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15-16 OCTOBER 2023

QNDCC 2023 White Paper

Innovations in Climate Change

December 4, 2023

وزارة البيئة والتغيّر المناخي
Ministry of Environment and Climate Change
State of Qatar • دولة قطر

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White Paper
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Innovations in Climate Change

December 4, 2023
Prepared by Strategy Hub

About Earthna

Earthna Center for a Sustainable Future (Earthna) is a non-profit policy, research, and advocacy organization, established by Qatar Foundation to promote and enable a coordinated approach to environmental, social, and economic sustainability and prosperity.

Earthna is a facilitator of sustainability efforts and action in Qatar and other hot and arid countries, focusing on sustainability frameworks, circular economies, energy transition, climate change, biodiversity and ecosystems, cities and the built environment, and education, ethics, and faith. By bringing together technical experts, academia, government and non-government organizations, businesses and civil society, Earthna fosters collaboration, innovation, and positive change.

Using their home – Education City – as a testbed, Earthna develops and trials sustainable solutions and evidence-based policies for Qatar and hot and arid regions. The organization is committed to combining modern thinking with traditional knowledge, contributing to the well-being of society by creating a legacy of sustainability within a thriving natural environment.

For more information about Earthna and to stay updated on our latest initiatives, please visit www.earthna.qa

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Executive Summary

In the systematic exploration of climate change mitigation, this analytical discourse delves into discussions emanating from the third annual Qatar National Dialogue for Climate Change (QNDCC) panel session titled "Innovations in Climate Change." The comprehensive scope of the study unfolds with particular attention to insights, elaborative research, and recommendations crafted to support Qatar's national sustainability objectives, with a particular emphasis on established sustainable innovations.

The findings highlight the immediate need for a paradigm shift in the adoption of innovative solutions that can significantly mitigate climate change through reductions in carbon emissions across different sectors. The analysis discusses prominent international agreements and emergent solutions, focusing on the Energy, Industrial, and Agricultural sectors. Advocating for the need for a sustainable economic transition, the discourse highlights numerous technological and practical implementations of novel sustainable innovations for renewable energy generation, resource-efficient manufacturing processes, and advanced methodologies to farm and cultivate the Earth.

The analysis highlights several common challenges faced by countries all over the world, including Qatar. Such challenges encompass resistance to change, financial barriers, infrastructure challenges, technology transfer disparities, and workforce capacity constraints. The paper then presents a judicious set of recommendations curated to address multifaceted challenges and facilitate the implementation of sustainable innovative solutions. These recommendations include a multi-dimensional approach to overcoming resistance to change, international and local innovation financing, revising strategic objectives and planning infrastructure upgrades, global cooperation and partnerships, and collaborative national and sectoral capacity building.

In adopting these recommendations, Qatar can substantially contribute to global climate objectives and ascend to the forefront of sustainable development, symbolizing a strategic alignment with the visionary principles outlined in Qatar's National Vision 2030 (QNV 2030).

Scope and Methodology

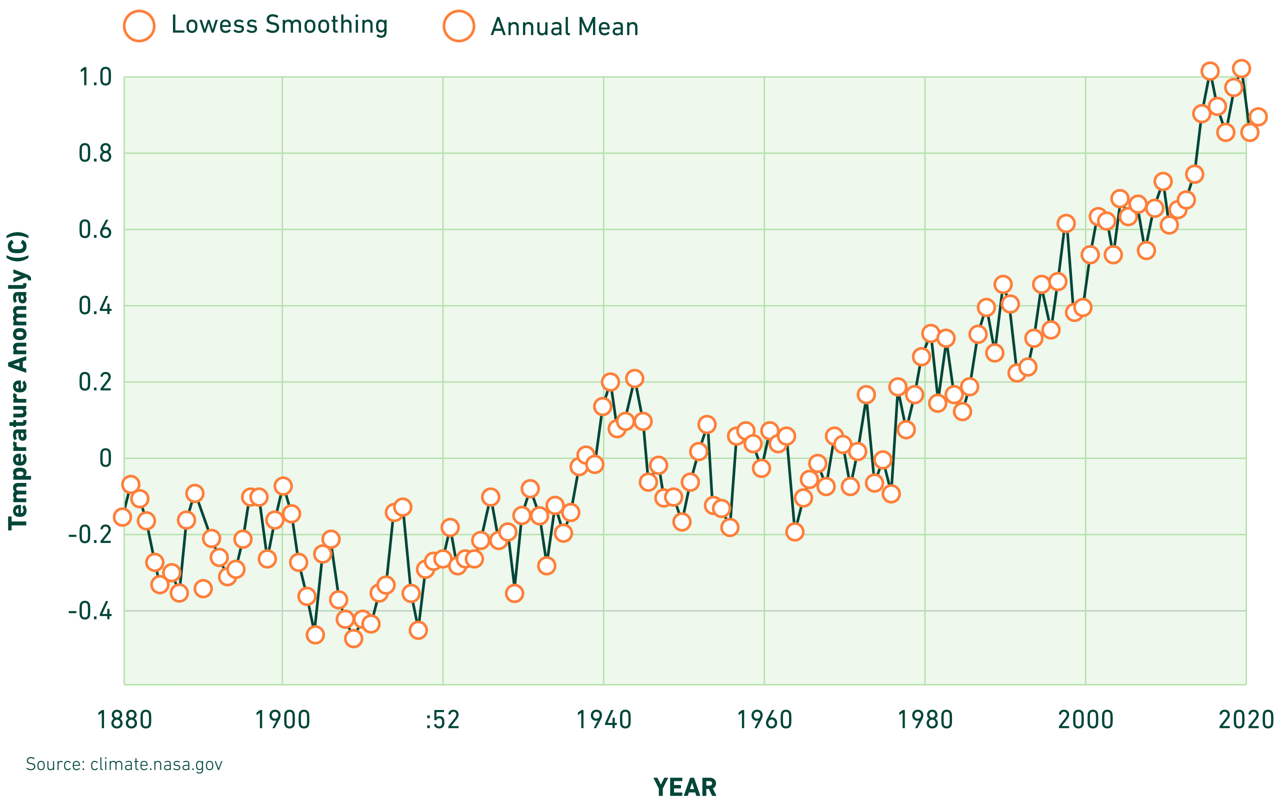
The scope of the analysis covers the topics discussed in the panel session "Innovations in Climate Change" held on the first day of the QNDCC, in addition to supplementary research to substantiate the session's key findings and produce optimally relevant recommendations. The discussed findings can be utilized to enhance Qatar's national sustainability goals and develop relevant local and regional sustainability initiatives. The methodology followed for data collection includes preliminary academic research, on-site session note-taking, and post-session supplementary research and benchmarking. Due to the international and national focus on specific sector innovations to maximize climate change mitigation, the examined research highlights the innovations in three important sectors: energy, industry, and agriculture. Based on the detailed insights, this paper provides a set of general recommendations applicable across sectors and countries to support the implementation of innovative sustainable solutions for the aforementioned sectors.

