel conserved through AI applications and the corresponding price of the commodity avoided.[14,121,122]
- Avoided investments, notably in the power sector (e.g., through increased deployment of renewables and reduced need for grid upgrades, as experienced with dynamic line rating applications). Reductions in electricity demand through extensive AI use are expected to lead to lower capital expenditures, with the extent of these savings depending on the projected energy mix in each region.
- Operational and maintenance (O&M) cost savings (e.g., predictive maintenance or improved wind turbine performance). As an example, in the power sector, predictive maintenance in power plants can reduce O&M costs by 5% to 10%.[4] These percentage reductions are applied to the O&M costs associated with each region's electricity mix to calculate the resulting cost savings.

Avoided emissions are calculated using the emission intensity of fuels and annual average emission footprint of the electricity generation source, reflecting the impact of both reduced non-renewable consumption and increased renewable energy integration.

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# Deloitte Center for Sustainable Progress

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# Endnotes


1. World Economic Forum, "Fostering Effective Energy Transition 2025", June 2025.
2. Deloitte Global, "AI for infrastructure resilience", June 2025.
3. World Economic Forum, "Artificial Intelligences Energy Paradox", January 2025.
4. International Energy Agency, "Energy and AI", April 2025.
5. Deloitte Global analysis based on the sources highlighted in Figure 1.
6. National Energy System Operator, "Demand Flexibility Service", August 2023.
7. Adil Ahmed and Muhammad Khalid, "A review on the selected applications of forecasting models in renewable power systems", Renewable and Sustainable Energy Reviews, vol. 100, pp. 9-21, 2019.
8. Deloitte Global, "Powering artificial intelligence: A study of AI's environmental footprint—today and tomorrow", November 2024
9. Deloitte Global analysis based on the methodology explained in Appendix 1. Calculation of the impact of AI applications in energy systems"
10. International Energy Agency, "Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach – 2023 update", September 2023.
11. European Commission, Emissions Database for Global Atmospheric Research (EDGAR), "GHG emissions of all world countries – 2024 report", 2024.
12. World Economic Forum, "Sovereign AI: What it is, and 6 ways states are building it", April 2024
13. European Stability Mechanism, "Renewable energy can fuel increased energy security", July 2024.
14. International Energy Agency, "World Energy Outlook 2024", October 2024
15. International Energy Agency, "Growth in global energy demand surged in 2024 to almost twice its recent average", March 2025.
16. Jingfan Wang, "Automating the detection and classification of methane pollution: integrating deep learning and techno-economic analysis", Stanford University, December 2019.
17. ANZ Research, "Commodity Call", January 2024.
18. Net savings are calculated based on Deloitte Global analysis, taking into account operations and maintenance (O&M) cost savings achieved through automated leak detection and repair (LDAR), as well as the resale value of methane emissions avoided. A conversion factor of 46.4 has been used to transform MMBtu to tonne or methane.
19. Factor This, "Case study: The first US electric utility to integrate dynamic line ratings into real-time and market operations", January 2025.
20. NVIDIA, "How AI Factories Can Help Relieve Grid Stress", July 2025
21. PR Newswire, "Emerald AI Launches with $24.5M Seed Round to Transform AI Data Centers into Grid Allies" , July 2025
22. Arun Sukumaran Nair et al., "Computational and numerical analysis of AC optimal power flow formulations on large-scale power grids", Electric Power Systems Research, vol. 202, 107594, January 2022.
23. cBrain, "AI-assisted environmental permitting", 2024.
24. IEA, Africa's electricity access planners turn to geospatial mapping, 2024
25. University of Cambridge, "Heidelberg Materials adopts Carbon Re's AI and ABB Ability™ for improved kiln operations", October 2024.
26. Chi Chen et al., "Accelerating computational materials discovery with artificial intelligence and cloud high-performance computing", arxiv, January 2024.
27. Deloitte Global analysis based on the assumption that the efficiency of lithium-ion batteries is 89% based on Raphael I. Areola et al., "Integrated Energy Storage Systems for Enhanced Grid Efficiency: A Comprehensive Review of Technologies and Applications", Energies, vol. 18, issue 7, April 2025; and the efficiency of solid-state batteries is 97% based on Hongming Yi et al., "Low-Cost Mn-Based Cathode Materials for Lithium-Ion Batteries", Batteries, vol. 9, issue 5, April 2023. Electricity cost savings is calculated based on the difference in energy loss between these batteries, projected capacity increase from 2023 to 2030 using IEA, "Batteries and Secure Energy Transitions", 2024; and average electricity cost in 2023 in leading battery markets from IEA, Prices – Electricity 2025 – Analysis - IEA, Accessed in October 2025.
28. Kibaek Kim, "Real-Time AI-Based Power Demand Forecasting for Peak Shaving and Consumption Reduction Using Vehicle-to-Grid and Reused Energy Storage Systems: A Case Study at a Business Center on Jeju Island", Applied Sciences, vol. 15, issue 6, March 2025.
29. Magnus Briggt and Greg Johansson, "Optimizing Electric Vehicle Performance through Advanced AI-Driven Battery management System (BMS)", SSRN, December 2023.
30. D.B. Hulwan et al., "AI-Based Fault Detection and Predictive Maintenance in Wind Power Conversion Systems", EDP Sciences, E3S Web of Conferences, vol. 591, November 2024.
31. Elia, "System imbalance forecasts", accessed August 2025.
32. Hitachi Energy, "Nostradamus AI Energy Forecasting Software", accessed August 2025.
33. Hendrik F. Hamann et al., "Foundation models for the electric power grid", Joule, vol. 8, issue 12, pp. 3245-3258, December 2024.
34. European commission, "Methane emissions", accessed in August 2025.
35. Gunnar Myhre et al., "Anthropogenic and Natural Radiative Forcing", Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
36. Martin Lavoie et al., "Evaluating the benefits of alternative leak detection programs", Pembina Institute, May 2021.
37. International Energy Agency, "Global Methane Tracker 2025", May 2025.
38. Deloitte Global analysis using maintenance and repair cost reductions and the total methane emissions.
39. OreFox Exploration, "Pioneering New Frontiers in Mineral Discovery with AI ", accessed August 2025.
40. Earth AI, "Turbocharging exploration to build the electric future", accessed August 2025.
41. Halliburton, "LOGIX™ drilling performance", accessed August 2025.
42. Latitude Media, "Can Zanskar use AI to de-risk conventional geothermal?", June 2025.
43. Entek Elektrik, "Artificial Intelligence in Hydrology Prediction", EDİDER AI Applications in the Energy Sector Conference, Ankara (Türkiye), October 2024.

