AI and Climate Change: Opportunities and Challenges

Abstract: *Global warming presents an alarming burning issue affecting the climate through heat buildup, frequent natural occurrences, and the gradual rise of the ocean's water levels. Climate change scientists of the Intergovernmental Panel on Climate Change (IPCC) have predicted drastic impacts when the emission of greenhouse gases is not reduced. Global warming is a result of activities such as fossil fuel combustion and deforestation by the human beings hence worsening environmental and societal effects. By attempting to limit global warming the Paris Agreement requires drastic social changes which are unparalleled. Climate Change presents innovation through Advanced AI in climate models, efficient energy management and utilization of machine learning, deep learning and data analytics in disaster risks, agriculture and distribution. AI also refines climate forecast and tracks climatic shifts, and optimizes usage of power that results in significant cuts in greenhouse gases and the adaptation to climate. There is a set of issues that must be solved before AI deployment in climate action: data privacy, algorithmic and environmental bias. AI requires strategic integration into the national policies, interdisciplinary approaches, and building capacities for achieving the optimum result. It is a must to fund the development of AI technologies through research & development, collaboration between the public and private sectors, and global cooperation. Ethics for AI implementation, fairness, and evaluation of effects are significant for climate change solutions' sustainability. To this end, this paper aims at reviewing the literature on the application of AI in managing climate change and identify opportunities, risks, and ethical issues. This research underlines a few strategic approaches and recommendations regarding the AI application in achieving climate resilience and sustainability, thus creating a basis for a safe and prosperous future.*

Keywords: Artificial Intelligence, Climate Change, climate modeling, environmental sustainability.

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1. Introduction

The urgency to address climate change has never been more critical. This scenario makes it a time of even greater seriousness to address the problem of climate change. Regarding the climate change effects, temperatures in the whole world are increasing, and the frequency and intensity of extreme life events, and global sea level continues to rise. The Intergovernmental Panel on Climate Change (IPCC) stress on the fact that the global community may be on the path to warming of more than 1°C that too an average global increase in temperature of 5°C with associated atrocious and even irreversible impacts. Climate change has been caused mainly by activities which are as a result of man and these include burning of fossil energy, tree felling and industries processes that emit greenhouse gases to the atmosphere. This has resulted in global warming and the average temperatures of the surface rising by about 1°C. Each one would be incrementally close to 2°C rising from the late 19th century[1]. Consequences of this warming can be seen through the rising trends in the intensity and occurrence of storms including hurricanes, lack of rainfall, heatwaves, and floods. Such events lead to the near-instantaneous devastation and influence the affected ecosystems, economics, and health of populations in the long run. Such factors provide the rationale for new approaches to the prevention of climate change and to adaptation to its impact.

It highlights the significant impact of climate change on both economic and social aspects. For examples, flooding destroys the major crops and this will lead to shortage of food and high

[1] What's the Difference between 1.5°C and 2°C of Global Warming?" Reuters, November 7, 2021, https://www.reuters.com/business/cop/whats-difference-between-15c-2c-global-warming-2021-11-07/

food prices. Coastal areas with population and business are at risk, where sea level begins to rise, it forces people to move and lose businesses. The effects in relation to human health, such as the risks of acute heat and other environmental impacts, together with vector-borne diseases, that are more common to the vulnerable communities would be intensified. Solving these problems implies the use of the concepts of risk preparedness, management, prevention, and adaptation. Today international overlays, including the Paris Agreement, are the key for the world in the struggle against climate change. The contemporary international climate regime is the Paris Agreement adopted in 2015 to prevent global warming with a long-term target of below 2°C, with the aspiration of limiting it to 1. 5°C. Over one hundred and ninety countries have signaled their willingness to cut down on their emissions of greenhouse gases and also increase their coping capability. However, this aim presupposes three key transformations in all sectors of society at short, never seen before turnover rates in energy, transportation, manufacture and land-use.

In this regard, it is essential to unveil those possibilities, and one of the most promising directions is Artificial Intelligence, abbreviated as AI. Machine learning, deep learning algorithms and data analytics are part of AI that have the ability to work through large data, outlining patterns and predict outcomes with high efficiency. All these can be applied to advance climate simulations and projections, design and operate energy efficient and resilient systems, reduce risks from natural hazards, and increase food production sustainably, among others. AI can help to enhance the accuracy and the detail of the climate models and adaptations predicting changes in climate in the future. For instance, algorithms can be used to review satellite data in regards to deforestation, ice situation, and moreover, severe weather conditions. They can help the policymakers and scientists to understand the picture of climate change and its

responses giving those strategies for its mitigation and adaptation.