Climate Change and the Need for Innovation

Over the last 200 years, the world's climate has been dramatically changing as a result of human-led activities, especially after the Industrial Revolution. As energy consumption increases for industrialization, greenhouse gas (GHG) emissions wrap around the Earth, trapping in the sun's heat and increasing climate temperatures. In addition to energy consumption, other economic activities heavily contribute to higher GHG emissions, including land clearing, deforestation, mass agriculturalization, construction and urbanization, and transportation.[1] Figures 1 and 2 below display the changes in global temperatures and CO_2 emissions respectively over the last decade, signifying an alarming trend of continuous climate deterioration over time.

While these heightened activities have led to unprecedented globalized economic, financial, and population growth, they have also negatively impacted different environments all around the world by contributing to climate change. Consequently, many communities have experienced and may face new intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms, and declining biodiversity. All of these challenges can heavily affect human life, health, housing, work, and resources. Although some regions are more vulnerable to climate change results than others, especially areas surrounded by rising sea levels and saltwater intrusion, scientists anticipate that the number of people who will be displaced and negatively impacted by weather-related changes will notably increase over the coming decades.[4]

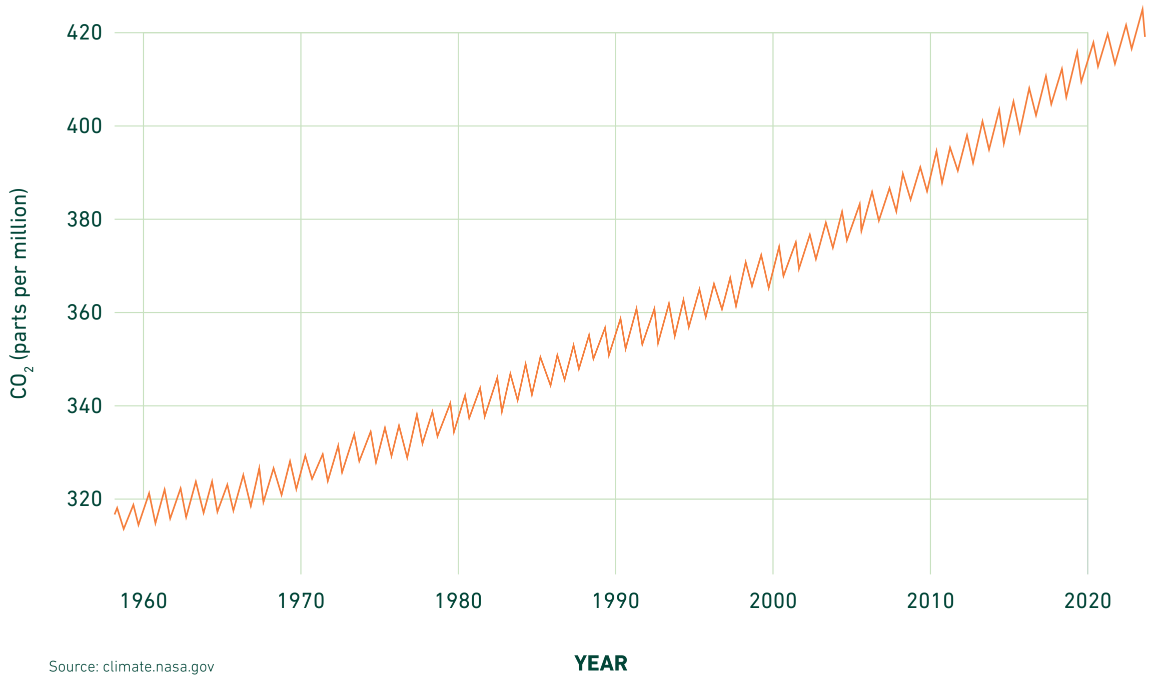
Figure 1 The increase in global temperatures over the last century. [2]



