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Summary

Climate change, a growing threat to our societal and economic stability, is predicted to cross the 1.5 degrees Celsius threshold by 2027, leading to extreme climate changes and mass biodiversity loss. These changes impact social, economic, and environmental systems in complex, interconnected ways. Thus, there is a pressing need for effective strategies to increase resilience and mitigate the associated risks. Digital technologies, including AI, data analytics, blockchain, and IoT, are emerging as crucial tools in this battle, offering the potential to transform climate change preparedness. Climate technology, though still an emerging field, is becoming a necessity for survival and societal sustainability. It ranges from high-profile applications like geoengineering and carbon capture to low-profile innovations like renewable energy technologies. The ability to collect and analyze vast amounts of environmental data is key to understanding climate vulnerabilities and developing targeted interventions. This policy brief aims to help stakeholders understand how digital technology can fortify climate change preparedness.

Securing Our Future: How Climate Solutions Can Power Sustainable and Resilient Societies

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Introduction

The Climate change is becoming a persistent threat to our social and economic stability. The European Union's Copernicus Climate Change Service noted that in the 12 months leading up to February 2024, the world's global mean temperature was 1.52 degrees Celsius higher than preindustrial times. Although there is contention over the use of the "1.5-degrees Celsius" climate threshold, it is clear that the warming of the earth is bringing and will continue to bring about extreme climate changes and mass biodiversity loss. When significant climate changes occur, social, economic, and environmental systems are affected in interconnected, complex ways. Effective strategies are needed to increase resilience and mitigate the significant risks associated with climate change, from rising sea levels to extreme, unexpected weather events that cause disruptions in water supply, food production, and other necessary global processes.

Developed and developing nations increasingly need climate mitigation and adaptation strategies. Digital technologies can become a crucial ally in this battle and bolster climate change preparedness in a transformative way. Advancements in artificial intelligence (AI), data analytics, blockchain, the Internet of Things (IoT), and other technologies have given nations the tools to develop a robust framework for developing and deploying technologies that mitigate the effects of climate change.

Climate technology, while still emerging in the realm of development and investment, will soon no longer be a luxury or novelty but a necessity for survival and ensuring the sustainability of our societies. While the more controversial applications of climate tech, such as geoengineering and carbon capture and storage (CCS), have been gaining significant media attention, climate tech also includes low-profile innovations already familiar in our society, such as renewable energy technologies. The ability to gather vast amounts of environmental data from weather stations, satellite imagery, open-access media, and other sources has given us the ability to discover trends and patterns crucial for understanding climate vulnerabilities and impacts. This data gives us the basis for developing targeted technologies and interventions to enhance the climate resilience of our societies.

The rise of interconnected IoT sensors has furthered the breadth and depth of the data we can gather in real-time, allowing for early warning systems and accurate risk assessments. Meanwhile, AI has allowed us to simulate adaptive strategies and scenarios. This paper seeks to help public and private stakeholders understand how digital technology, particularly emerging technologies, can fortify countries' climate change preparedness. This report offers insights along three overarching themes:

1. All countries should have critical digital tech deployments in place to fortify their climate change preparedness.
2. Emerging technologies are changing what these deployments are and can do.
3. The value of climate data needs to be maximized to ensure widespread impact.

Key Digital Tech Deployments All Countries Should Have in Place to Fortify Their Climate Change Preparedness

Climate tech has increasingly become a buzzword in business and policy discourse. "Climate technology" encompasses a diverse range of technological innovations designed to address the impacts of climate change. This category touches upon a broad range of industry sectors, from agriculture to transport to utilities, and includes a broad spectrum of technological applications, solutions, and tools. Building resilience against a warming climate and facilitating the transition to a sustainable, low-carbon world is the primary goal of deploying climate tech. Climate tech can help society reach this goal by lowering greenhouse gas emissions, helping communities and ecosystems adapt to changing temperatures and environmental conditions, predicting weather and climate events, and ensuring food security. Aside from environmental impacts, climate tech also has the potential to drive economic growth and job creation while ensuring equity and justice for communities that are disproportionately affected by climate change.

Perhaps the most ubiquitous example of climate tech already embedded in our societies is renewable energy systems. Solar and wind power and hydroelectricity are increasingly common in nations around the globe, with recent data from the International Renewable Energy Agency indicating that countries such as China, the USA, Brazil, India, and Germany are leading the way in renewable energy capacity. Renewable energy has been growing to incorporate a greater variety of energy sources. For example, along with innovations in solar and wind power, geothermal energy has been growing lately, with experiments in generating electricity by bringing geothermal water to the surface to power generators. Burning biomass or waste is used for generating heat, producing biofuels, or generating biogas. Marine energy is also a growing renewable energy source, with energy from tides and waves being used to generate electricity.