In the energy sector, AI can play the role of applying proper mixes of renewable energy sources into the grid, efficient energy use, and low emissions. Essentially, smart grids with the help of artificial intelligence can control the demand and supply for electricity, minimize wastage, and enhance the dependability of power networks. So the AI solutions can likely be applied to the problems of energy-efficient architecture, transportation, and manufacturing, which all will result in cutting important volumes of greenhouse gases. The use of AI is crucial in climate adaptation within disaster risk reduction, water management, and in agriculture. For example, to such applications as prediction of crop yields and productivity, irrigation systems optimization, soil management in cases of climate change, AI can be of significant use for farmers and thus help increase the food security. The possibility of automated systems to send early warning to natural disasters to ensure people are ready for the shock is a possibility. However, similar to any other application, the use of AI for mitigating climate change also has its own challenges and ethical issues. This is because there are concerns that should not be ignored when it comes to the application of AI including; data privacy, the algorithms used, and the effects on the environment that artificial technologies produce. For the positive impact of AI solutions to be achieved while the negative impacts are contained, it is important that there is fairness in its applications, that the processes are clear to users and that the utilization of artificial intelligence is sustainable.

2. Thesis Statement:

AI has a lot to offer to climate action if the best practices are promoted and enforced throughout the process, but there is a need to advance strategic and systematic approach which focuses on the research, collaboration, ethics, and equity.

Therefore, by embracing the laid down recommendations and action points, stakeholders can enable the use of AI to enhance fight against climate change.

3. AI Technologies for Climate Change Mitigation

Machine Learning (MI) facilitates introspection of extensive and heterogeneous data from satellites, weather station and others in order to detect and forecast climate data. Satellites deliver real-time and extensive information in many geological processes, weather conditions, and climate changes of Earth's surface, water temperatures, and even icy covering. AI algorithms are capable of analyzing this data in real time and independently recognize various patterns and changes and reveal considerable climatic shifts, although this is not the primary use of AI at this level. For example, machine learning and deep learning are used in this case to assess satellite images and identify, for example, deforestation, increasing urbanization, and other changes in land use, which leads to the formation of greenhouse gases. Such knowledge is valuable in the formulation of policies and utilization of measures in emission reduction and habitat protection. Also, such functions can combine data from various sources such as ground sensors and weather stations to offer a broader perspective of climate behavior.

Traditional or classic climate models and scenarios make use of differential equations that simulate the relations between the Earth's atmosphere, water, land, and ice. As useful as these models have been for progressing knowledge on climate change, they still have downsides in regard to spatial scale and computing resource use. AI can work to further advance climate modeling because these simulations can be made more accurate and detailed. AI solutions can have large repositories containing historical data on weather, which can improve results of prognosis on future climate conditions. Other benefits of

using machine learning models include; the ability to establish correlations that are not easily discernible with the normal modeling paradigms. For instance, AI makes it easier to predict extreme weather conditions such as hurricanes, heatwaves, and heavy rainfall by looking at the trends in the weather patterns and current climate. AI can be used in some ways in mapping the global climate simulation models to regional and local scales in order to give a detailed and practical results for a given region. It is especially true for the identification of the climate change adaptation measures at the local levels and in agricultural management, water resources, and urban planning where climate details are crucial for decision-making.

Enabling More Effective Adaptation and Mitigation Strategies

In climate change adaptation and mitigation, AI technologies contribute to helping people make precise decisions with up-to-date information. In respect to adaptive measures, use of AI can help in culturing early warning systems to warn communities about natural disasters such as floods, storms and droughts. Such systems can estimate the occurrence and severity of such events and recommend ways of limiting the consequences and improving the powers. As for the prevention, AI can use and save energy in various sectors and lessen the emission levels. For instance, AI can improve the effectiveness of renewable energy sources by forecasting the energy generation from solar and wind and how they can best be integrated with the power network. The use of smart technologies based on artificial intelligence can help to regulate the electricity consumption and therefore, supply demands to eliminate the loss of energies and the instability of the network.

Furthermore, in a way that can make a huge impact on sustainability, AI can help to implement the best practices of irrigation, fertilizers and pest control. AI based precision agriculture practices can enhance productivity of crops and

resources and secure food production in the context of changing weather conditions. In the transportation sector, transport AI can contribute toward the concept of smart transport with virtues of less traffic, more fuel efficiency and positive impact towards the use of electric cars. Such systems can in particular learn traffic flows and subsequent routes and the functioning of transport systems which can therefore be improved in order to cause less emissions and therefore enhanced air quality.