Source: climate.nasa.gov

[1] The United Nations, "What Is Climate Change?" https://www.un.org/en/climatechange/what-is-climate-change
[2] NASA, "Global Climate Change: Vital Signs of the Planet," https://climate.nasa.gov/
[3] Ibid.
[4] The United Nations, "What Is Climate Change?" https://www.un.org/en/climatechange/what-is-climate-change

Figure 2 The increase in global CO_2 emissions over the last century. [3]



Source: climate.nasa.gov

Accordingly, it is of the utmost importance that globally governments, institutions, industries, and communities cooperate to work towards mitigating climate change impacts and reducing GHG emissions enough to contain the damage from rising temperatures. Referred to as "the generation, acceptance, and implementation of new ideas, processes, products, services, or technologies,"[5] innovation can play a large role in transitioning our economies and accustomed practices to become more sustainable, without compromising our continuous economic expansion and advancement. Eco-innovation is a broader concept that encompasses any form of innovative development, whether in the creation of new products or processes, aimed at minimizing environmental impact or enhancing resource productivity.[6]

Numerous industries have initiated the research and development of relevant, innovative solutions that can lead to more efficient and sustainable operations. Such industries include and are not limited to the energy sector, the commercial-industrial sector, the agricultural sector, and cross-collaborations between the technological sector and academia. These industries are often driven by overarching governmental guidance, frameworks, policies, and/or financial support to meet national sustainability targets. Fundamentally, research plays a foundational role in advancing innovative practices and solutions for such industries. The collaboration between the public and private sectors for the widespread advancement and application of novel solutions is integral to the successful global and local shift towards a low-carbon economy, necessitating the reorganization of economic practices to prioritize sustainability goals.[7] As concisely presented by Mr. Ali Bin Tawar – Qatar TV Presenter and Ooreedoo Brand Ambassador – nature does not need humans, but humans fundamentally need nature. In order for future generations to survive and lead comfortable lives without the looming threats of climate crises, the world must urgently act by implementing preventative and innovative solutions to preserve our environment and human livelihood.

[5] Moreira, Fernando, Maria Manuela Cruz-Cunha, and João Varajão, "Handbook of Research on Enterprise 2.0: Technological, Social, and Organizational Dimensions- Background on Climate Change: Overview of Climate Change Trends and Impacts," Volume in the Advances in Business Information Systems and Analytics (ABISA), (2013).

[6] José Palacín, "Addressing Climate Change Through Innovation – The Challenges Ahead," The United Nations Economic Commission for Europe, (2009). https://unece.org/fileadmin/DAM/oes/nutshell/2009/3_ClimateChangeInnovation.pdf

[7] Ibid.

International Climate Agreements and Innovation

In the collective endeavor to address climate change and foster sustainable development globally, numerous international agreements and declarations have emerged to galvanize concerted action toward shared objectives. A prominent example is the Paris Agreement, a binding treaty on climate change adopted by 196 nations in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC). Mandating substantial economic and social transformations at the national level, the Paris Agreement seeks to limit global warming to well below 2 degrees Celsius. Each country is required to submit its Nationally Determined Contributions (NDCs), outlining specific actions and plans to curtail greenhouse gas emissions and align with the Paris Agreement's objectives. While not explicitly concentrating on innovation, the Agreement nonetheless advocates for the advancement and dissemination of climate-related technologies, underscoring the significance of innovative financial and technological support for developing nations to realize their ambitious goals.[8]

The COP26 Glasgow Climate Pact, established during the 26th UN Climate Change Conference, involves 196 nations and the European Union. Its primary goals include strengthening global climate ambitions, revisiting NDCs for more ambitious targets, mobilizing climate finance for developing nations, and prioritizing adaptation efforts, especially for vulnerable countries. Key initiatives arising from COP26 include the Global Methane Pledge, the commitment to halt deforestation by 2030, and pledges to accelerate the transition to clean energy. The Pact emphasizes the need to enhance global and sectoral efforts in innovation and research to promptly and effectively address climate change. It especially calls for increased financial and technical support for developing countries to foster innovation and the deployment of climate-related technologies.[9] Such international agreements display the successful efforts of international cooperation toward achieving common goals, and they provide the basis for developing future action plans and implementing innovative solutions to address climate change.

[8] United Nations Framework Convention on Climate Change Secretariat, "The Paris Agreement," https://unfccc.int/process-and-meetings/the-paris-agreement

[9] United Nations, "COP26: Together for Our Planet,
" https://www.un.org/en/climatechange/cop26#:~:text=The%20Glasgow%20Pact%20calls%20for,climate%20change%20and%20building%20resilience.