Once energy is produced, however, how it is stored and discharged presents environmental challenges. Energy storage and regulation systems are thus being developed to minimize energy waste. When renewable energy sources are abundant, but energy demand remains low, these systems store excess energy and save it for release when demand rises. Smart grids and demand response systems are among the most popular options, allowing consumers to adjust their energy based on peak demand periods. These technologies greatly help reduce energy loss during electricity distribution and transmission. Specialized batteries (solid-state, flow, and lithium-ion) balance energy supply with demand, making energy systems more efficient and sustainable. Other innovations in this area include compressed air energy storage, which uses compressed air and turbines to generate electricity, and thermal energy storage, which store energy in materials such as molten salt or ice.

Beyond energy creation and storage, systems that track, monitor, and model climate and weather conditions are growing in importance in a world where adverse climate events are becoming increasingly commonplace. Climate monitoring systems are the first interfaces that detect patterns in weather and unusual activity in the atmosphere or the on-ground environment. Weather stations and satellites are a standard part of these systems, tracking temperature, precipitation, greenhouse gas levels, ocean temperatures, ice cap cover, and deforestation. Radar systems also observe severe weather events, whereas lidar uses laser light to measure and track pollutants, cloud profiles, and air quality. Biological monitoring is also a growing tool in which biological systems are analyzed to show the effects of climate change. This process includes tracking shifts in species distribution in particular areas, changes in plant flowering and breeding, and the rate of coral bleaching.

Once environmental data has been gathered, climate modeling and simulations are needed to model climate systems and events. These systems are crucial in planning for different climate scenarios and play an increasing role in policy and management around natural disasters. Thanks to the rise of AI and data analytics, their accuracy has grown exponentially in recent years. One of the most advanced of these tools is general circulation models, which project the planet onto a grid and model the currents of the ocean and atmosphere, applying the laws of physics to each section of the grid. Earth systems models are based on this same technology and model the carbon cycle, ecosystems, and chemical processes, while integrated assessment models combine climate and socioeconomic models. Process-based models are also used to focus on particular processes that are affected by climate change, such as rising sea levels or ice cap melt.

In addition to predicting and analyzing future climate scenarios, it is crucial to prepare for climate change by innovating how we manage food and agriculture. Green agriculture is a burgeoning field that focuses on making agriculture more adaptive and resilient to climate change while increasing productivity. Precision agriculture, in particular, involves using IoT devices, AI, data analytics, GPS, and other technologies to apply precise amounts of pesticides, water, and fertilizer to crops where needed, maximizing the efficiency of crop yields and minimizing environmental impacts. Agrovoltaics is another growing area in which agriculture and solar power generation are combined on the same plot of land. This practice maximizes the use and productivity of the land, allowing for less arable land to be repurposed, crops to be protected from excessive sunlight and heat, the performance of solar panels to be maximized, and wildlife and biodiversity to be provided with a safe habitat.

Finally, carbon capture and storage is a developing yet controversial area of climate tech that has received much attention in the scientific media. The idea behind this tech is to capture carbon dioxide emitted from fossil fuel processing sites, such as power stations, and transport and store it underground to prevent it from being released into the atmosphere. This tech can also potentially stimulate oil production and advanced oil recovery. Examples include geological and ocean storage, direct air capture, and pre-and post-combustion capture. Only a few dozen carbon capture and storage initiatives are actively being deployed and used, with several of them having surpassed 95% efficiency in capturing and storing CO_2 from power plants. However, improving the reach and efficiency of these systems would involve more expense on the part of power plants and more significant investments in infrastructure development and effective policy.

Emerging Technologies and the Changing Face of Climate Tech

All the areas mentioned above of climate tech are playing a crucial role in nations' climate change preparedness, with many areas still developing as innovations are pushed forward and regulatory and social environments change. Emerging technologies are playing a crucial role in improving the efficiency of these systems, although much remains to be discovered and tested regarding how these technologies can be deployed safely and efficiently. Emerging tech will be the future foundation of how nations prepare and adapt to climate change, and they have to be increasingly considered in climate tech regulation, development, and deployment.