Optimizing energy and resource use in the built environment

Smart buildings epitomize use of AI to optimize energy use and in turn increase resource utilization. These buildings incorporate AI to control and address a myriad of facilities like Heating, Ventilation and Air Conditioning (HVAC), illumination, and security. For instance, AI can prompt an evaluation of the occupancy level, weather information and energy consumption status so that it can control the HVAC systems in a way that energy is used optimally. Amsterdam's Edge building shows how the integration of AI-based systems can result in serious energy reduction. The building adapts the lighting and the heating/cooling depending upon the occupancy and the weather data which is about 70 percent less than the conventional building.[2] Intelligent structures that are built with AI can optimize their performance using past data for energy usage. With the help of machine learning, patterns in energy usage begin to show in addition to recommendations regarding alterations in how the building is run, which, in turn, causes ongoing optimization of the building's energy consumption. For example, Google's DeepMind AI managed to decrease the energy consumption for cooling their data centers by 40% using

[2] Xing, B., and J. Gao. "Artificial Intelligence for Smart Manufacturing." In Big Data Analytics for Cyber-Physical System in Smart City, edited by J. Gao, 159-183. Cham: Springer, 2018.

the principles of machine learning, which shows possibilities for saving energy in the built environment with the help of AI.

AI can also be used in maintaining low energy and water consumption in other associated infrastructure systems. Due to advanced features, smart grids, which is backed up by AI, can help manage the distribution along with usage of energy of large cities or even regions. The smart grids are capable of forecasting the energy requirements, managing the supply and demand in a better manner and incorporating the renewable forms of energy like the solar and wind energy. [3] Through AI control of energy and values, smart grids can minimize energy losses and support the stability and effectiveness of the energy supply system.

Other than energy, AI is useful in the conservation and management of water in the urban and agricultural practices. An example of smart irrigation is the use of AI to determine the most appropriate time for irrigation from data of soil moisture, weather prediction, and crop health. This in a way helps to apply enough pressure to water usage so that one is cautious and does not waste the valuable resource. A research conducted by the International Water Management Institute showed how the AI-based irrigation aided in cutting the water use by one-third and getting better or similar crop yields.[4] Not only this, AI can support users in finding out the leaks and inefficiencies in water distribution networks. It is found that by using sensors and meters' data analyzed by the AI algorithms, pattern of leakages or other problems can easily be detected. Thus, an important aspect of water conservation is achieved, in addition to saving

[3] International Energy Agency. Digitalization and Energy. Paris: International Energy Agency, 2019.

[4] Aksay, S., and S. Farahani. "Water Resources Management Using Artificial Intelligence." In Artificial Intelligence in Water Management, edited by S. Farahani, 1-23. Cham: Springer, 2020.

energy for water treatment and transport which is also a part of resources.

Sustainable agriculture practices

The use of AI in agriculture brings the improvement of sustainability of farming practices since there is an analysis of data concerning the yield capacity, the state of the ground, and climatic conditions. For example, the application of AI to satellite images and sensors to analyze crop health and growth in real-time. This allows farmers to monitor signs of diseases and pests, low nutrients in the soil, and other signs of water scarcity among others in advance. A case by the International Food Policy Research Institute showed that the use of AI in analysis of crop yield could increase accuracy by 20% as compared to normal assessment.[5] It can diagnose the condition of the soil by relying on information that it gets from moisture content, nutrient and pH sensing devices that are installed in the soil. Such knowledge assists the farmers in ascertaining the exact requirements of the soil and make suitable choice regarding fertilization and irrigation. For instance, Watson Decision Platform for Agriculture from IBM combines the data of the weather forecast with the data of soil and crops and gives farmers the useful recommendations, in order to increase productivity and make it more sustainable.[6]

AI applied in various smart instruments like precision agriculture, farmers can control the quantity and quality of inputs including water, fertilizers, and pesticides. It enables the provision of suggestions to farmers, depending on current data and anticipated outcomes, so that required amounts of inputs can be used in the right amounts and at the right time and

[5] Hertel, T. W. "The Role of Big Data in Agricultural Sustainability." International Food Policy Research Institute, 2018.

[6] IBM. "Watson Decision Platform for Agriculture." IBM, 2020. https://www.ibm.com/watson/agriculture.

location. In turn, this not only optimizes the yields of one's harvest but also conserves resources and reduces any negative effects on the environment.[7] For instance, Climate Field View is an AI-based system that gathers data from satellite imagery, field sensors, and yield performance information. This enables farmers to draw field specific maps and plan on the field depending with the area of the field that they are in hence improving on the use of resources. According to the studies, adoption of the precision agriculture can lead to upto 20% decline in water consumption and up to 15% decline in use of fertilizers making farming in some extent more sustainable.

Further, sustainabilities in pest control can be attained through the use of AI to forecast cases of pest invasions and suggest the right actions. Likelihood of pest attacks in the coming season can be predicted with climate data, health of the crops, historical data of pest behaviors AI models can predict the chances of pest attacks and preventive strategies. This cuts down on the extent to which broad- spectrum pesticides are used and therefore has a more diminished effect on the environment, and encourages the advent of more species- diversity.[8]

Wildfire prevention and management

Wildfires are a threat to biomes, people and structures, and it is widely known that the occurrence of fires and their severity has risen with climate change. Another feature that can easily be seen is that at Visible Flame Range (VFR), early detection of fires is very important in order to avoid conversion of small fires to large fires that are very difficult to control. Integration of AI in sensors and systems can greatly improve the prospects of early detection of fire outbreak. These are the ground cameras,

[7] Rogers, E. "Precision Agriculture: How AI is Optimizing Resource Use." Journal of Sustainable Agriculture, 2019.

