The Role of AI in the Energy Sector

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ABSTRACT

The digital era is transforming traditional approaches across various fields, fostering innovations that enhance efficiency and timeliness. The effective implementation of modern technologies and automated methods accelerates decision making by enabling the rapid processing of large datasets. Furthermore, these technologies facilitate continuous communication across borders and ensure the continuity of operations, even during crises. In this context, artificial intelligence (AI) serves as a crucial tool for digital transformation. Clearly defining

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its role can significantly advance digital transformation in various sectors, including energy. Therefore, it is essential to explore how AI systems can be integrated into the energy sector, how this integration will support the effective implementation of energy policies, and what challenges may arise from the use of AI. To mitigate these risks, an ethical and legal framework should be developed to promote the concept of reliable artificial intelligence in the energy sector. Moreover, the European Union has adopted the Artificial Intelligence Act, and the Council of Europe has prepared the Framework Convention on AI and Human Rights, Democracy, and the Rule of Law, which establishes a substantial foundation for defining international legal standards for the general use of artificial intelligence.

INTRODUCTION

Rapidly developing digital technologies, big data collection, and the global COVID-19 pandemic demonstrated the need to introduce information and communication technologies into all key areas like education, healthcare, agriculture, energy, finance, foreign affairs, and security and military policy. Furthermore, the accurate usage of such technologies ensures the continuity of activities in the aforementioned spheres, the development of which affects the interests of citizens, society at large, and the state itself. Amid the accelerating digital transformation of societies, the role of digital technologies in shaping and implementing energy policies is increasingly important. In this regard, examining the usage of artificial intelligence (AI) gains particular relevance, as AI is a key instrument for an accelerated digital transformation that can enable users to make systematized, consistent, and timely decisions.

An analysis of international practices shows that information and communication technologies permit states to implement energy policy priorities on time. Digital technologies create the possibility of identifying outages quickly and enhancing threat detection instruments to avoid challenges. The use of technological and innovative programs eases the decision-making process to clarify solutions within energy policy. Overall, this process enlarges communication networks among the authorities responsible for energy issues and strengthens coordination mechanisms, which are necessary preconditions for the effective implementation of energy policies.

In the era of climate change and fossil fuel consumption, AI can help minimize some of the impacts of climate change and propel the world toward the energy transition. Importantly, AI is currently an extremely

energy-intensive technology that is being developed and deployed at a rapid rate, so for better or worse, the energy industry will need to focus on AI systems, both as a tool to improve energy resource allocation and as a challenge, to meet high energy demands in a clean and sustainable way. Still, the potential of AI systems to transform the energy industry cannot be overstated, as AI integration into the energy industry can ensure rapid responses, propelling the evolution of energy markets.

THE NOTION OF ARTIFICIAL INTELLIGENCE AND ITS STRATEGIC FRAMEWORK

AI refers to systems that display intelligent behavior by analyzing their environment and which take actions—with some degree of autonomy—to achieve specific goals. AI-based systems can be purely software based, acting in the virtual world, or AI can be embedded in hardware devices.[1] Because of growth in computing power, data availability, and progress in algorithms, AI has become one of the most strategic technologies of the twenty-first century.[2]

AI technologies help optimize industrial processes, making them more resilient and efficient. AI also enables innovative self-learning and real-time solutions, from predictive maintenance to collaborative robots, from digital twins to augmented reality.[3] In particular, it is possible to introduce AI in the energy system by enabling timely data processing and accelerating the decision-making process of what resources to deploy when and where. In the energy context, there is endless potential and opportunity, in the form of promoting the development of proper AI systems in the public and private sector; investing in digital and telecommunication infrastructure to support AI development;[4] creating a digital hub for public-private partnerships; assisting subject matter experts with data-driven business development and digitalization; establishing educational institutions in a technology pact to foster technical and digital skills; strengthening cyber security in companies to protect against threats to the grid; and crafting agile regulations to facilitate new business models and experimentation.[5]

Some existing strategic frameworks prioritize the energy sector when introducing AI systems. For example, the Danish government aims to set goals for work on AI within specific priority areas such as healthcare, energy and utilities, agriculture, and transport.[6] Norway intends to invest in AI for energy and mobility. The government wants Norwegian organizations to be attractive cooperation partners for leading business and research communities in AI. Norway will continue to pursue its investment in basic

and applied Information and Communications Technology research. It aims to exploit the innovative potential of AI,[7] which can enable Norway to take a leading position in introducing AI in oil and gas, energy distribution systems, the maritime and marine industries, and the public sector more broadly.[8]