AI and machine learning are increasingly becoming the foundation of climate tech, with innovations in this area occurring almost alarmingly. The ability of algorithms to analyze massive datasets and identify correlations and patterns gives them astounding power to improve our understanding of climate conditions and environmental degradation. This tech allows us to combine data from numerous sources, from sensor data from IoT devices to satellite imagery to historical climate records, to understand how the climate is changing and how we can be better prepared for future climate scenarios. AI also allows us to monitor other tech and processes, such as climate models, heating and cooling systems, and supply chains, to improve efficiency and performance. Predictive analytics extends these powers to forecast future processes and events based on past data.

AI has also provided the foundations of blockchain technologies, revolutionizing climate tech. The security, transparency, and decentralization of blockchain tech give it unique powers in this context. Blockchain is used in carbon and renewable energy trading, enabling peer-to-peer energy trading platforms and preventing carbon credits from being fraudulently claimed by ensuring each credit is traceable and unique. Blockchain verifies that products are sustainably sourced, waste is recycled correctly, and resources such as water are allocated efficiently and fairly, revolutionizing supply chains and natural resource management. Nevertheless, blockchain has raised sustainability concerns due to its high energy consumption in certain implementations, challenges in scalability, and lack of standardization and regulation. More research and policy are thus needed to ensure that blockchain can become a regular and positive aspect of a nation's climate tech.

AI has also enabled the rise of IoT devices, which consist of sensors embedded with software on a network of physical objects that exchange data among themselves, providing detailed data on some parameters. This data is crucial for environmental and climate monitoring, allowing scientists to trace and record changes in temperature, atmospheric pressure, and pollutant levels. These devices also play a crucial role in precision agriculture, where they collect data about crop health, soil health, and nutrient levels, and in water resource management, they measure water quantity and quality. The monitoring capabilities of IoT devices are also used to track wildlife and biodiversity loss and detect early signs of extreme weather events and natural disasters.
AI has also led to significant developments in virtual and augmented reality and the metaverse, which have given rise to the innovation of digital twins. This groundbreaking approach to managing cities involves simulating virtual models of objects or systems, utilizing data from IoT devices and other sources to simulate their state, behavior, energy consumption, and other aspects. These digital twins can be done on individual buildings, transport systems, or even entire cities. The ability to monitor and simulate these urban aspects is revolutionizing energy and resource management, allowing us to model responses to climate emergencies and minimize energy and resource waste. These digital twins can also be tested to see the effects of sustainable urban policies, such as using more sustainable building materials or heating and cooling methods. These digital twins can also help encourage public participation in urban policy by allowing city residents to visualize different urban design and infrastructure possibilities.

In transport technology, drones and autonomous vehicles also play a growing role in climate monitoring and environmental conservation. Drones can access difficult-to-reach areas in the natural environment, using high-resolution cameras, sensors, and other equipment to gather crucial environmental data such as tracing ice cap melt or monitoring species distribution. Drones can also play a crucial role in disaster management, reaching survivors after disastrous natural events, accessing damaged areas, and gathering data on the state of the natural environment after the disaster. Autonomous vehicles can also potentially transport personnel and supplies, minimizing the risk of rescue missions. These vehicles also have the potential to be more sustainable by reducing carbon outputs and optimizing and smoothing out traffic flows. However, fully autonomous vehicles are not yet available to the public and will face many technical and regulatory hurdles before they become mainstream.

Beyond emerging technologies already being deployed, many experimental technologies have great potential to revolutionize climate change preparedness. Quantum computing is one such technology with vast potential to revolutionize climate modeling, simulation, and other areas of climate tech. This emerging technology utilizes quantum bits that store and represent data, allowing it to compute, process, and solve complex problems exponentially faster than traditional computing. This massive increase in computing power can revolutionize the accuracy and capabilities of climate modeling and simulation, leading to more effective climate change mitigation policies. This technology also has enormous potential to model the behavior of materials and molecules, aiding greatly in discovering and synthesizing more sustainable materials for carbon capture and other efforts.

Another emerging and experimental technology is synthetic biology, which involves engineering organisms to have new abilities that aid in mitigating the effects of climate change, combining knowledge and techniques from engineering and biology. This tech is often referenced concerning genetically engineering crops to resist droughts or enhance photosynthesis. There is also speculation and experimentation concerning carbon capture tech, especially regarding engineering microorganisms such as microalgae and cyanobacteria to produce biofuels and bioplastics that sequester carbon. This technology can produce sustainable biofuels and biodegradable bacteria by engineering yeast and bacteria to ferment sugars into biofuels or produce bioplastics from agricultural waste or CO2. Nevertheless, this tech is also marked by practical, regulatory, and ethical considerations, such as whether there should be a limit on how much humanity can engineer living organisms and whether this tech can and will be evenly distributed across developed and emerging economies.