44. Google DeepMind, GraphCast: AI model for faster and more accurate global weather forecasting", November 2023.
45. Léonard Tschora et al., "Electricity price forecasting on the day-ahead market using machine learning", Applied Energy, Elsevier, 2022
46. Felix Nitsch et al., "Applying machine learning to electricity price forecasting in simulated energy market scenarios", Energy Reports, Volume 12, Pages 5268-5279, December 2024
47. Grid Singularity, "Grid Singularity Technical Approach", accessed August 2025.
48. Optimal Power Flow (OPF) is an important calculation used by grid operators to determine the most efficient and secure real-time operation of electricity generators. It solves a complex optimization problem reflecting the physical limits of the grid (such as power flows, voltage, and equipment constraints) to meet demand at the lowest cost. While the most accurate version (AC-OPF) is computationally intensive, operators often use a simplified version (DC-OPF) for faster decisions—though this can result in less efficient and more carbon-intensive grid operation.
49. Xiang Pan et al., "DeepOPF: A Feasibility-Optimized Deep Neural Network Approach for AC Optimal Power Flow Problems", arxiv, July 2022.
50. IBM, "What Is a Digital Twin?", 2021.
51. Mohsen Attaran and Bilge Gokhan Celik, "Digital Twin: Benefits, use cases, challenges, and opportunities", Decision Analytics Journal, Vol. 6, 100165, 2023.
52. National Energy System Operator, "Energy System Digital Twin - Benchmarking Report", February 2022.
53. Deloitte Touche Tohmatsu, "Optimal Reality", accessed July 2025.
54. World Economic Forum, "How permitting processes are hampering Europe's energy transition", September 2024.
55. PACES, "Introducing the Accelerated Development Framework", February 2025.
56. Deloitte Global analysis based on BNEF, "1H 2024 US Clean Energy Market Outlook: Moving Past 2030", May 2024.
57. Deloitte Consulting LLP documentation of Rate Case Assistant.
58. Siemens Energy, "Siemens Energy announces new AI-driven cybersecurity monitor and detection service for the energy industry", October 2020.
59. L2L, "Artificial Intelligence in Maintenance: How AI Helps Maintenance Teams?", October 2024.
60. MIT Sloan Management Review, "A Maintenance Revolution: Reducing Downtime With AI Tools", Column, September 2025.
61. Entek Elektrik, "Entek Maintenance Assistant", EDİDER AI Applications in the Energy Sector Conference, Ankara (Türkiye), October 2024.
62. The Economist, "AI models are dreaming up the materials of the future – Better batteries, cleaner bioplastics and more powerful semiconductors await", March 2025.
63. Gamesh Vijayakumar et al., "Enabling Innovation in Wind Turbine Design Using Artificial Intelligence", the ARPA-E Energy Innovation Summit, May 2022.
64. Muhammad Noman et al., "A comprehensive review on the advancements and challenges in perovskite solar cell technology", RSC Advances, vol. 14, issue 8, pp. 5085-5131, February 2024.
65. Fatou Diaw Ndiaye et al., "Toward More Scalable Processes for Perovskite Solar Cells: A Comparison Between Planar and Mesoporous Architectures", Nano Select, vol. 6, issue 5, March 2025.
66. Naoto Eguchi et al., "Performance optimization of perovskite solar cells with an automated spin coating system and artificial intelligence technologies", EES Solar, vol. 1, issue 3, pp. 320-330, April 2025.
67. Montree Sawangphruk, "Solid-State Batteries: Materials, Technologies, and Future", Handbook of Energy Materials, living edition, February 2025.
68. The Faraday Institution, "Solid-State Batteries: The Technology of the 2030s but the Research Challenge of the 2020s", Faraday Insights, issue 5, February 2020.