A number of countries are increasingly recognizing the potential of AI to help achieve some of their green transitional goals and are using this critical juncture as an opportunity for international collaboration. For instance, in Singapore's second National AI Strategy (NAIS 2.0), there is a call for the country to stay well-connected to global innovation networks, working with the best to overcome complex challenges surrounding AI today (e.g., energy, data, and ethics). It must contribute to AI breakthroughs and products that the world values.[9] In February 2023, AI Singapore (AISG) and the Republic of Korea's (ROK) Institute for Information & Communication Technology Planning and Evaluation (IITP) launched a joint grant call to fund research on AI-based net zero energy building management optimization systems. This grant call supported a research project between Nanyang Technological University and Korea University, to study AI-based energy management and optimization frameworks to enhance the energy efficiency of heating, ventilation, and air conditioning (HVAC) systems. The project also drew in industry partners from both countries.[10] In the medium-to-longer term, Singapore plans to chart a roadmap toward the growth of net zero green data centers that are powered by renewable energy. This includes continued collaboration with industry on innovative proposals to push the sustainability agenda.[11]

Overall, AI strategic frameworks define priority areas for using artificial intelligence, including the energy sector. Simultaneously, these conceptual documents clarify the necessity of adopting appropriate standards and approaches for developing reliable AI systems. This stimulates the creation of proper grounds for ethical and legal frameworks.

THE CONCEPT OF RELIABLE AI

To ensure the lawful and ethical usage of AI, it is essential to build rules for the development of the concept of reliable AI. In this regard, after expert group meetings on April 25, 2018, and December 7, 2018, the European Commission set out its vision for AI, which supports "ethical, secure and cutting-edge AI made in Europe."[12]

In this context, an independent group of experts has developed ethics guidelines for AI. The goal of the guidelines is to promote reliable AI with

three components that should be met throughout the system's entire life cycle: (1) it should be lawful, complying with all applicable laws and regulations; (2) it should be ethical, ensuring adherence to ethical principles and values; (3) it should be robust, both from a technical and social perspective. Each component is necessary in itself, yet not sufficient for the achievement of reliable AI. All the abovementioned components work in harmony and overlap in their operation. If tensions arise between these components in practice, society should endeavor to align them.[13]

Generally, AI ethics focuses on the normative issues raised by the design, development, implementation, and use of AI. Within ethical discussions, the terms "moral" and "ethical" are used. The term "moral" refers to the factual patterns of behavior, customs, and conventions that can be found in specific cultures, groups, and individuals. The term "ethical" refers to an evaluative assessment of such concrete actions from a systematic and academic perspective. Ethical AI is used to indicate the development and use of AI that ensures compliance with ethical norms, including fundamental rights as special moral entitlements and core values.[14]

From a legal standpoint, in 2021, the European Commission proposed an Artificial Intelligence Act. The proposed regulatory framework on AI focused on the following four specific objectives: (1) to ensure that AI systems placed and used on the European Union (EU) market are safe and respect EU values and the existing laws around fundamental rights; (2) to facilitate investment and innovation on AI; (3) to enhance governance and effective enforcement of existing laws on fundamental rights and safety requirements applicable to AI systems; (4) to facilitate the development of a single market for lawful, safe, and reliable AI applications and prevent market fragmentation.[15]

The proposed Artificial Intelligence Act was a good starting point to ensure that the development of AI in the EU was legally acceptable, ethically sound, environmentally sustainable, and socially equitable and that AI was able to support society, the economy, and the environment.[16] Furthermore, in 2023, EU policymakers reached an agreement on the first comprehensive legal framework to regulate AI systems[17] and created legal grounds to develop the concept of reliable AI at the regional level. The EU Artificial Intelligence Act lays down a uniform legal framework, in particular, for the development, sale, uptake, and use of AI systems in the EU, by EU values, to promote human-centric and reliable AI while ensuring a high level of protection of health, safety, and fundamental rights.[18]

