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ARTIFICIAL INTELLIGENCE APPLICATION THROUGH ELECTRIC POWER AND CLIMATE CHANGE

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Abstract Assessing and directing the implications of artificial intelligence (AI) and machine learning (ML) continues to be embedded in our daily lives and involves a united effort across academics, policy, and industry with ambiguity for impacting the present and the future. AI has the potential to improve outcomes, boost productivity, and improve the precision and effectiveness of the numerous facets of society that depend on probabilities and forecasts. In summary, its applications with the greatest potential might arise from those exceptionally complicated technological challenges that lie beyond the reach of human capability rather than from uses that impact civil freedoms and the social fabric of our society. One such complicated issue is climate change, which calls for significant adjustments to the building, energy, transportation, and agricultural sectors. In order to provide more accurate forecasts of impending weather phenomena, particularly extreme events, it can also expand on the discoveries made on climate links. The article critically examines the growing application of artificial intelligence through the Electric Power Sector in India.

Keywords
artificial intelligence, electricity generation, power industry, global warming, mitigation, adaptation

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1 Introduction

Regarding climate change, the electric power industry and other industries that are the leading producers of greenhouse gases are in a special position. It is expected that climate change will present significant new challenges for this industry (McAllister, 2011). Changing climatic conditions can have a variety of positive and negative effects on the energy sector. Climate change can have direct effects on the supply and demand for energy, but it can also have indirect consequences through other economic sectors or disrupt energy-related transportation and infrastructure. Studies on how climate change affects energy are being generated in greater numbers (Pryor & Barthelmie, 2010). Among all economic sectors, the energy sector is one of the most resilient, but climate change is expected to present significant new problems for it (Bull et al., 2007). The industry will have to adjust to the shifting supply and demand brought on by climate change. The main obstacle facing the electrical industry is probably going to be the rise in demand for air conditioning brought on by warmer weather.

Furthermore, a growing portion of electricity comes from renewable energy sources, which are especially susceptible to climate change (Vine, 2012). The planning and operation of energy systems depend on making decisions in the face of uncertainty, and one of the many variables in uncertainty is climatic variability. A range of models are used in energy systems planning and operation to assess how climate change affects these processes. Conventional energy analysis, on the other hand, assumes that climatic variables are stationary, which may actually lead to more uncertainty when making decisions within a framework for climate change (Kopytko & Perkins, 2011). Assumedly, those renewable sources will be more heavily impacted by climate change than fossil ones (Schaeffer et al., 2012). It is anticipated that future climate change will differ significantly amongst locations. Changes in the local temperature and precipitation patterns may significantly impact the architecture of our current and future electricity systems. All significant facets of the electric power industry, such as power generation, transmission and distribution networks and end-user demand are susceptible to weather and climatic fluctuations (CEEESA, 2019). (Figure 1)

The climate will suffer if we continue to build fossil fuel power plants to accommodate our expanding need for electricity. However, if we push AI to become more efficient—that is, to do more with less energy—and use the increased demand for electricity as a spur to shift our focus toward renewable energy and other low-carbon power sources, we may continue to gradually clean up the grid even as AI continues to permeate every aspect of our lives (Crownhart, 2024). While ML and other forms of AI are becoming more popular in supporting climate change estimates and impacts, there has been little research on the application of AI to climate change adaptation (Cheong et al., 2022). Adopting methods and technology that promote both climate change adaptation and mitigation is possible during this transformational process (EPA, 2011). The complexity of adapting to climate change derives from the need to balance trade-offs and synergies arising from the interdependencies between social-ecological systems and the sectors involved in adaptation. As the process of adjusting to current or anticipated climate change, adaptation is usually sector- or local-specific (Field et al., 2014), and it may ignore the transfer of climate hazards across regions and sectors (Challinor et al., 2018). AI technologies are not meant to replace human decision-makers. Instead, they contribute to raising human productivity (Sharma, 2023). The research community must create a comprehensive and operational understanding of the various ways that ML can influence mitigation and adaptation plans for climate change in order to explicitly and consistently account for ML in long-term climate and energy projections and the design of appropriate policies (Kaack et al., 2022). The majority of experts concur that concentrating on just four sectors—electricity, transportation, agriculture, and buildings—can have a significant impact on decarbonizing society. Only one is covered in this article: electricity. It is not meant to be a comprehensive analysis of AI's uses in the energy sector. While the article advocates using AI to reduce some of the low-hanging fruit that contributes to the issue of widespread greenhouse gas (GHG) emissions, it does not propose that AI can address climate change.