69. The National High School Journal of Science," AI-Driven Solutions: Quantitative and Case Study Analysis for Transforming CCS Technologies", January 2025.
70. US Department of Energy, "Grid-interactive Efficient Buildings Technical Report Series: Heating, Ventilation, and Air Conditioning (HVAC); Water Heating; Appliances; and Refrigeration", December 2019.
71. Schneider Electric, "AI-powered HVAC in educational buildings: A net digital impact use case", December 2024.
72. Scalacode, "AI in Transportation Industry: Everything You Need to Know", June 2025.
73. The CDO Times, "UPS and Agentic AI: A Case Study in Logistics Innovation", January 2025.
74. Marc A. Rosen and Aida Farsi, "Battery Technology - From Fundamentals to Thermal Behavior and Management", Chapter 6, Elsevier, 2023.
75. International Council on Clean Transportation, "A total cost of ownership comparison of truck decarbonization pathways in Europe", 2023.
76. Atlas Public Policy , "Comparing the Total Cost of Ownership of the Most Popular Vehicles in the United States", 2024.
77. World Economic Forum, "How AI is transforming the factory floor", June 2025.
78. World Economic Forum," Global Lighthouse Network: Adopting AI at Speed and Scale", December 2023.
79. International Energy Agency," Digitalization and Energy – Analysis - IEA", November 2017.
80. GE Vernova, "Empower Intelligent Grids With AI", 2025.
81. Eugenio M. Cerutti et al., "The Global Impact of AI", IMF Working Papers, vol. 2025, no. 76, 2025.
82. Deloitte Global, "Financing the green energy transition: A US$50 trillion catch", November 2023.
83. Oracle, "What Is Sovereign AI?", April 2025
84. NVIDIA, "What Is Sovereign AI?", February 2024
85. David. L. Shrier et al., "Considerations regarding Sovereign AI and National AI Policy", IMPERIAL Trusted AI Alliance, March 2025
86. Eurelectric, "Cybersecurity in the power sector", February 2025
87. International Telecommunication Union, "AI for Good Impact Report: Choices to shape the future", October 2024.
88. RealTyme, "Why Data Sovereignty Matters for Secure Collaboration?", December 2024.
89. The World Bank Group – Data, "Energy imports, net (% of energy use)", accessed August 2025.
90. Deloitte Global analysis; calculation based on dividing energy savings by natural gas and oil imports, which account for 314 bcm - 3,068 TWh[88] and around 4,300 TWh[89] respectively.
91. European Commission, "REPowerEU - Affordable, secure and sustainable energy for Europe", accessed August 2025.
92. International Energy Agency, "Why AI and energy are the new power couple", November 2023.
93. World Economic Forum, "AI's energy dilemma: Challenges, opportunities, and a path forward", January 2025.
94. Orange Business, "Optimizing artificial intelligence and machine learning with cloud computing", July 2024.
95. Deloitte Netherlands, "Our joint capabilities. Your trustworthy AI.", accessed October 2025.
96. The White House, "Winning the AI Race: America's AI Action Plan", July 2025.
97. Swiss Re Institute, "Tech-tonic shifts - How AI could change industry risk landscapes", May 2024.
98. IBM, "What is artificial intelligence (AI) in finance?", July 2025.
99. Operationalising a Just Transition in Africa, "Harnessing Artificial Intelligence (AI) To Propel A Just Energy Transition In Africa", Policy Brief, February 2025.
100. ENERSHARE, "The Energy Data Space for Europe", accessed August 2025.
101. Business.gov.nl, "R&D tax credit (WBSO)", accessed August 2025.
102. Workday, "Elevating Human Potential: The AI Skills Revolution", Jan 2025.