The EU Artificial Intelligence Act emphasizes that AI should be a human-centric technology. It should serve as a tool for people, with the

ultimate aim of increasing human well-being. Critically, the Act includes standardization requests, which amount to deliverables on reporting and documentation processes to improve AI systems' resource performance. These include reducing the high-risk AI system's consumption of energy and other resources during its lifecycle and the energy-efficient development of general-purpose AI models. When preparing a standardization request, the Commission shall consult the European Artificial Intelligence Board and relevant stakeholders, including the advisory forum.[19]

In light of these documents and initiatives, we should also define the criteria for the ethical and reliable usage of AI systems in the energy sector. More precisely, developing and using AI systems in the energy field can adhere to the following key ethical components: respect for human autonomy, fairness, and the prevention of damage. Deploying reliable artificial intelligence in the energy sector can combine the principles of human oversight, technical robustness and safety, inviolability of privacy, protection of data governance, diversity, non-discrimination, transparency, and accountability.

Overall, because of the growth in the scope and capabilities of AI, the need to create an appropriate framework has become obvious. The adoption of ethical and legal frameworks should help create reliable AI and clarify the lawful purposes of AI systems in key fields, including the energy sector. It will define the legal grounds to avoid the unlawful usage of AI in energy systems. At the same time, human rights should be respected and protected by the creators and users of AI applications. Additionally, to achieve the appropriate goals, AI systems should be provided with objective information. By processing such data, they would be able to make the right conclusions and assist humans to effectively perform different tasks, including automatic routine tasks for implementing the energy policy.

INTRODUCING AI IN ENERGY POLICY

AI can bring innovation to the energy sector specifically by improving safety and operational effectiveness. AI systems perform automated routine tasks and simplify the decision-making process through quick analysis of big data. AI can also promote sustainability within the energy industry and assist stakeholders in implementing both short-term and long-term strategic development plans.[20]

With the help of AI, it is possible to improve predictive maintenance, analyze data for actionable insights, manage smart grids, forecast renewable energy output, and enhance supply chain strategy.[21] Improving predictive maintenance means that machine learning algorithms can analyze data from

sensors, usage data, and historical maintenance records to predict when the equipment is likely to fail or require maintenance. It will bolster the reliability and resilience of services and reduce downtime and repair costs.[22]

Analyzing data for actionable insights considers that the vast amounts of data generated across various parts of energy systems, such as sensors, meters, and operational grids, require AI-powered analytical tools to sift through large datasets and identify trends and patterns. By extracting insights from this information, companies can optimize operations, improve decision making, and drive innovation across the organization.[23] At the same time, AI can help manage smart grids to optimize energy distribution in real time by balancing supply and demand more effectively, which can in turn improve grid reliability.[24] As renewable energy sources such as solar and wind play an increasingly significant role in the energy mix, AI becomes even more valuable. AI plays a crucial role in analyzing weather data, historical energy production, and other factors to forecast renewable energy output. This enables grid operators to anticipate fluctuations in supply and adjust energy distribution accordingly.[25] As for enhancing supply chain strategy, AI can optimize logistics, predict demand fluctuations, identify cost-saving opportunities, and enhance overall operational efficiency.[26] AI can also analyze complex market dynamics in energy trading. It can enable energy companies to make informed trading decisions, optimize their energy portfolios, and simulate market scenarios for the appropriate predictions. This process allows stakeholders to identify market opportunities and risks.[27]

Ultimately, by deploying AI as a tool in the energy sector, costs can be minimized in the areas of smart grids, demand response management, predictive maintenance, renewable energy forecasting, energy storage, carbon capture utilization and storage, energy trading, smart homes and buildings, oil and gas exploration, and nuclear power plant monitoring.[28] Data analytics can empower energy enterprises by diving deep into data sources, quality, and lineage, thus shedding light on the structure and content of information. This knowledge fuels better data discovery, leading to more accurate AI model training, and maximizing overall data utility. By considering time, location, user behavior, and environmental conditions, context analytics enables AI models to generate truly meaningful insights.[29] AI brings new knowledge, experience, and expertise into the sector. It is vital to keep an adequate balance among generation and consumption, and AI can prevent faulty predictions and optimize energy possibilities.[30]

The major attraction of introducing AI in energy is to facilitate energy efficiency. However, the digital transformation of the energy sector demands

time for various reasons, not least of which is a lack of trust in the possibilities of AI. Still, when the regulatory framework is put in place, it is time to enhance practice. The first step is to explain the benefits of introducing AI into the energy sector and increasing awareness of its potential. The opinion-making process is a sensitive phase and requires planning before it commences. The next step is the decision-making process, which demands appropriate qualifications and a strong understanding of the role of AI in the energy sector. As for the decision implementation phase, it needs to be translated into results. Overall, policymakers should take a key role in keeping progress going and demonstrating tangible outcomes.