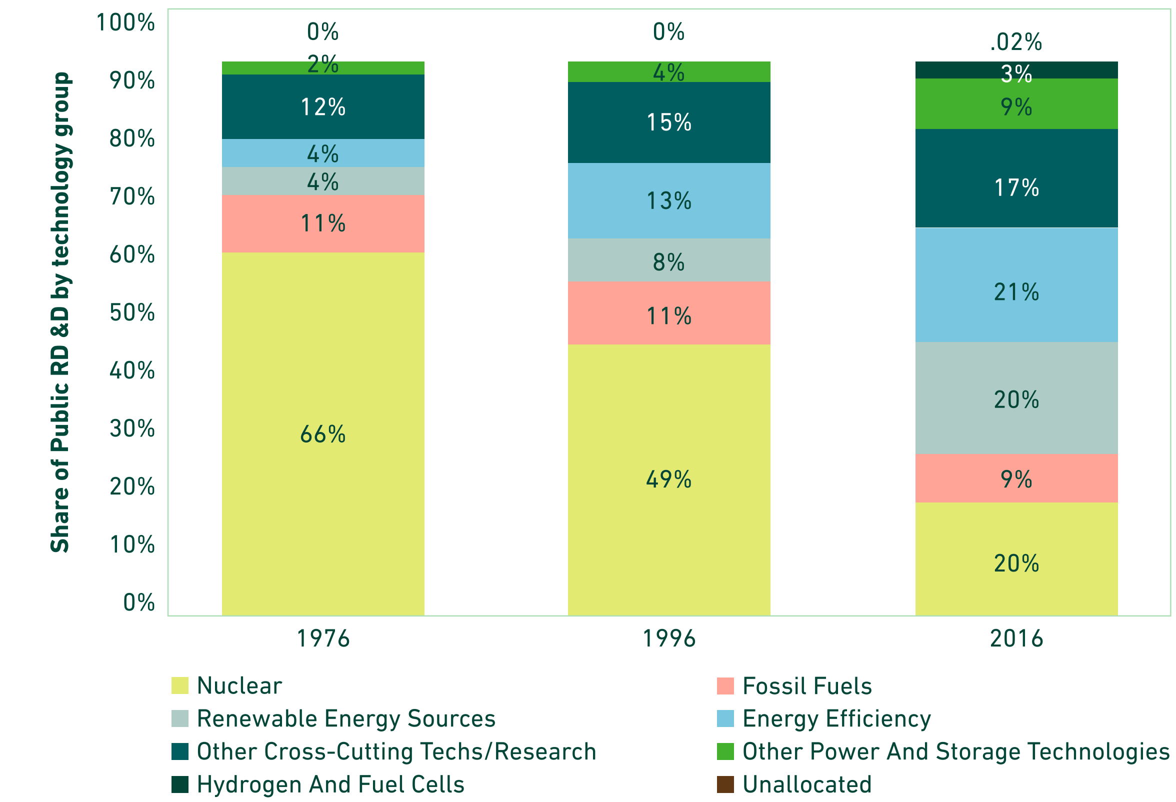
Sector Innovations in Climate Change

The Energy Sector

The energy sector is one of the largest contributors to carbon emissions in the global economy. With the continuous international dependency on conventional energy mix it is considerably difficult for states to drastically transition to cleaner energy sources. In order for countries to achieve their lowered emission targets and ensure long-term national energy security, governments and energy companies must cooperate by aligning their strategies and coordinating their operations to heighten the scale and speed of the investment in and adoption of clean energy solutions and innovations.[10]

Over the past half of the century, public investment in energy Research, Development, and Demonstration (RD&D) has proliferated to accommodate the drive for technological advancement, energy efficiency, and energy independence of different states. Notably, the types of technology being invested in have changed over the years, with the dramatic decrease in nuclear energy investments and the wide range increase of low-carbon technologies including renewables, energy efficiency, storage, and hydrogen. Figure 3 below displays this change in public energy RD&D investments between 1976, 1996, and 2016.[11] During the QNDCC panel session discussion, Mr. Laurent Furedi - Country Manager at Engie Qatar – provided a corporate reflection of these RD&D results. Mr. Furedi discussed Engie's plans to achieve carbon neutrality by 2045 through exploring means to diversify energy utilization away from coal, experiment with synthetic fuels, and explore carbon capturing technologies.

Figure 3 The change in public energy RD&D investments between 1976, 1996, and 2016. [12]



[10] Federico Ferrario, "Infrastructure solutions: Power for clean energy innovation," European Investment Bank, (September 2022). https://www.eib.org/en/essays/green-energy-innovation

[11] Mathew Hannon and Ronan Bolton, "Energy Innovation and the Sustainability Transition," Handbook of Energy Economics and Policy: Fundamentals and Applications for Engineers and Energy Planners (1st Edition), Academic Press, 2021. https://pure.strath.ac.uk/ws/portalfiles/portal/112897884/Hannon_Bolton_AP_2021_Energy_innovation_and_the_sustainability.pdf

[12] Ibid.