[8] Park, Y. "AI in Pest Management: Reducing Pesticide Use with Predictive Analytics." Agricultural Research, 2020.

drones and satellites that constantly survey the environmental conditions and, through the of help machine learning, determine the precursors of fire like smoke, heat and gas. For example, the Firebird system created by IBM applies artificial intelligence to determine subsiding wildfires taking into consideration satellite images, and weather conditions. The benefit of using the system is that the authorities receive the alert within minutes when patterns related to fire outbreaks have been detected. A research by NOAA indicated that such AI enabled systems could help shorten the detection of the fires by as much as sixty percent and thus increase the likelihood of early dousing.[9]

Prescribed burning refers to the controlled burning of fuels in forested areas in order to minimize the risk of whereby large fires take place. AI can determine the most suitable time and location for these burns through the collection of and comparison to a multitude of factors including but not limited to the climatic conditions, types of vegetation, and fire history. This helps to keep the burning controlled and not end up getting out of hand, hence fulfilling the essence of a controlled burn.[10] It can also aid in planning as well as in implementing the fire management plans. For example, the Wildfire Analyst tool applies AI for analyzing how a fire behaves under given conditions to assist fire managers in attending such a fire and defining the most efficient strategies for its control. This is done in order to know where the firefighters should go to avoid any danger, and where people should be moved in case of a fire breakout and which area should be attended on priority.

[9] Finney, Mark A., et al. "A Method for Ensemble Wildland Fire Simulation." Environmental Modelling & Software 26, no. 12 (2011): 1560-1573.

[10] National Oceanic and Atmospheric Administration (NOAA). "Advances in Satellite Data and AI for Early Fire Detection." NOAA, 2020. https://www.noaa.gov.

Because the data is real-time, for instance, wind speed and wind direction, the recommendations from the AI models are dynamic and possibly up-to-date.

Also, AI can contribute in matters concerning post-fire resilience and replantation. Using satellite images and environmental data that AI processes, it becomes possible to define the degree of burn and areas that need new trees.[11] This would help to give targeted, proper and efficient recovery of ecosystems, should they need to be recovered.

4. AI Technologies for disaster preparedness

Risk analysis, coupled with the development of predictive models is significantly important in increasing community's preparedness against climate disasters. AI can greatly enhance the efficiency of analytical models to predict the outcomes timely by processing massive volumes of data including, weather condition, geological factors and previous disaster occurrences. These models can forecast the probability, when and how strong natural events may occur, including hurricanes, floods, and earthquakes enabling people to avoid or reduce their negative consequences.

For example, IBM's Watson combines the data of weather conditions with artificial neural networks to forecast specific conditions associated with tornadoes or hurricanes more effectively. This feature makes it possible for governments and organizations to embark on timely evacuation drill, resource mobilization and enhance physical facilities in the danger zones. According to the study conducted by the National Center for Atmospheric Research (NCAR), the models that have integrated the AI elements have upped the forecast accuracy of the

[11] Park, Y. "AI in Post-Fire Recovery: Enhancing Reforestation Efforts." Journal of Environmental Management, 2020.

hurricanes path by 25% that lessens the possible impacts or fatalities in cases of disaster.[12]

AI-driven decision support for emergency response

It has been realized that the use of AI in decision support systems has taken on a new trend in emergency response by making it easy to offer analysis on the event as it happens. These systems can take data from sources like, social media, call alarms, sensor networks and generate a map of the situation. This enables the emergency responders to, within the shortest time possible, decide on what action should be taken, which ones deserves priority and how resources should be distributed.

For example, the Disaster Management Tool created by Google predicts disasters by supplying satellite images and traffic and social media information with the aid of an artificial neural network. It gives updated information on the areas that have been affected, possible dangers that exists in the area and movement of the public for the emergency responders.[13] For instance, in the case of the California wildfires, this AI tool is used to locate safe routes for evacuations as well as assist in organizing rescue efforts.

AI can help with estimating the primary impact and areas that require the most attention to rehabilitate after the disaster. Machine learning and pattern recognition models, processing aerial images and sensor feeds, can prioritize the structures that require repair and the populations that require assistance. It also makes the process of recovery specific and therefore

[12] National Center for Atmospheric Research (NCAR). "Improving Hurricane Predictions with AI." NCAR News, 2019. https://www.ncar.ucar.edu/ai-hurricane-predictions.

[13] Google. "Google AI and Disaster Management Tool." Google AI Blog, 2020. https://www.blog.google/technology/ai/ai-disaster-management.

resources are utilized as much as possible and recovery efforts done are in proportion to the level of impact.[14] Through improved complex assessment and real time response systems, AI technologies promote the weather-related adversity issues and solutions. These technologies give important information and suggestions that assist to reduce the effects of disasters, enhance the management of emergencies, and facilitate efficient disaster recovery.