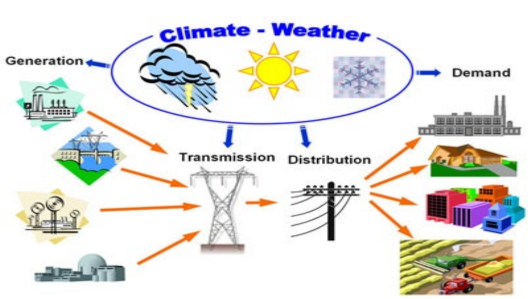

Figure 1: Climate impacts on power system Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)

2 Climate Change

One of the biggest problems (most significant ecological and social challenges) facing humanity in the twenty-first century is climate change. Numerous direct and indirect effects are caused by climate change. The consequences of climate change are becoming more apparent. The intensity and frequency of storms, droughts, fires, and flooding have increased. Other consequences follow from these acute impacts of climate change. Water scarcity and shortages brought on by drought have an impact on different industries and vital infrastructures. The production of energy in power plants will be adversely affected, for example, by a shortage of water for cooling reasons (Rübbelke & Vögele, 2011). As a result of human activity, the US National Climate Assessment found that the "earth's climate is changing faster than at any point in the history of modern civilization" (Reidmiller et al., 2017). Global ecosystems are changing, affecting agriculture and natural resources that are essential to human survival. The worst of its effects are probably yet to come; in the meantime, more pressing issues that fall into an election cycle tend to occupy center stage in politics. Experts in behaviour even point out that, as a kind of self-defense, people tend to downplay the worst threats facing society (Stein, 2020). It became evident by the end of the nineteenth century that changes in GHG concentrations in the atmosphere might alter the temperature of entire planets (Weart, 2008). Human activity has raised atmospheric concentrations of GHGs such as CO_2, methane, nitrous oxides, and chlorofluorocarbons since the Industrial Revolution, particularly from the mid-1900s. At the same time, Earth's surface reflectivity, or albedo, has decreased. Long-term weather patterns, encompassing temperature, precipitation, and storm frequency, are referred to as the climate. Long-term averages are changing as a result of modern climate change, and there is also increasing volatility around these averages, leading to an increase in the frequency of extreme events. Although the temperature on Earth has always fluctuated, the current changes are so significant and quick that they may exceed the planet's ability to adapt and force the climate and biosphere into radically unsettling patterns (Roesch et al., 2020). Mitigation, or cutting emissions, and adaptation, or becoming ready for inevitable effects, are two parts of addressing climate change. Both are complex problems. Modifications to land use, industry, buildings, transportation, and energy infrastructure are necessary to mitigate greenhouse gas emissions. Given our knowledge of the climate and catastrophic occurrences, adaptation necessitates preparation for resilience and disaster management. One can view the wide range of issues as a chance because there are numerous methods to make a difference

(Rolnick et al., 2022). Since the middle of the 20th century, human influence on the climate has dominated the observed warming, and "human influence has become a principal agent of change on the planet."

Along with changes in many other aspects of climate, the average temperature change is accompanied by sea level rise, ocean acidification, and other changes. These processes are interdependent with other global environmental changes (GECs) that negatively affect ecosystems and interfere with services that humans depend on, such as the loss of biodiversity, changes to biogeochemical cycles, and the broad dissemination of materials and chemicals (Steffen et al., 2018). There have been suggestions to name the current geological epoch the Anthropocene due to the magnitude of these changes, which means they will probably be seen in the geological record millions of years from now. From the local to the global, GECs and our responses to them will probably have a revolutionary impact on people and societies (IPBES, 2019). Research already conducted indicates that communities based on identity may have different goals and attitudes about climate change. It is also evident that the people who have contributed the least to global warming have the least sway over international policy and stand to lose the most from the effects of climate change. The sociology of climate change gains a normative component as a result of these realities, which raise moral and ethical concerns regarding how climate justice ought to be implemented (Harlan et al., 2015). Critical infrastructures are not the only ones that climate change directly threatens; downstream infrastructures may also suffer as a result of their aftereffects (Rübbelke & Vögele, 2011).

3 Electric Power Sector

One of the most important aspects of infrastructure is power, which is essential for national welfare and economic progress. The global energy system is significantly impacted by climate change, particularly the power sector, which is especially vulnerable and sensitive to climate change (Perera et al., 2020). All facets of the electricity system are immediately impacted by the physical concerns associated with climate change. Systems for the transmission and distribution of electricity may be impacted by changes in the potential and demand for power generation brought on by global warming. Severe weather phenomena like heat waves and floods will also physically harm energy assets (Vafadarnikjoo et al., 2022). The evolution of the electric power industry is thus indirectly impacted by the transition risks connected to climate policy. One of the main pillars of climate policy is the electric power industry, which has great potential for emission reduction (Sen et al., 2020). Given its ability to completely change sectors, artificial intelligence has been dubbed the "new electricity". Interestingly, one of the businesses that AI is expected to disrupt is the electrical sector. Data is permeating many electrical networks, and the sector is starting to imagine next-generation systems (smart grids) (Ng, 2017). A quarter of all GHG emissions that humans generate annually are caused by electricity systems. Furthermore, the need for low-carbon electricity will increase as structures, transportation, and other industries look to replace fuels that release greenhouse gases. In order to lower emissions from electrical systems, people must:

- Make a swift switch from carbon-emitting energy sources (including coal, natural gas, and other fossil fuels) to low-carbon sources (like solar, wind, hydro, and nuclear).
- Lower greenhouse gas emissions from the infrastructure are now in place for fossil fuels and energy, as the switch to low-carbon power happens gradually.
- These adjustments should be put into practice in all nations and situations because electrical systems are present everywhere (Change, 2014).