In 2022, the top 5 national budgets for RD&D in energy technology have been the United States, France, Japan, Germany, and the United Kingdom in decreasing order. All of these countries have allocated over one billion USD to explore diverse energy focuses and technologies. In 2022, energy efficiency RD&D received the highest total allocated budget of 5.8 billion USD, followed by nuclear fusion and fission, renewable energy sources, hydrogen and fuel cells, as well as other cross-cutting technology and research.[13]

Qatar has also prioritized its investment in environmental sustainability research. In the QNDCC panel session discussion, Professor Mariam Al-Maadeed - Vice President for Research and Graduate Studies at Qatar University - discussed Qatar University's (QU) opening of various research centers such as the Gas Processing Center (GPC), the Environmental Science Center (ESC), and the Center for Sustainable Development to explore sustainability opportunities. Since the energy sector, and natural gas in particular, is very important for Qatar's economy, the Gas Processing Center was established in 2007 by QU's Board of Regents, chaired by Qatar's Emir Sheikh Tamim Bin Hamad Al-Thani. The center addresses the challenges and opportunities Qatar's gas processing industry faces, and it focuses on two main themes: asset management/process optimization and sustainable development. Moreover, the objective of the center is to facilitate research and development in areas pertinent to its consortium members and provide pilot plants for scalable trials of numerous processes, acting as a regional leading research center and offering market-led opportunities for growth.[14]

Professor Mariam Al-Maadeed also expanded that QU provides numerous internal and external grants to support students and academics researching sustainability in applicable practices. The Quintuple Helix innovation framework that QU has adopted is key in forming connections between education, research, services, culture, and the environment. In addition to collaborating with public and private institutions, QU has partnered with international organizations such as the United Nations (UN), with the formation of Industrial chairs with the United Nations Educational, Scientific and Cultural Organization (UNESCO). Another example is the Academic Network for Development (AND) which is a network for academic collaboration between QU and the UN. Supporting grassroots and internationally collaborative research is crucial for the advancement of sustainable technology and practices across all sectors, especially in energy.

Recently, the most prominent renewable energy technologies involve biomass, geothermal, hydropower, solar photovoltaic (PV), concentrated solar power (CSP), offshore wind, and onshore wind energy. Over the last decade, 4 out of 6 of these technologies have become cheaper and more competitive on a cost basis without the need for government subsidies, excluding geothermal and hydropower technologies. Table 1 below further details the different types of renewable energies and the methodologies for their generation and application.

Table 1: Prominent Renewable Energy

Biomass	A renewable, organic substance derived from plants and animals. Biomass contains stored chemical energy from the sun as a result of photosynthesis. It can be utilized by directly burning it or transforming it into liquid and gaseous fuels. Sources of biomass include: wood and wood processing waste, agricultural crops and waste, biogenic material in municipal solid waste, animal manure, and human sewage. [15]
Geothermal	Energy derived from the Earth's heat that utilizes reservoirs of hot water found naturally or created at different depths. The continuous flow of heat from the Earth's interior, sustained by the decay of radioactive elements, ensures a long-term and renewable energy source. Wells, drilled to varying depths, can harness steam and hot water from underground reservoirs for diverse applications, such as electricity generation, direct use, and heating and cooling.[16]
Hydropower	One of the earliest and largest renewable energy sources, harnessing the natural movement of water to generate electricity. Facilities can vary in size, from large dams to small installations utilizing water flows in municipal systems or irrigation channels. This technology exploits the elevation difference created by dams or diversion structures to generate power. Apart from its cleanliness and cost-effectiveness, hydropower provides immediate grid support and offers benefits like flood control, irrigation support, and water supply.[17]
Solar PV	A non-mechanical device that transforms sunlight, and occasionally artificial light, directly into electricity. The semiconductor materials within the PV system capture photons from sunlight, which carry varying energy levels. Larger PV systems have the capacity to generate electricity for water pumping, powering individual homes or businesses, or supplying electricity to numerous consumers. These systems can directly contribute electricity to an electric power grid as well as function in areas without established electricity distribution systems.[18]
CSP	A method of electricity generation using mirrors to reflect and concentrate sunlight onto a focal point, converting it into heat. This heat is utilized to produce steam which drives a turbine for electrical power generation. The stored heat enables continuous operation, allowing CSP technology to function on days without sunlight or during periods before sunrise and after sunset.[19]
Offshore Wind	Energy derived from the force of winds out at sea and transformed into electricity that is supplied to the onshore electricity network. Megastructures are installed in designated sea areas and equipped with the latest technologies to withstand difficult conditions and convert the wind into an electric current. [20]
Onshore Wind	Energy derived from the natural movement of winds over land and transformed into electricity that is supplied to the electricity network. Onshore wind farms are easier to install and much less expensive than offshore wind structures. The level of electricity generated, however, is often less than offshore wind facilities due to the usually less powerful in-land winds. [21]

[13] IEA, "Energy Technology RD&D Budgets Data Explorer," Last Updated October 2023. https://www.iea.org/data-and-statistics/data-tools/energy-technology-rdd-budgets-data-explorer