103. Staff Industry Analysts, "Companies face growing shortage of AI skills in the workforce", March 2025.
104. EU Artificial Intelligence Act, "AI Literacy Programs in Europe – Supporting Article 4 of the EU AI Act", May 2025.
105. US Department of Labor, "US Department of Labor promotes AI literacy across the American workforce", August 2025.
106. Next Century Cities, "Closing the Digital Divide is Essential to Achieving Environmental Justice", accessed August 2025.
107. World Economic Forum, "How public-private partnerships can ensure ethical, sustainable and inclusive AI development", November 2024.
108. Smart Nation – Singapore, "National AI Strategy", accessed August 2025.
109. The Economist Intelligence Unit, "EIU Viewpoint", accessed August 2025.
110. Stanford University, "Artificial Intelligence Index Report", 2025
111. Organisation for Economic Co-operation and Development, Artificial Intelligence Review of Germany", June 2024.
112. Dylan Harrison-Atlas et al., "Machine learning enables national assessment of wind plant controls with implications for land use", Wind Energy, vol. 25, issue 4, pp. 618-618, April 2022.
113. Shumail Sahibzada et al., "AI-Driven Aerodynamic Design Optimization for High-Efficiency Wind Turbines: Enhancing Flow Dynamics and Maximizing Energy Output", European Journal of Science, Innovation and Technology, vol. 4, no. 6, 2024.
114. Qiang Wang et al., "Integrating artificial intelligence in energy transition: A comprehensive review", Energy Strategy Reviews, vol. 57, 101600, 2025.
115. World Economic Forum, "Intelligent Transport Greener Future", January 2025.
116. Orca AI, "AI could help reduce global commercial shipping $CO_2$ emissions by more than 47 million tonnes per year", June 2024.
117. World Economic Forum, "Artificial intelligence can make aviation more sustainable", November 2023.
118. Fero Labs, "The Convergence of AI and Sustainability in the Manufacturing sector", June 2024.
119. ABB, "How cement producers are using AI to transform their operations — and future trajectory", February 2022.
120. Po-Ching Hsu et al., "Comparative study of LSTM and ANN models for power consumption prediction of variable refrigerant flow (VRF) systems in buildings", International Journal of Refrigeration, vol. 169, pp. 55-68, 2025.
121. Deloitte Global, "Low-carbon fuels: The last mile to net zero - The role of synthetic fuels in decarbonizing the skies and the seas", November 2024.
122. DNV, "Energy transition outlook 2024 – A global and regional forecast to 2050", 2024.
123. Deloitte Global, "Green hydrogen: Energizing the path to net zero – Deloitte's 2023 clean hydrogen outlook", June 2023.
124. Takuya Nakashima et al., "Accelerated adoption of maritime autonomous vessels by simulating the interplay of stakeholder decisions and learning", Technological Forecasting and Social Change, Volume 194, 122710, 2023.
125. World Maritime University, "Transport 2040: Automation, Technology, Employment - The Future of Work", 2019.

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