CHALLENGES OF USING AI SYSTEMS IN THE ENERGY SECTOR

The energy sector is fast growing and in great need of permanent development. Electricity demand is increasing from year to year, yet we are at a crossroads where measures must be taken to use energy efficiently.

Introducing AI into the energy sector can result in huge benefits around electricity transmission, distribution, and generation. However, there are barriers to AI adoption in energy, including a lack of theoretical knowledge, lack of practical expertise, old infrastructure, and financial pressure.[31] Decision makers do not have the necessary knowledge about the responsible usage of AI systems. Companies do not have the technical background to understand how to introduce AI applications. AI is a new technology. Therefore, it is difficult to find experts who can develop new AI software with practical experience. Outdated systems are a challenge to the use of AI in the energy sector in particular, as companies need financial resources to replace old infrastructure.[32]

At the same time, cybersecurity risks are increasing, and the energy sector is often a major target of attacks. There are two basic types of cyberattacks: passive attacks and active attacks. The goal of passive attacks is to get system information and learn how the system is managed. In active attacks, the purpose is to disrupt or change system information, which is mostly confidential.[33] Without appropriate safeguards in place, a stable and reliable energy supply that quite literally powers an economy could be put at great risk.

AI is also an issue of fundamental rights, especially with respect to the labor rights of people who have responsibilities to analyze data or perform routine tasks in the energy field. AI should be developed as an effective instrument for performing tasks in the energy sector without infringing upon fundamental human rights. The application of AI enables the digital

transformation of the energy sphere if it builds on reliable digital cooperation. Such an approach excludes the usage of malicious applications for unlawful and unethical purposes and tasks. Successful digital transformation requires identifying the opportunities and challenges of this process and adopting legal norms at national, regional, and global levels to guarantee the responsible application of AI tools.

As AI is increasingly integrated into energy systems and beyond, there should be clear rules for accountability if such systems cause damage. In the future, this may become the basis for a clear determination of the legal personality of AI. AI may become a modern digital juridical person, taking into account the components of an electronic person. A state will grant it legal status based on certain restrictions to protect the legal interests of a natural person, especially in terms of labor rights, and simultaneously, the scope of the liability of AI should be determined following its specific characteristics.

Overall, AI still needs to gain the trust of academia, practitioners, businesses, and governments. Only then can AI facilitate the digital transformation of the energy sector. As for AI systems, elaborating and using reliable AI in the energy sector requires critical, strategic, and innovative thinking to adapt to new technological changes and avoid challenges.

CONCLUSION

AI is a unique tool that promotes rapid development and fills gaps around data analysis and real-time monitoring and evaluation. From the energy market perspective, AI can make markets more flexible in terms of price, innovation, infrastructure, and scientific achievements. AI can also deliver commercial benefits by reducing expenses at the various stages of energy production and consumption.

It is impossible to stop the growth of AI in the energy industry. This process will take its course. With the reduction of human intervention, there are no man-made mistakes, operations are optimized, and living standards are increased via a stable, steady, and reliable supply of electricity.

Predictions, forecasts, and assumptions are expensive and time-intensive, meaning they are not always feasible. AI is helpful in these critical circumstances. AI implementation in the energy sector can provide more accurate forecasts by conducting objective data analysis. Such activities allow leaders to make timely decisions and focus on strategic planning. AI hedges mistakes and enhances better results in terms of quality, thereby avoiding unpredictable emergency cases.

Finally, the digital transformation of the energy sector in the future will depend on how states instrumentalize digital achievements in their policies and activities. This process includes the development of digital policies complying with legal and security standards and supports personnel in building their digital skills. In the twenty-first century, in parallel with traditional approaches, digital transformation of key fields is inevitable for present and future realities. In modern strategies, the articulation of reliable AI applications enables timely processing of data, especially big data, and plays a role in making adequate decisions. Overall, AI will be a vital tool for determining the future energy landscape. ***f***

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