Perhaps the most experimental—and controversial—emerging technology is geoengineering, which involves large-scale interventions to combat climate change in the earth's natural ecosystems. It is important to note that these technologies are speculative and currently only exist as small-scale experiments. Some ideas in this area include solar radiation management, which involves reflecting some of the sun's heat and light into space, and carbon dioxide removal technologies, which aim to remove CO2 from the earth's atmosphere. The former involves projected techniques such as releasing reflective materials into the atmosphere, spraying seawater drops, and placing reflective materials in space to deflect sunlight. The latter involves ideas such as growing plants to absorb CO2, speeding up the process of mineral weathering that naturally removes CO2, or adding nutrients to the ocean. It is crucial to note that concerns have been raised about this tech's potential to damage natural earth ecosystems. Thus, any nation that wishes to investigate this tech further must do so with caution and a robust regulatory environment in place.

Maximizing the Value of Climate Data

A recurring theme throughout all the climate tech reviewed so far is the prevalence of climate data. Climate data provides the backbone for all other climate technologies; it is necessary to understand current climate and environmental states, analyze changes, predict future scenarios, and design solutions. Nations worldwide need to maximize the value of climate data and ensure that it is integrated into their climate tech policy, development, and deployment. Efforts must also be made to level the playing field between developed and emerging economies. Emerging economies can be disadvantaged due to infrastructure, funding, training, and other aspects. International collaboration and funding hold great potential to level the playing field and ensure that the benefits of climate data are accessible to all.

Whether a developed or emerging economy, investments in infrastructure are among the first efforts that need to be made to maximize the benefit of climate data. Gathering and processing vast amounts of data require a certain amount and quality of hardware and software, from the smallest IoT devices to vast data centers that provide computing and storage power for algorithms and other AI systems. The latter is especially crucial, as data centers can be complex to establish in areas with extreme weather conditions or challenges maintaining a steady electricity supply. Private-public partnerships are valuable in providing and funding this infrastructure, especially in economies where government funds are inadequate for such wide-scale projects.

Once infrastructure concerns are settled, a robust regulatory environment is necessary to ensure climate data is utilized ethically and within legal limits while maximizing its value. Laws and guidelines must be established for how this data is collected and used, concerning individual citizens' rights to data privacy and provisions for how this data is to be safely stored and processed. Cybersecurity is crucial in this regard, as it aligns national regulations with international ones, such as the EU General Data Protection Regulation. Nations developing a robust climate tech policy framework for the first time can follow examples and best use cases from other nations while still being sensitive to their unique local needs, sociocultural systems, and economic environments.

Interoperability must also be ensured since coordinating different hardware and software in climate tech can present challenges when integrating different data standards and systems. Advanced AI and machine learning capabilities should be taken advantage of to speed up the data analysis process, as long as these techniques are implemented carefully and concerning ethical and regulatory limits. Finally, accessibility and open data are vital for any climate tech regulation or initiative. If data is openly available to a wide range of stakeholders, such as businesses, governments, and independent research institutions, then not only will governments be lauded for valuing transparency, but innovation and climate tech breakthroughs will also be enabled to a high degree.

Climate data that is publicly available can help enhance citizens' trust in government and give citizens a clear picture of what is happening to their environment and how their government is trying to mitigate climate change. Local and indigenous knowledge can also be invaluable as a complement to climate data. Indigenous communities may have ancestral knowledge about co-existing with the natural environment that can help explain local climate or biodiversity patterns and become an invaluable component of climate change solutions. Climate data can also be incorporated into community planning initiatives and urban planning projects. Open-access platforms can make the data available to the public in user-friendly outputs, allowing citizens to understand the goals and results of such initiatives and projects.

10 Recommendations for Maximizing Climate Tech Deployments at the National Level

1. Establish a National Climate Tech Strategy: Developing, deploying, and managing the outcomes of climate tech requires an integrated national strategy. This strategy will require carefully crafted goals, a centralized vision, funding and resource allocation plans, coordination with international bodies and climate change mitigation plans, frameworks for intersectoral partnerships, and the outlines of a regulatory and legislative framework.

2. Develop Robust Policies: Climate tech is a new frontier for both developed and emerging economies, making robust policymaking necessary for this new tech to be developed and deployed safely and efficiently. Governments must work with private corporations and other actors to ethically develop climate tech without over-prioritizing profit or political interests.