[14] GPC, "About Us," Qatar University: Research and Graduate Studies. https://gpc.qu.edu.qa/sites/en_US/research/gpc/about

[15] EIA, "Biomass Explained," Independent Statistics and Analysis, Last Updated June 2023. https://www.eia.gov/energyexplained/biomass/

[16] EERE, "Geothermal Basics," United States Energy Departments. https://www.energy.gov/eere/geothermal/geothermal-basics#:~:text=Geothermal%20energy%20is%20heat%20energy,depths%20below%20the%20Earth's%20surface

In addition to adopting new solutions, it is important for the energy sector to consider the decarbonization transition an overall systematic change. Applying new technology is not as simple as plugging in new power plants or parts and continuing operations; these novel solutions are different machines with different mechanisms and conditions to operate. Thus, the energy sector must consider a holistic adaptation strategy to upgrade its current practices in transforming, transporting, storing, and using energy.[22] Moreover, the clean energy transition requires "transformational change across a myriad of social and technical dimensions, including policy, markets, culture, science and user preferences." [23]

[17] EERE, "Hydropower Basics," United States Energy Departments, https://www.energy.gov/eere/water/hydropower-basics

[18] EIA, "Solar Explained," Independent Statistics and Analysis, Last updated May 2023. https://www.eia.gov/energyexplained/solar/photovoltaics-and-electricity.php#:~:text=A%20photovoltaic%20(PV)%20cell%2C,converts%20sunlight%20directly%20into%20electricity.

[19] Brunel, "Concentrated Solar Power (CSP), Explained," (March 2021). https://www.brunel.net/en/blog/renewable-energy/concentrated-solar-power

[20] Iberdola, "What is Offshore Wind Energy?" https://www.iberdrola.com/sustainability/how-does-offshore-wind-energy-work

[21] National Grid, "Onshore Vs. Offshore Wind Energy: What's the Difference?" Last Updated March 2022. https://www.nationalgrid.com/stories/energy-explained/onshore-vs-offshore-wind-energy

[22] Federico Ferrario, "Infrastructure solutions: Power for clean energy innovation," European Investment Bank, (September 2022). https://www.eib.org/en/essays/green-energy-innovation

[23] Mathew Hannon and Ronan Bolton, "Energy Innovation and the Sustainability Transition," Handbook of Energy Economics and Policy: Fundamentals and Applications for Engineers and Energy Planners (1st Edition), Academic Press, 2021. https://pure.strath.ac.uk/ws/portalfiles/portal/112897884/Hannon_Bolton_AP_2021_Energy_innovation_and_the_sustainability.pdf

Sector Innovations in Climate Change

The Industrial Sector

Industrial development has played a significant role in advancing the global economy, guiding governments and business activities, and impacting the working citizens of different countries. Activities within the industrial sector include the manufacturing, processing, production, formulating, assembling, repairing, ornamenting, finishing, transforming, recycling, or the research and development of any goods, substance, food, products, or articles for commercial purposes. While industrialization evidently drives economic growth, it is also a contributing source to climate change, responsible for 24% of global carbon emissions.[24] Therefore, it is crucial for the industrial sector to explore innovative solutions to reduce its impact on climate change whilst meeting market demands.

For Qatar, the development of the industrial sector is considered integral to overall national development and achieving self-sufficiency. The government recognizes the unyielded potential in national industrial transformation, and it has facilitated the cross-sectoral collaboration of industry sectors, the private sector, academia, and the government to develop such opportunities. In the panel session, H.E. Mr. Saleh bin Majed Al-Khulaifi - Assistant Undersecretary for Trade Affairs at the Ministry of Commerce and Industry (MOCI) – discussed how the Ministry has placed strict environmental regulatory policies for the industrial sector that define the way specific factories are permitted to operate. Such policies include a highly controlled heavy emission licensing process. Nonetheless, H.E. Mr. Al-Khulaifi recognized that the current policies have limitations and can be further enhanced to reflect global changes in industrial practices and frameworks. Additionally, MOCI is taking notable steps to support commercial firms in optimizing their efficiency by implementing sustainable practices that align with QNV 2030. To actualize such sustainable transitions, the Ministry is working to create a bridge between academics and manufacturers to develop meaningful and impactful synergies.

One result of the cross-sectoral collaboration was presented on May 31st, 2022, with the launch of Qatar's Advanced Manufacturing Hub (AMHUB). The hub was launched by MOCI in cooperation with Qatar Development Bank (QDB) in partnership with the World Economic Forum (WEF), and it is a part of the 13 global platforms initiated by WEF to advance the international industrial sector through knowledge exchange, addressing challenges like workforce issues, government policies, and environmental concerns both in Qatar and internationally. Positioned as a regional sectoral-research leader, AMHUB aims to elevate Qatar's manufacturing system by enhancing efficiency and fostering growth, particularly in alignment with Fourth Industrial Revolution trends. [25]

A large range of emerging technologies show significant promise in decreasing industrial GHG emissions through innovative advancements. Such technologies are often grouped into different categories depending on their objectives, such as energy efficiency, fuel switching, and power recovery. Within each category, some technologies are widely applicable across different industries, such as the utilization of efficient electric motors for motor systems. Other technologies, like the top-gas pressure recovery in blast furnaces, are very process-specific within particular industries. [26]