Using renewable electricity sources is crucial to combating global warming. There are two types of these sources: controlled and variable. Variable sources change according to outside conditions; for example, solar panels only generate electricity when the sun is shining, and wind turbines only generate electricity when the wind is blowing. Conversely, controlled sources such as nuclear or geothermal power facilities can be turned on and off (though not instantly) (Lokhov, 2011).

3.1 Variable sources

The majority of electricity is distributed to customers via a physical network known as the electric grid, in which the amount of power produced and consumed must always be equal (Aneke & Wang, 2016). This means that natural gas plants, storage, or other controllable sources are used to support solar panels, wind turbines, and other variable electricity generators so that they can withstand fluctuations in their output, such as sudden cloud cover or less wind than expected (Hittinger & Jaramillo, 2019). These days, natural gas and coal-fired power facilities that operate in a CO_2-emitting standby mode known as spinning reserve frequently supply this buffer. Future energy storage technologies, including batteries, pumped hydro, and power-to-gas, are anticipated to fill this function (Evans et al., 2012). Variable generation and demand for energy are both erratic. Thus, forecasting them in advance is necessary to guide both long-term system planning and real-time electricity scheduling. Improved short-term projections can help system operators manage the growing number of variable sources proactively and lessen their dependency on dirty standby plants. Improved long-term projections can assist investors and system operators in deciding where and when to build variable plants (Anderson et al., 2018).

3.2 Controllable Sources

Since today's fossil fuel power plants are also controllable, achieving climate change targets with controlled low-carbon electricity sources can be accomplished with little adjustments to the electric system. Numerous regulated low-carbon technologies, such as nuclear fission, geothermal, and (in certain situations) dam-based hydropower, are already offered for sale. Methane may be created by dam-based hydropower, mostly from biomass that breaks down during a hydro reservoir flood, though the quantity produced differs throughout power facilities (Steinhurst et al., 2012). Multi-objective optimization has also been utilized in earlier research to locate hydropower dams in a way that meets ecological and energy objectives. Lastly, by anticipatorily identifying problems from high-dimensional sensor and simulation data, or by finding cracks and anomalies from image and video data, ML can aid in maintaining nuclear fission reactors or nuclear power plants (Wu et al., 2018). With an almost infinite supply of hydrogen fuel, nuclear fusion reactors have the potential to generate safe, carbon-free electricity; yet, at the moment, their energy consumption exceeds their energy output (Cowley, 2016). Even if there is still a great deal of research to be done in science and engineering, ML can assist in accelerating this process by, for example, directing experimental design and tracking physical processes. Fusion reactors have many tunable characteristics thus their experimental design needs to be carefully considered (Humphreys, 2020).

4 Electric Power Sector in India

India has one of the world's most diverse electricity industries. For the Indian economy to grow steadily, sufficient electrical infrastructure must exist and be further developed. The provision of reasonably priced power to all people in an environmentally sustainable manner has been the cornerstone of India's power sector. Over the last few years, the Ministry of Power has worked hard to achieve universal household electrification, strengthen the distribution network, and create a unified national grid in order to transform the nation from one experiencing a power deficit to one experiencing a surplus (Central Electricity Authority, 2024). Power generation can come from a variety of sources, including feasible non-conventional sources like wind, solar, agricultural, and household waste, as well as conventional sources like coal, lignite, natural gas, oil, hydro, and nuclear power. The nation's need for electricity has grown quickly, and this trend is predicted to continue in the years to come. Massive additions to the installed production capacity are needed to keep up with the nation's growing demand for electricity (Power Industry Report, May 2024). As of January 31, 2024, India ranked third in the world both in terms of electricity production and consumption, with an installed power capacity of 429.96 GW. India had 182.05 GW of installed renewable energy capacity (including hydro) as of January 31, 2024, accounting for 42.3 percent of the country's total installed power capacity. Solar energy accounted for 82.63 GW of total energy as of April 30, 2024. Wind power accounted for 46.16 GW, biomass for 10.35 GW, small hydropower for 5.00 GW, waste to energy for 0.59 GW, and hydropower for 46.93 GW. The increase in non-hydro renewable energy capacity was 15.27 GW in FY23 compared to 14.07 GW in FY22. In FY23, India's power generation saw its fastest growth rate in more than 30 years. By January 2024, India's power generation has grown by 6.80 percent to 1,452.43 billion kWh. India consumed 1,503.65 BU of power in April 2023, according to data from the Ministry of Power. January 2024 had a peak power consumption of 243.27 GW nationwide. For the first nine months of FY23, the coal plants had a PLF of 73.7 percent up from 68.5 percent during the same period in FY22. The load on thermal power plants is predicted to increase by 63 percent in FY24, driven by both robust demand growth and moderate capacity addition in the industry (Power Industry Report, May 2024).