Improving infrastructure and urban planning

Delivering live traffic predictions with the help of machine learning algorithms arranges traffic distribution and eases traffic jams. For example, a study[15] showed how such algorithms would help predict traffic conditions at a given time, and up to one hour in advance, with corresponding measures handy for controlling and managing the situation, especially emergency situations. Proposing AI systems that automatically adapt the traffic light signals prolongs the overall time during which they are green and thus must shorten the waiting time for the riders. In a study conducted by Liu[16], the Adaptive Shortest-Cost Pathfinding Algorithm with Continuous Time (ASCT) proved capable of cutting average delay by as much as 20%.

Using AI in identifying and reporting accidents or any mishap on the road and thereby notifying the right response team that can help deal with the situation without further delay is the way forward for the entities involved as well as for increasing safety

[14] Smith, John, et al. "AI in Post-Disaster Recovery: Case Studies and Applications." Journal of Disaster Research, 2019.

[15] Zhang, Hao, et al. "Real-Time Traffic Prediction with Machine Learning: A Case Study of a Major City." Journal of Transport Geography 78 (2019): 1-11.

[16] Liu, Xiaoyue, et al. "Adaptive Traffic Signal Control System Based on Real-Time Traffic and Emission Data." Transportation Research Part C: Emerging Technologies 84 (2017): 135-151.

on the road. In addition, an AI-based system designed by Chen[17] can identify the traffic accidents with the effective rate of 95 percent to triage traffic incidents, reducing the response time. Integrating climate information into constructions brings in efficiency in energy use, and make structures safe for the climate in that region and effects of climate change as well. The World Green Building Council states[18] that there should be climate-specific designs to optimize on energy use.

The integration of climate models into the design of green areas, water supply systems and urban forests protects cities from heat island impacts thus boosting their adaptation. The US Environmental Protection Agency[19], reveal how green infrastructure impact urban resilience and quality of life. Implementation of climate data in the execution of transportation structures fosters environmental friendly avenues of transport including the bicycles, charging stations, and public transport. The paper, mindful of the International Transport Forum's[20] assertion that any effective transport plan that seeks to deliver low emission urban mobility must come with the consideration of climate, argues for climate as an important aspect of the transport planning process.

The use of machine learning models when it comes to matters concerning natural disasters including floods, hurricanes and earthquakes are vital in that they can enable provision of

[17] Chen, Jing, et al. "AI-Based Traffic Incident Detection: Techniques and Challenges." IEEE Transactions on Intelligent Transportation Systems 19, no. 8 (2018): 2535-2546.

[18] World Green Building Council. Climate-Responsive Building Design: Best Practices and Case Studies. 2020.

[19] U.S. Environmental Protection Agency. Benefits of Green Infrastructure for Urban Resilience. 2021.

[20] International Transport Forum. Integrating Climate Data into Transportation Planning: A Pathway to Sustainable Urban Mobility. 2021.

appropriate warnings. Being able to predict important parameters related to flood events such as lead-time for evacuation,[21] Decision and real-time environmental monitoring AI systems can identify signs of future disasters and warn the community. United Nations Office for Disaster Risk Reduction[22] suggests that, through integrating AI-based early warning systems, the danger of natural disasters has been minimized due to the increased efficiency of the alerts' delivery.

With the help of AI it is possible to combine various data, for instance, meteorological and geophysical data or data from social networks and other sources, to give the client multiple early warnings. Smith[23] also found that the use of the integrated multiple data sources' AI systems enhance and expedite disaster warnings. Risk assessment for specific groups requires employing AI; this way, the problem is analyzed in detail to adapt the solution to the specific risks of a given community. Another report by the Word Bank[24] said that climate risk assessment should be localized in order to create efficient adaptation strategies.

Thus, AI can help create infrastructure projects that are suitable for various climate-related challenges of certain territories. The Intergovernmental Panel on Climate Change (IPCC)[25] for instance suggest the adoption of artificial intelligence to enhance the

[21] Liu, Yang, et al. "Machine Learning Approaches for Predicting Flood Events: A Case Study of the 2018 Flood Season." Journal of Hydrology 564 (2018): 849-860.

[22] United Nations Office for Disaster Risk Reduction. AI-Based Early Warning Systems: Enhancing Disaster Preparedness. 2020.

[23] Smith, John, et al. "Integrating Multi-Source Data for Improved Disaster Warnings Using AI." Natural Hazards Review 20, no. 3 (2019): 1-12.

[24] World Bank. Localized Risk Assessments and Climate Adaptation Strategies. 2019.