Out of the different emerging industrial innovations, 3D printing is a prominent sustainable solution in manufacturing processes. Additive manufacturing, commonly known as 3D printing, constructs three-dimensional objects layer by layer through computer-generated designs. This process involves depositing, joining, or solidifying material under computer control. 3D printing significantly reduces carbon footprints through efficient energy and material use in additive manufacturing processes. The technology also generates minimal waste, utilizing hollow infill structures to further reduce material consumption and allow manufacturers to produce only what is essential. Additionally, 3D printing eliminates carbon-intensive supply chain activities associated with traditional manufacturing. By enabling versatile point-of-need fabrication, 3D printing reduces the environmental impact by cutting out the need for multiple carbon-heavy steps, thereby enhancing overall operational efficiency. [27]

[24] EPA, "Global Greenhouse Gas Emissions Data," United States Environmental Protection Agency: Global Emissions by Economic Sector, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Reference%201

[25] MOCI, "Ministry of Commerce and Industry & Qatar Development Bank launch Qatar's Advanced Manufacturing Hub," (May 2022). https://www.moci.gov.qa/en/mec_news/ministry-of-commerce-and-industry-qatar-development-bank-launch-qatars-advanced-manufacturing-hub/

[26] Lenny Bernstein et al., "Industry," In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (2007), https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter7-1.pdf

[27] AMFG, "How Sustainable is Industrial 3D Printing?" (March 2020). https://amfg.ai/2020/03/10/how-sustainable-is-industrial-3d-printing/

The integration of 3D printing and multi-material structures has given rise to 4D printing, an additive manufacturing method where the printed object undergoes shape changes in response to time, temperature, or other stimuli. 4D printing enables the creation of dynamic structures with adaptable shapes, properties, or functionality. This technology facilitates the customized printing of shape-changing and shape-memory materials, opening possibilities for new applications and uses in various industries, including space, commercial, and medical fields. The potential of 4D-printed objects to alter shape or properties in response to stimuli offers the opportunity to develop dynamic structures that demand reduced energy for specific functions. For instance, adaptive building designs could optimize heating or cooling needs, thereby enhancing energy efficiency. Furthermore, incorporating 4D-printed materials designed for self-repair or extended durability can extend product lifecycles, decreasing the need for frequent replacements and lessening the environmental impact associated with manufacturing new products. [28]

In addition to technological innovations, companies in the industrial sector continuously benchmark and develop internal management practices to improve their general approach to efficiency, energy conservation, and sustainable integration. Energy audit and management systems, for example, can help companies recognize opportunities to decrease their energy utilization, leading to notable emission reductions. Additionally, more companies over the past decade have implemented a GHG inventory and reporting system to better understand the sources and intensity of their emissions and contribution to climate change. The knowledge of the company's operational environmental consequences allows it to develop business strategies to adapt to changing government and consumer requirements.[29]

Different sector-specific protocols for inventory development and sustainability reporting have been created and used by different industries. In the industrial sector, the Greenhouse Gas Protocol developed by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) is an internationally recognized and recommended protocol for companies to follow. By adopting such innovative management system approaches to mitigating climate change in supplement with technological innovations, the industrial sector can assuredly transition alongside other economic sectors to more sustainable and decarbonized productivity.[30]

The Agricultural Sector

The agricultural sector should be a primary focus when researching and implementing innovative sustainability solutions. The sector is especially vulnerable to climate change, including changes in temperatures, soil health, water availability, invasive pests, and frequent extreme weather events. Any resulting changes to weather conditions can lead to global food shortages, economic declines, industrial raw material supply shocks, and trade reductions, thus negatively impacting the nation-state as a whole and its individuals' livelihoods.[31]

Due to their hyper-arid, dry, and hot climate, countries in the Gulf Cooperation Council (GCC) are particularly vulnerable to negative weather changes as the region is already disadvantaged in natural freshwater resources and agricultural cultivation. These factors pose great challenges for the region and require innovative strategies to tackle the issue of water scarcity and food insecurity, all the while achieving an environmentally sustainable model of farming.[32]

Beyond the importance of its maintenance for national food security, it is vital for states to adopt sustainable innovations in the agricultural sector due to its major contribution to GHG emissions, both directly (through on-farm production emissions) and indirectly (through land clearing due to agricultural expansion), as agriculture, forestry, and other land use account for 22% of global GHG emissions. [33]

[28] Ali Akbar Firoozi, Ali Asghar Firoozi, "A systematic review of the role of 4D printing in sustainable civil engineering solutions," Heliyon, Volume 9, Issue 10, (2023), https://www.sciencedirect.com/science/article/pii/S2405844023081902

[29] Lenny Bernstein et al., "Industry," In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (2007), https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter7-1.pdf

[30] Ibid.

[31] OECD. "Agriculture and Climate Change." Meeting of Agriculture Minsters. (2022). https://www.oecd.org/agriculture/ministerial/documents/Agriculture%20and%20Climate%20Change.pdf

[32] Tarek Ben Hassen, Hamid El Bilali, and Mohammed Al-Maadeed, "Agri-Food Markets in Qatar: Drivers, Trends, and Policy Responses," Sustainability 12, no. 9: 3643, (2020). https://doi.org/10.3390/su12093643

[33] Ibid.