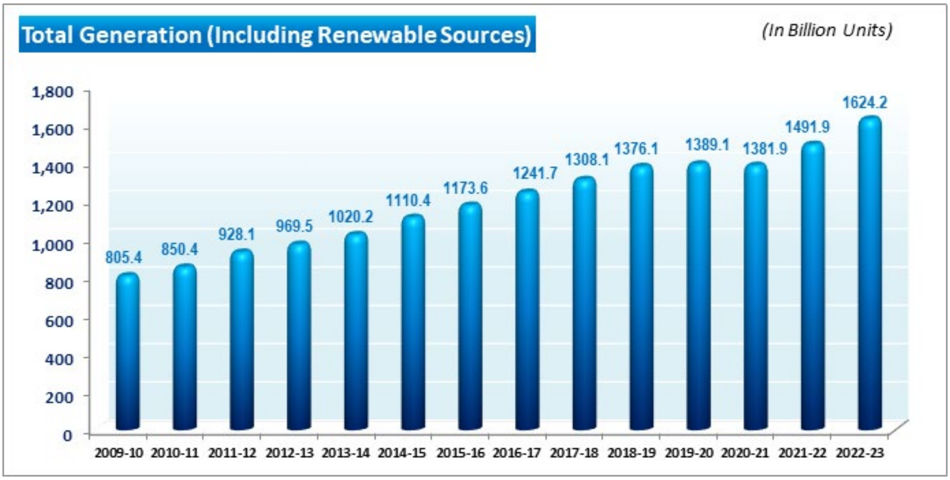

Figure 2

Source: Government of India: Ministry of Power

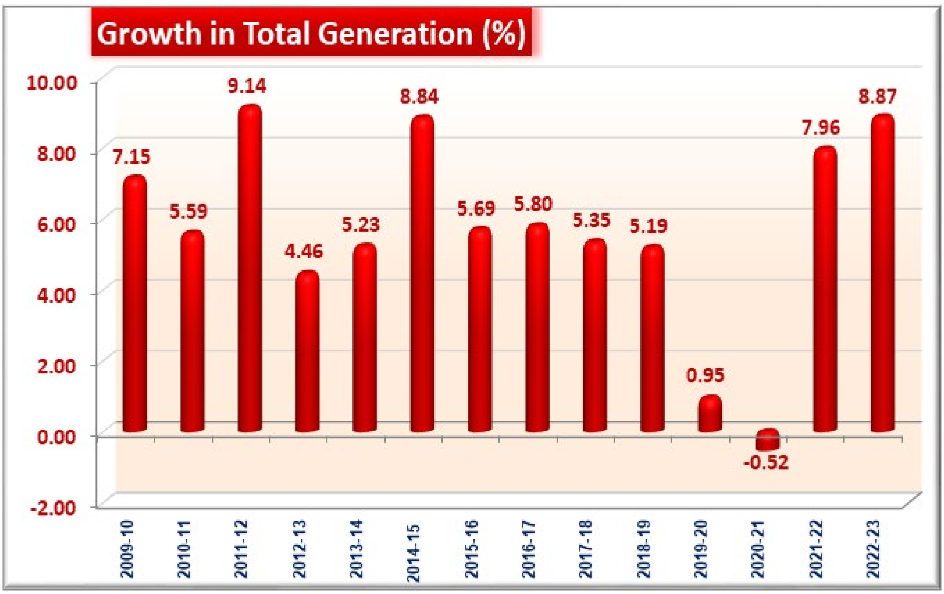

Figure 3

Source: Government of India: Ministry of Power

4.1 Electricity generation by the electric power sector in India

- Installed Capacity: As of April 30, 2024, India's installed power capacity stands at 442.85 GW.
- Renewable Energy: As of January 31, 2024, India's installed renewable energy capacity (including hydro) was 182.05 GW, accounting for 42.3 percent of the overall installed power capacity.
- Non-Hydro Renewable Energy: The addition of non-hydro renewable energy capacity stood at 15.27 GW in FY23, up from 14.07 GW in FY22.
- Thermal Power: Thermal power plants registered a Plant Load Factor (PLF) of 73.7 percent for the first nine months of FY23, compared to 68.5 percent in FY22 for the same period.
- Hydro Power: Hydro power generation capacity stood at 46.16 GW as of April 30, 2024.
- Nuclear Power: India's nuclear power capacity is expected to rise from 7,480 MW to 22,480 MW by 2031.
- Coal Crisis: The recent coal crisis has raised concerns, as over 60 percent of electricity produced in India is derived from thermal power plants, which rely on coal. In 2021, the industrial sector accounted for the largest share of electricity consumption (43.9 percent).
- Electricity Generation Targets: The government has set a target of 1750 BU (billion units) for electricity generation in 2023-24, comprising:
  - 1324.110 BU Thermal;
  - 156.700 BU Hydro;
  - 46.190 Nuclear;
  - 8 BU Import from Bhutan;
  - 215 BU RES (excluding hydro).
- Growth Rate: Electricity generation in India has grown steadily over the past decades, with a growth rate of around 7.2 percent over the previous year (2022-23).
- State-wise Capacity: As of October 31, 2023, the state-wise installed power generation capacity in India is:
  - Dadra and Nagar Haveli and Daman and Diu: 46.47 MW (100 percent renewable)
  - Jammu and Kashmir: 3751.41 MW (95.33 percent renewable)

  - Andaman and Nicobar Islands: 127.87 MW (27.50 percent renewable)
- Foreign Direct Investment (FDI) in the Power Sector:
    - Total FDI inflows in the power sector: US$ 18.28 billion (April 2000-March 2024).
    - Renewable energy sector: US$ 6.1 billion (April 2020-September 2023).
    - Solar energy sector: US$ 3.8 billion (April 2020-September 2023).

5 Electric Power Sector and Climate

For human existence, well-being, and sustainable development, electricity is necessary. The zones of prosperity—those with access to electricity—are depicted in night-time images of the planet. About 20 percent of people on the planet, however, still live in the dark and lack access to running water, computers, lighting, refrigerators, and quality education (Berga, 2016). As one of the largest industrial systems in the world, the electric power industry need a particular operational strategy to be run effectively: a dedication to highly structured, interconnected, authoritarian systems. This makes it an embodiment of a unique sociotechnical structure that is likely to attract, reward, and retain energy professionals whose character traits enhance and support these underlying systems (Kahsar, 2019). Climate change can have direct implications on energy supply and demand, but it can also have indirect consequences through other economic sectors or affect several other components of the energy sector, like energy transportation and infrastructure (Schaeffer et al., 2012). Extreme weather events' frequency, severity, and duration have a major impact on human life and productivity. The electric power industry is the backbone of the economy and a major contributor to climate change adaptation and mitigation. Thus, in light of climate change, it is imperative that the stable power sector manage various