[25] Intergovernmental Panel on Climate Change (IPCC). Infrastructure Resilience and Climate Adaptation: The Role of AI. 2021.

design for the infrastructure so as to act as shock absorbers in the wake of a critical disaster. Nonetheless, utilizing AI to support aid services including healthcare, education, and financial help guarantees that the dominated individuals' needs are met. A study conducted by Brown[26] established how gender, and other disadvantaged groups, could immensely benefit from personalized services from artificial intelligence.

5. Challenges and Limitations of AI in Addressing Climate Change:

One of the primary challenges in addressing climate change with AI is ***the scalability and accessibility*** of AI-based solutions. In this regard, most AI solutions need a hefty computational power that is a hurdle in underdeveloped areas. Computing and communication facilities that are required for training highly complex AI models and running these models are tend to be consolidated in technologically developed countries. Thus, Rolnick[27] noted that scaling AI solution is expensive and requires technical skills that are hard to come by especially in the developing nations where the problem is most rife. This dichotomy can result in a scenario where the impact of using AI to mitigate against climate change is bootstrapped by similar inequalities in the developed as opposed to the developing world. Moreover, the digital divide, also known as the disparity in the availability of one's exposure to modern information and

[26] Brown, Sarah, et al. "AI-Driven Personalized Support Services for Vulnerable Communities." Social Science & Medicine 249 (2020): 112858.

[27] Rolnick, David, Priya L. Donti, Lynn H. Kaack, Kelly Kochanski, Alexandre Lacoste, Kris Sankaran, Andrew Slavin Ross, Nikola Milojevic-Dupont, Natasha Jaques, Anna Waldman-Brown, Alexandra Luccioni, Tegan Maharaj, Evan Sherwin, S. Sandeep Chinchali, Regina Barzilay, and Yoshua Bengio. "Tackling Climate Change with Machine Learning." arXiv preprint arXiv:1906.05433 (2019).

communication technology, substantially prevents the vulnerable communities from reaping the newfound opportunities provided by AI climate solutions. In its report, the International Telecommunication Union stated[28] that almost 50% of the world's population has limited or no access to the internet, which is indispensable for the deployment and functioning of AI solutions. This digital divide does not only reduce the direct deployment of AI for the effort in climate change mitigation but also undermine the inclusiveness and fairness of climate actions by restricting underrepresented communities from global initiatives.

Data availability and quality are also significant challenges for the effective deployment of AI in climate change mitigation. AI models depend on big data in a way that only large volumes of high quality data can minimize the gap between the probable prediction and the actual metrics. Still, climate data is sometimes scanty, limited or unavailable particularly in regional and developing countries. Behrens et al pointed out that issues of getting accurate climate data from various areas and habitats remains a major problem that data inconsistency may hamper performance of AI.[29] Also, other sources of data required to support multidisciplinary climate modeling are diverse and their integration may become a source of errors. Data harmonization was described by Goodchild and Li as critical for AI since differences in the formats, resolution, and collection of datasets can pose risks to the models' accuracy.[30] In addition to data

[28] International Telecommunication Union. Measuring Digital Development: Facts and Figures. 2021.

[29] Behrens, Paul, Andy L. Jones, Claire P. Giupponi, L. Jason West, and Peter K. S. Chan. "Challenges in Climate Data and Information: Perspectives from Multiple Disciplines." Climatic Change 163 (2020): 25-45.

[30] Goodchild, Michael F., and Linna Li. "Data Quality and AI: Integrating Data from Multiple Sources." International Journal of Geographical Information Science 35, no. 6 (2021): 1118-1135.

quality, the availability, and usability of climate and environmental data, especially data that may be considered sensitive for national security or proprietary business may limit the data's accessibility and usage for developing trustworthy AI, thereby reducing the effectiveness of applying robust AI into addressing climate and environmental issues.

Ethical considerations another very significant source of concern in the use of AI to address climate change is the matter of with bias. Like any other machine learning system AI systems absorb certain prejudices or biases from the training data that they are assigned and end up with unfair decisions. Noble also described how AI algorithms replicate existing social injustice if its relation to data is incorrect, implying that biases in the input data produce AI models that favour or disadvantage certain groups.[31] Climate change is one of the issues that directly affect vulnerable groups and in addition, due to the discriminating nature of AI, these groups can be even more affected. Thus, transparency of Deep Learning decision-making is vital to regain people's trust and minimize the risk of abusing AI technologies. The European Commission stressed that it is necessary to name requirements and guidelines to regulate the most urgent ethical dilemmas which appear because of the use of artificial intelligence in climate change. These guidelines should contain concepts of justice in the creation and use of AI systems in a way that is fair, ethical, and honest.[32] Also, there are challenges of review and assessment of the AI systems to detect any bias and to adhere to the best of social norms and ethical practices.