3. Invest in Infrastructure: Developed and emerging economies need to work together to ensure a robust infrastructure for developing and deploying any aspect of climate tech. Infrastructure needs begin with basic needs such as electricity, robust internet connection, and necessary hardware and software and extend to more profound computing needs such as the ability to support data centers that will support advanced AI systems. Funding and tech transfer processes supported by international bodies are invaluable, leveling the playing field between developed and emerging economies.

4. Utilize the Scientific Method: An empirical mindset is necessary to shepherd the growth of climate tech, most of which are still in the testing and beta stages, and some are still speculative. Pilot projects and sandboxes are invaluable for testing tech before deployment and supporting an innovation ecosystem that allows entrepreneurs, organizations, and start-ups to test their ideas with appropriate guidance and funding. Much climate tech has garnered controversy for making grand claims about its abilities without data to support these claims, so it is necessary to integrate data collection and analytics into any testing or pilot projects.

5. Embrace Agile Development: An agile approach to developing climate tech will ensure that the tech is developed and deployed correctly immediately without depleting resources, wasting time, or losing public support. An agile development process involves incorporating user feedback at every stage of the development and deployment process, from initial idea to testing to deployment to long-term use in society.

6. Design for Public Use: Some climate tech is already being used by the public, such as solar power for heating homes and IoT in smart home systems. Small, gradual tech deployments like this can help integrate climate tech into society and ease public fears about climate change and its effects. These efforts can involve incorporating climate tech and data into public places and processes, such as integrating renewable energy into public buildings and climate data literacy into school, university, and professional training curriculums.

7. Embrace Cross-Industry Collaboration: Pooling knowledge and resources is the best way for any nation to maximize the value of climate tech and data. Private-public partnerships are already an established model for funding various public projects and initiatives, and this model can be extended to include climate tech development and deployment. Input and consulting from third-sector organizations, universities, private research institutions, and international bodies can also help ensure that climate tech is developed effectively, deployed ethically, and maximizes value for all.

8. Invest in Human Resources: It is crucial not to forget the human element in any climate tech or climate data initiative. If climate tech and data become integrated into citizens' daily lives and/or the private or public sector, a trained workforce will be needed to understand, handle, and further develop this tech and data. Reskilling and upskilling initiatives are invaluable in this regard, and they can be implemented at the national or organizational levels. These initiatives can offer certificates and credentials that are valuable for an individual's entire career.

9. Ensure Even Distribution: Climate tech is an expensive endeavor for both nations and individual citizens. Only wealthy populations can afford specific tech, such as electric vehicles or advanced renewable energy systems. Meanwhile, citizens from disadvantaged socioeconomic areas and backgrounds are unable to access the benefits of climate tech and are significantly more exposed to pollution and other environmental hazards. Any piece of climate tech must be made publicly available where appropriate and incorporated into everyday life in ways that emphasize public good. These efforts can include incorporating renewable energy into public transport and establishing public projects to provide specific categories of climate tech to disadvantaged communities free of charge.

10. Encourage Ecosystems of Innovation: A nation's start-ups and emerging entrepreneurial ventures headed by novice entrepreneurs are just as crucial to innovation as governments and large, established corporations. Providing funding and training, establishing innovation sandboxes and start-up incubators, and hosting climate tech competitions, conferences, and training seminars are valuable in fostering an innovation ecosystem where new ideas can thrive and lead to invaluable climate tech solutions.

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Engy Shibl | Marouen Ghezal | Shuaib Kunouth

Research at The Mohammed Bin Rashid School of Government

The Mohammed Bin Rashid School of Government (formerly Dubai School of Government) is a research and teaching institution focusing on public policy in the Arab world. Established in 2005 under the patronage of HH Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the United Arab Emirates and Ruler of Dubai, in cooperation with the Harvard Kennedy School, MBRSG aims to promote good governance through enhancing the region's capacity for effective public policy.

Toward this goal, the Mohammed Bin Rashid School of Government also collaborates with regional and global institutions in delivering its research and training programs. In addition, the School organizes policy forums and international conferences to facilitate the exchange of ideas and promote critical debate on public policy in the Arab world. The School is committed to the creation of knowledge, the dissemination of best practice and the training of policy makers in the Arab world. To achieve this mission, the School is developing strong capabilities to support research and teaching programs, including:

- Applied research in public policy and management;
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- Executive education for senior officials and executives; and,
- Knowledge forums for scholars and policy makers.

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1. Future Government and Innovation
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