climate change risks and enhance their climate change resilience. The risk management framework should incorporate climate change risks in order to improve the ability of electric power to respond to changing climate conditions (Sun et al., 2023). To provide certain energy services, energy resources must be transformed into final energy sources. Climate change can have a range of effects on energy transformation facilities, which can impact the system's ability to provide consumers with energy. Since the effects of global climate change are expected to manifest themselves in the mid to long-term, climate impact analyses need to factor in the likelihood that a significant portion of the current energy system, including those being built now or in the near future will continue to function when the new climate conditions materialize (Schaeffer et al., 2012). In addition to the existing generation capacity, the variability of water inflows to the power plants' reservoirs determines how much electricity can be produced by hydropower plants. The design and functioning of hydropower systems are already significantly impacted by natural climatic variability. Climate change may have an impact on how well the current hydroelectric system functions and might jeopardize the feasibility of future business ventures (De Lucena et al., 2009). The effects of climate change on the energy system are not limited to the supply side because changes in temperature and precipitation patterns can also have an impact on final energy consumption. In the upcoming ten years, climate risk will continue to be the most significant worldwide risk, making it imperative to mitigate and adapt to global climate change (WEF, 2022). Reaching the new Sustainable Development Goals (SDGs) by 2030 is a challenge facing humanity today. To direct development efforts, these objectives form a sustainable development agenda.

6 Mitigation and Adaptation

Among the most complicated challenges of our day is climate change. This crucial topic is centered on mitigating and adapting to climate change in electrical power infrastructure and energy systems (Arabnya, 2024). There are two different kinds of responses to climate change: adaptation and mitigation. Regarding climate change mitigation, the electric power industry has received a lot of attention, but not when it comes to climate change adaptation. The industry is accountable for over one-third of the nation's greenhouse gas emissions; nevertheless, there are numerous options for mitigating its impact. The adaptation-related characteristics of these mitigation options differ significantly, including their reliance on water resources that are anticipated to become scarcer due to climate change, their susceptibility to disasters linked to climate change, and their effects on the environment outside of climate change (Ebinger & Vergara, 2011). The goal of mitigation is to reduce greenhouse gas emissions and atmospheric concentrations of these gases. The goal of adaptation is to help natural and human systems adapt to a world with a changing climate. Both mitigation and adaptation aim to lessen the impact of climate change by lowering the rate at which the climate changes and the amount of harm that results from it. Climate change policy has frequently treated adaptation and mitigation separately despite the fact that they are interconnected (McAllister, 2011). Mitigation and adaptation have often inhabited various policy areas and followed different policy trajectories for a wide range of causes. All things considered, mitigation has received far more attention than adaptation. Proponents of climate change policy believed that mitigation was a better response than adaptation and that, with careful consideration, adaption could be avoided (Arabnya et al., 2024).