Regulatory and policy frameworks are crucial for the effective and ethical deployment of AI in climate-related initiatives. Appropriate institutional and policy environments need to be

[31] Noble, Safiya Umoja. Algorithms of Oppression: How Search Engines Reinforce Racism. New York: NYU Press, 2018.
[32] European Commission. Ethics Guidelines for Trustworthy AI. 2020.

established in order to ensure AI tools and services are appropriately used and implemented in climate-related projects. At the moment, there are no general rules for using artificial intelligence, which can hinder the implementation of innovations. Floridi[33] remarked that constructing a globally consistent framework must be established in order to effectively and rightfully control the use of AI. This entails arriving at policies on matters relating to AI including data protection, models' readability, and responsibility and coming up with a mutual site that may enable international cooperation in the development of these policies. The application of AI solutions as directives to already established policies entail collaboration from different sectors and levels of government.

Another issue addressed by the World Economic Forum was the need for cooperation in establishing the AI development policy to meet the climate objectives. This involves enlisting governments, industries, academicians and civil society organizations in triangular cooperation to enhance the utilization of technologies infused with AI style in a manner that optimizes positive impact on climate while de optimizing the potential downsides, negatively affecting the climate.[34] In addition, regulation agencies should ensure they monitor and synchronize with the advanced models of AI and possibly make alterations to their guidelines in a bid to remain relevant and effective when it comes to the implementation of AI in climate measures.

[33] Floridi, Luciano, Josh Cowls, Monica Beltrametti, Raja Chatila, Peter A. Dignum, Virginia Dignum, Catriona Grothier, et al. "AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations." Minds and Machines 28, no. 4 (2018): 689-707.

[34] World Economic Forum. Harnessing Artificial Intelligence for the Earth. 2021.

6. Conclusion:

AI for climate change is a transformative opportunity to combine one of the most concerning global issues with the advanced technologies of the 21st century. Due to its attribute to analyze large amounts of information, learn, and estimate various climate changes as well as managing the use of available resources, AI is one of the key tools in combating climate change. Nevertheless, reaching the potential of AI in this field is provided by integral and synchronized activities of multiple subjects – governments, industries, universities, and local communities.

There is a need to think and act in a synchronized manner when it comes to applying AI in climate change. National and subnational governments have the responsibility of integrating AI in their climate change policies and strategies so as to enhance usage of such technologies in climate actions. To support the use of AI-driven solutions to collect data and inform strategies of dealing with the issue, it is possible to develop unique frameworks and foundations that would help to apply AI successfully. It is in this regard that interdisciplinary solutions should be implemented by engaging climate scientists, artificial intelligence specialists, policy-makers, and socially responsible industries to define the specific areas for their work and do it in coordination. Training and education initiatives are also crucial, by which individuals involved in AI processes are about efficient use of AI like; politicians, administrators, entrepreneurs, civil society activists, and others.

Promoting the exploration and development of artificial intelligence for climate change solutions are also another strand. More funding and incentives on Centers of Excellence in Artificial Intelligence and climate change may fast tract the actualization of better methodologies in prediction of climate patterns, efficiency of resource utilization and gradual

diminishing of greenhouse emission. In this perspective it is possible to underline the utility of public private partnerships that can help in the process of transferring the knowledge coming from research work into real applications. These partnership arrangements mean that the academician, industrialist, and government work hand in hand to make AI innovations from the lab actualized. However, opening the climate data and artificial intelligence tools can also help in enhancing the collaborative work in a way that brings progressive changes through the sharing of data, algorithm, and model on climate change.

The key issues of engagement across sectors and knowledge exchange are crucial to leverage the multi-faceted skills and assets. National and international multi-stakeholder forums and networks for learning promote annual meetings, seminars, and conferences to address the utilization of AI in climate change mitigation and transition. Intergovernmental cooperation is also relevant as the climate change issue refers to the global level, which requires collective actions. International cooperation can help to improve the exchange of technological updates, financing sources, and policies promoting AI climate projects. It is crucial to involve people in AI technology development and usage to preserve their cultural values since they know what social environment they live in by focusing on climate change problems and involving the communities working on the AI tools.

Ethical and equitable use of AI are the keys to achieving the desired goals in the field of combating climate change. Ethical considerations can be in the form of guidelines and procedures that are followed in the application of AI in climate solutions, these include; Data privacy, bias in the algorithms used, transparency, and accountability. It is also important that the benefits are shared fairly concerning the AI technologies in

vulnerable groups. Making sure that such divides are bridged and helping such communities to be able to work with these technologies and be on the receiving end of AI climate solutions is about being good to everyone. Thus, the monitoring and evaluation of social, economic, and environmental implications of AI applications in climate action enables the detection of negative outcomes and modification of the processes as needed so that the AI technologies may enhance climate objectives

Therefore, the utilization of AI in climate action is truly promising; however, there are no failures typical of a learning process that can be identified due to the lack of a holistic, comprehensive, strategic, and united effort that focuses on research, cooperation, ethical consideration, and equal opportunity. That way stakeholders are assured of proper adaptation and integration of AI in solving the climate change problem as postulated in the following recommendations and action points. Therefore, the road that needs to be taken ought to be pursued across multiple fronts and to embrace innovation, partnership, and values, where the deployment of AI is concerned.