7 Artificial Intelligence / Machine Learning

AI is available in a wide variety of formats and AI is a more general term that includes ML. The most widely used type is ML, a prediction-making technique that works best with enormous volumes of data and processing power (Stein, 2020). There has been a spike in interest in discovering how ML, and specifically AI, may affect climate action as ML is increasingly used in society (Zhang et al., 2021). The research community must create a comprehensive and operational understanding of the various ways that ML can influence mitigation and adaptation plans for climate change, both positively and negatively, in order to explicitly and consistently account for ML in long-term climate and energy projections and the design of appropriate policies. Specifically, the effects that are most likely not to have the most significant consequences are probably not the easiest to assess. This may make it challenging to estimate macro-scale effects, identify underlying dynamics and trends, and prioritize activities that will best integrate ML with climate policies (Kaack et al., 2022). By assisting in the advancement of critical technologies (forecasting, scheduling, and control) and in the creation of sophisticated electricity markets that can handle both variable electricity and flexible demand, ML can help both lower emissions from today's standby generators and facilitate the switch to carbon-free systems (Ahmed et al., 2020). Although a lot of system operators still rely on simple forecasting methods, in order to serve these use cases, predictions will need to be more precise, cover a broader range of time and space, and more accurately measure uncertainty (Das et al., 2018). ML is helpful in each of these aspects. Numerous ML techniques have been used to the supply and demand of energy to date. In order to produce short- to medium-term forecasts of solar power, wind power, "run-of-the-river" hydropower, demand, or more than one of these at aggregate spatial scales, these methods have utilized historical data, physical model outputs, pictures, and even video data (Perera et al., 2014). These techniques cover fuzzy logic, hybrid physical models, and supervised ML techniques of all kinds. They also differ in how they quantify—or do not quantify—uncertainty. Some studies have sought to understand certain categories of demand at a more spatially granular level, for example, by utilizing game theory, optimization, regression, and/or online learning to disaggregate electricity signals or cluster households (Elkin & Witherspoon, 2019). Future ML algorithms will need to account for domain-specific knowledge. For example, as weather is a primary driver of both variable generation and energy consumption, ML algorithms that estimate these quantities should leverage advances in hybrid physics-plus-ML modeling techniques, weather forecasting, and climate modeling. Since weather distributions change over time, these methods can help short- to medium-term forecasts and are also essential for ML to contribute to longer-term (e.g., year-scale) forecasts (Voyant et al., 2017). ML has the potential to enhance the current centralized scheduling and dispatch process by increasing the speed at which power system optimization issues are resolved and the caliber of optimization solutions. For example, ML can be used to discover redundant restrictions, uncover excellent starting points for optimization, identify current optimization problems and/or simplify them, learn from the actions of power system control experts, or a combination of these (Fioretto et al. 2020). Recent research has examined ways to (at least partially) decentralize scheduling and dispatch utilizing energy storage, flexible demand, low-carbon generators, and other grid-connected resources, even though many modern electrical systems are centrally controlled (Dobbe et al., 2019). Variable power generation can be advanced by machine learning in numerous other ways. As an example, it is critical to ensure that variable low-carbon generators generate energy as profitably and efficiently as feasible (Reisi et al., 2013).

7.1 Artificial Intelligence and Climate Change

ML has gained popularity recently as a widely effective method for advancing technology. The need for a concentrated effort to determine how these technologies may be most effectively used to address climate change persists, despite the expansion of movements using ML and AI to solve issues of social and global benefit. Many ML practitioners want to take action but do not know how. Conversely, numerous domains have initiated proactive efforts to obtain feedback from the ML community (Berendt, 2019). The usefulness and applicability of ML approaches to advance our comprehension of local and global settings have been hotly debated in the scientific community. Predictive and probability-based computations are made possible by ML, and these are helpful tools for assessing the advantages and disadvantages of our current course of action. Understanding the benefits and drawbacks of contemporary ML methods helps anyone working in climate research to better comprehend and critique published data and conclusions

(Beardmore, 2022). Microsoft's AI for Earth Programme is one emerging commercial platform that uses ML to address climate change. It was established in 2017 with the goal of awarding 200 research grants totaling $50 million to initiatives that use AI to mitigate environmental damage (Geoff, 2018). Researchers and scientists can directly allow for enhanced transparency and critical analysis by sharing data, techniques, and results using Microsoft's platform and interface. The idea is to draw specialists together to establish a collaborative environment that will lessen the effects of climate change. Additional projects are the Climate Science for Service Partnership China and Climate Change AI, which are cooperative science projects between academic institutions (Scaife et al., 2021). AI technologies have demonstrated their efficacy in improving legacy systems and simplifying intricate business processes. AI has the potential to change a number of "clean tech" domains, including the efficiency of freight transportation, the design of environmentally friendly structures, and sustainable supply chains (Demianchuk, 2019).