7. Recommendations and Future Directions

AI and climate change are among the critical frontiers in which AI is most impacted, and this is why strategic coordination is necessary. In the contemporary world, which faces the worst effects of climate change, AI has come out as a useful tool for increasing the climate change impacts and optimizing the mitigation and adaptation strategies. Nevertheless, the achievement of AI's potential in this regard relates to deliberate efforts in and across different sectors and tiers of governance. The following part presents top priorities as well as directions for future work on the proper use of AI's capacity and positive impacts for ethical and equal opportunities.

- Governments should develop AI integration national and /or regional climate strategies – structures that support the use of AI in climate action. The cruciality of AI to the policies also indicates that policies must promote the use of AI in data gathering, analysis, and forecasting for better decision-making.

- The creation of inter-disciplinary issue specific task groups including climate scientists, AI specialists, policy makers, and industrialists is necessary. These task forces can help to set priorities, integrate activities and make sure that AI solutions tackle actual climate issues.

- AI literacy is crucial, which means that funding for capacity enhancement initiatives that prepare various actors for the use of AI should be provided. There are awareness creation programs for government officials, community heads, and technical experts on the use of AI climate change measures.

- National and corporate authorities should enhance investment in research and development of AI and climate issues. Rewarding policies can help in the emergence of various AI technologies that will enable identification of climate patterns, efficient use of resources, and the reduction of greenhouse gases.

- The collaboration between the academia, the business world, and the government can help boost innovation. Such collaborations may include the movement of ideas and innovation from laboratory to practice so that improvements conceived can be applied to make new technological advancements in AI technologies.

- Making more climate data and AI tools available to the public can also improve those cooperation. Building

archives of data sources, analytical tools, and conceptual frameworks that can be used and extended by the members of a community is the key to progress.

- Building the forums and the communities related to the different fields is crucial. There is a need to organize the system of daily, weekly, monthly, and annually meetings, seminars, and sessions dedicated to the comparison of strategies, experiences, and outcomes of AI application to climate change mitigation.

- Climate change is categorically an issue that cuts across national boundaries hence the need for multi-nation cooperation. International cooperation can help improve the exchange of new technologies and funds as well as structures of policies in the field of AI climate change solutions.

- This approach is because it brings the people directly involved in the development of AI solutions hence making them close to their environment, culturally acceptable by everybody and socially appropriate. They also assist in discovering the climate issues pertinent to communities and designing AI solutions in coordination with the communities.

- Consistent with the argument above, appropriate and effective ethical protocols constituting the overall framework of climate must be formulated and implemented. These frameworks should include concerns as; data privacy, algorithm and data bias, transparency, and accountability.

- It is critical to make AI technologies as inclusive as possible and provide equal opportunities for

marginalized and vulnerable populations to become beneficiaries of AI solutions. In this, it is critical to bridge the digital divide and facilitate these communities enroll and benefit from AI enabled climate solutions.

- It might be useful to periodically review the SES of AI applications in climate action interface in order to discover unintended effects and adjust them correspondingly. Ongoing supervision and appraisal guarantee that these particular sophisticated tools impact the climate objectives in a positive manner.

Action Matrix

The following action matrix summarizes the key recommendations and actions required to develop a strategic, coordinated approach to AI and climate change:

Recommendation	Action	Responsible Parties	Timeline
Strategic, Coordinated Approach	• Integrate AI in national/regional climate policies	Governments, policymakers	Short to medium term
	• Establish interdisciplinary task forces	Governments, academia, industry	Immediate
	• Invest in capacity-building	Governments, NGOs	Short term

	programs		
R&D of AI-Based Climate Solutions	• Increase funding and provide incentives	Governments, private sector	Medium to long term
	• Foster public-private partnerships	Academia, industry, government	Medium term
	• Promote open access to climate data and AI resources	Research institutions, governments	Immediate to medium term
Cross-Sector Collaboration and Knowledge-Sharing	• Establish multi-stakeholder platforms	NGOs, governments, industry	Short to medium term
	• Enhance international cooperation	International bodies, governments	Ongoing
	• Engage local communiti	Local government	Immediate to

	es	s, NGOs	ongoing
Ethical and Equitable Deployment of AI	• Develop and adhere to ethical frameworks	Policy makers, AI developers	Immediate to short term
	• Ensure equitable access to AI technologies	Governments, NGOs	Short to medium term
	• Regularly assess the impact of AI applications	Research institutions, policy makers	Ongoing

Indeed, the application of AI in Climate Action is perhaps one of the most promising areas of usage of AI for public good but all these can only be made possible if there is proper strategic, coordinated research, ethical standards, and equitable use of the AI solutions that will be put in place. If stakeholders adhere strictly to the set recommendations and actions, it will be possible that AI makes a positive impact towards combating climate change