7.2 Electric Power Sector Mitigates Climate Change Through AI

The Electric Power Sector can play a significant role in mitigating climate change through the application of AI. Here are some ways AI can help:

– **Predictive Maintenance**: AI-powered predictive maintenance can help reduce energy losses and emissions by identifying potential issues before they occur, allowing for proactive maintenance and reducing the need for backup fossil fuel-powered plants (Moulin, 2018).
– **Smart Grids**: AI can optimize the smart grid by analyzing energy demand and supply in real-time, enabling utilities to manage energy distribution more efficiently and reducing the likelihood of blackouts. AI-enabled smart grids can monitor and control energy distribution in real-time, allowing utilities to respond quickly to changes in demand and supply, reducing waste and minimizing emissions (Sumeet, 2022).
– **Energy Efficiency**: AI can help optimize energy consumption by analyzing energy usage patterns and providing personalized recommendations to consumers, reducing energy waste and emissions (Kamya Choudhary, 2022).
– **Renewable Energy Integration**: AI can help integrate renewable energy sources into the grid by predicting energy demand and supply, ensuring a stable

and efficient energy supply. AI can optimize the integration of renewable energy sources, such as solar and wind power, into the grid, providing a stable and reliable supply of clean energy (Sumeet Singh, 2022).

- **Climate Modeling**: AI can help improve climate modeling by analyzing large datasets and identifying patterns and trends, enabling more accurate predictions and better decision-making (Moulin, 2018).
- **Energy Storage**: AI can help optimize energy storage systems, enabling utilities to store excess renewable energy for later use, reducing the need for fossil fuels, and decreasing emissions (Anjali Raja, 2022).
- **Demand Response**: AI-driven demand response systems can adjust energy consumption in real-time to match supply, reducing the need for peaker plants and associated emissions (Anjali Raja, 2022).
- **Grid Optimization**: AI can optimize grid operations to reduce energy waste, lower peak demand, and increase the integration of renewable energy sources, thereby decreasing emissions (Moulin, 2018).

7.3 Challenges and Concerns

- **Energy Consumption**: AI-powered data centers and equipment require significant amounts of energy to operate, which can lead to increased emissions and energy consumption, which can offset the environmental benefits of AI applications in the Electric Power Sector.
- **Carbon Footprint**: The production and disposal of AI-powered devices and infrastructure can have a significant carbon footprint. The production and transportation of AI systems and equipment also contribute to emissions.
- **Climate Misinformation**: AI can be used to spread misinformation about climate change, which can undermine efforts to mitigate its effects.
- **Misinformation and Bias**: AI can perpetuate or amplify climate misinformation and biases, hindering effective climate change mitigation efforts.
- **Climate Change Risks**: The Electric Power Sector is vulnerable to climate-related risks such as extreme weather events, droughts, and heat waves, which can impact operations and infrastructure.
- **Economic Opportunities:** The transition to a low-carbon economy presents significant economic opportunities for the Electric Power Sector, including job creation, investment, and growth.

- **Policy and Regulation:** Strong policy and regulatory frameworks are necessary to support the transition to a low-carbon economy and ensure a level playing field for all stakeholders.
- **Finance:** Availability of project finance (India, Climate Action Taker, 2023).

7.4 Indian Government Initiatives

- PM-Surya Ghar: Muft (Free) Bijli Yojana – aims to install rooftop solar systems and offer complimentary electricity to one crore (ten million) households.
- Loan approval from the World Bank to improve electricity supply efficiency and reliability.
- Increased funding for domestic solar cells and module manufacturing under the PLI scheme.
- Building Energy Efficiency Programme (BEEP) by Energy Efficiency Services Limited (EESL) (Nidhi Bhardwaj, 2022).

7.4.1 Future Outlook

India's power sector is expected to continue its transition towards cleaner energy sources, with a focus on renewable energy and energy efficiency. The government's initiatives and policies will play a crucial role in achieving this transition. The sector will need to address the challenges mentioned above to ensure a smooth and sustainable growth trajectory. To address these challenges, the Electric Power Sector must prioritize transparency, energy efficiency, and responsible AI development and deployment practices. By doing so, AI can become a valuable tool in the fight against climate change, rather than a hindrance. While AI has the potential to play a significant role in mitigating climate change in the Electric Power Sector, it is essential to consider the challenges and concerns associated with implementing it. By addressing these challenges and ensuring that AI is developed and used responsibly and sustainably, the Electric Power Sector can help reduce its carbon footprint and contribute to a more sustainable future.

8 Conclusion

The problem of climate change will continue to impact civilization dramatically. Although people are becoming more conscious of the issue, we have not yet, as a species, taken the extreme measures required to reduce our carbon emissions. Over the next few decades, there will be significant changes in the electric power industry. The industry is likely to face regulatory pressure to reduce its emissions because it is a significant generator of greenhouse gases. The substantial effects of climate change will also become more evident over time, prompting a variety of adaptation strategies. AI is anticipated to be the smart grid's brain in the future. For the purpose of making prompt judgments about the most effective use of energy resources, the system will continuously gather and combine massive volumes of data from millions of smart sensors across the country.

Additionally, the supply and demand sides of the energy economy will undergo a revolution because of the developments made in "deep learning" algorithms, a method in which computers learn by identifying patterns and anomalies in massive data sets. Large regional networks will, therefore be replaced by specialized microgrids that can more precisely handle local energy needs. When combined with innovative battery technologies, these provide uninterrupted power supply to and from nearby areas, even in the event of severe weather or other power system disruptions. We find it challenging to act on climate change because it is a cognitively daunting phenomenon. As it happens, our environment and genes have hardwired us to continue with business as usual and to respond to threats that are both more tangible and more pressing than this intangible, abstract being. In an effort to encourage people to take action and have an influence, we are using current advancements in artificial intelligence to make the effects of climate change more tangible and relatable. The main advantage of ML is that it makes it possible for us to classify, simplify, and forecast using incredibly complicated datasets. Global monitoring and mobilization are made possible by the ability to analyze data at bigger spatial and temporal scales in order to make observations on intricate processes. Looking ahead, cloud computing's efficiency are driving down the cost of processing power and data storage, making ML an increasingly attractive tool for data analysis.

Furthermore, the increasing application of ML techniques to address climate change is made possible by a significant rise in data availability, which is driven by many resources like the Internet of Things and crowdsourcing methods. The final effects of ML on the climate are not set in stone, and society's choices will have a significant influence on how it plays out. In order to mitigate the effects of use cases that can run counter to climate change aims and encourage the use of ML in support of climate change strategies, a comprehensive portfolio of techniques spanning policy, industry, and academia will be needed. Above all, society needs to take action immediately since there is a unique opportunity to influence ML's effects for many years to come. This is because ML is becoming increasingly common, and climate change is becoming a more pressing issue. The limitations of AI must be recognized and moderated. AI and ML have shown to have great promise for changing our society, including the ways in which we work, live, and consume. These potent instruments will undoubtedly play a critical role in the international effort to stop catastrophic climate change in the years to come. AI must be incorporated into the plan. We want to be clear that ML is not a panacea. Though the applications we showcase are significant, there no single solution that can "cure" climate change. Ultimately, technology cannot address climate change on its own or take the place of other components of climate action, like policy. Although many helpful technology techniques for combating climate change have been around for a while, society has not yet embraced them widely. Although we expect ML can help expedite successful climate action initiatives, mankind must still decide to take action.

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End Notes

With major ramifications for energy efficiency, grid optimization, and carbon footprint reduction, the use of AI in the electric power industry is developing quickly. These applications are examined in this research within the framework of mitigation methods for climate change. Using insights from recent developments in AI, such as machine learning, predictive analytics, and automated decision-making systems, the study highlights the relationship between technology and sustainability. The legitimacy and validity of the results are guaranteed by the fact that the data and case studies used in this research were taken from peer-reviewed, publically accessible sources. This study's reliance on data availability and the variation in AI adoption across businesses and geographical areas are two major limitations.

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Povzetek v slovenskem jeziku

Ocenjevanje in usmerjanje posledic umetne inteligence (UI) in strojnega učenja (SU) ostaja prisotno v našem vsakdanjem življenju in vključuje skupna prizadevanja akademikov, politikov in industrije z nedvoumnim vplivom na sedanjost in prihodnost. UI ima sposobnost izboljšati rezultate, povečati produktivnost ter izboljšati natančnost in učinkovitost številnih plati družbe, ki so odvisne od verjetnosti in napovedi. V povzetku, njena uporabnost z največjim potencialom bi se lahko pokazala pri tistih izjemno zapletenih tehnoloških izzivih, ki so zunaj dosega človeških zmožnosti, in ne pri takšnih uporabah, ki vplivajo na civilne svoboščine in socialno strukturo naše družbe. Eden izmed takih zapletenih problemov so denimo podnebne spremembe, ki zahtevajo znatne prilagoditve v gradbenem, energetskem, prometnem in kmetijskem sektorju. Da bi zagotovili natančnejše napovedi prihajajočih vremenskih pojavov, zlasti ekstremnih razmer, lahko tudi razširi odkritja o podnebnih povezavah. Članek kritično obravnava vse večjo uporabo umetne inteligence prek sektorja električne energije v Indiji.