Despite its significant impact and vital potential, the agricultural sector falls behind other industries in terms of making commitments and taking action to address climate change. As of mid-2022, only 16 countries among the Organisation for Economic Co-operation and Development (OECD) and major emerging economies had established emission reduction goals specifically for agriculture. Unlike other sectors, agriculture is typically not subject to mitigation policies like carbon pricing or comparable regulatory measures. Additionally, only a limited number of countries utilize targeted subsidies to encourage mitigation efforts. Although agriculture receives substantial policy support, a minimal portion of it is directed toward fostering innovation or aligning with climate objectives.[34]

Academia plays a pivotal role in advancing sustainable agricultural research and technological development opportunities. Professor Mariam Al-Maadeed - Vice President for Research and Graduate Studies at Qatar University – discussed the different ways QU invests in agricultural research opportunities and supports sustainable RD&D within the sector. The Agricultural Research Station (ARS), for example, was established in 2020 to explore innovative agricultural technologies that can optimize natural resource utilization and address Qatar's challenges of cultivating dry lands such as advanced irrigation systems, integrated pest management and plant disease control, organic fertilizer production in farms, and testing agricultural technologies suitable for Qatar's climate.

As a result of the ARS's fruitful efforts, QU has had successful trials with vertical farming, improving date plant farming, coffee waste recycling, and algae cultivation. In the third session of the QNDCC 2023 on Water and Food Security, Dr. Kira Schipper - Research Associate at QU's Centre for Sustainable Development – further described the unique potential for biological innovation in Qatar's environment, given the presence of microalgae and cyanobacteria that thrive in the region's hot and dry climate. These organisms are useful for absorbing CO_2 from the environment and converting it into biomass, absorbing nutrients from wastewater to promote a circular economy, and serving as a source for sustainable feed production.

Out of the numerous emerging sustainable agricultural innovations, precision agriculture (PA) has emerged as a popular and beneficial approach that leverages technology to observe, measure, and respond to variability within and between fields. Throughout the farming process, sensors, satellites, and drones collect data to enable predictive analytics software to guide farmers on crop rotation, planting, harvesting, and soil management. By utilizing information technology (IT) and specialized equipment, PA accesses real-time data on crop and soil conditions so they receive optimal care, fostering productivity, profitability, and environmental protection.[35]

Aquaponics, an integration of hydroponics and aquaculture, is also another prominent agricultural innovation distinguished by its sustainability and minimal upkeep. Within this micro-environment, fish waste functions as fertilizer for plant crops and the plants reciprocally cleanse the water, establishing a self-contained cycle. This closed-loop system results in the reuse of approximately 95-99% of water, a notable advantage compared to the daily water disposal in traditional agriculture. Moreover, aquaponics necessitates less intricate plant maintenance in contrast to hydroponics, as the fish inherently supply essential nutrients. The system's adaptability ranges from small home setups to expansive industrial configurations, and its enduring sustainability hinges on effective nutrient recycling, water reuse, and decreased resource utilization, effectively addressing global water scarcity concerns. Ultimately, aquaponics provides space-efficient solutions that can adapt to diverse environments, mitigating the need for deforestation and streamlining food supply chains, effectively contributing to eco-friendly urban living.[36]

Conclusively, sustainable adoption of innovative solutions in different sectors is conditional upon the willingness of the state, businesses, academia, and citizens to collaborate toward effective sustainability transitioning. These mentioned initiatives in Qatar and around the world demonstrate diverse ways countries and sectors have invested in research and utilized new technologies to continue their economic advancement whilst mitigating their impact on climate change. In addition to such innovative solutions, there are different options states can explore to expedite this sustainable transformation process in order to meet their sustainability goals.

[34] Ibid.

[35] Ivy Wigmore, "What is precision agriculture?" Tech Target. https://www.techtarget.com/whatis/definition/precision-agriculture-precision-farming#:~:text=Precision%20agriculture%20uses%20information%20technology,and%20protection%20of%20the%20environment.

[36] Erin Yoo, "Aquaponics: An Emerging Method for Food Sustainability," Hadron, (February 2022). https://sites.imsa.edu/hadron/2022/02/01/aquaponics-an-emerging-method-for-food-sustainability/

Challenges in Implementing Innovative Solutions

Countries face numerous challenges when implementing innovative solutions to different sectors, but the obstacles are often interconnected as they reflect a larger, shared experience on a global scale. Some of the most common global challenges to implementing innovative solutions include:

- **Resistance to Change:** Altering long-held understandings of accepted operational practices and technological utilization might face resistance to change from individuals, communities, industries, and even governments. This resistance can be due to internal limitations of fear of experimentation, skill incapacity, or the lack of motivation and perception of importance. External limitations also play a barrier role in implementing innovative solutions, such as bearing high costs of implementation and transitions and a lack of clear sector or government guidance and incentivization.

- **Financial Barriers:** Across different industries, implementing innovative solutions requires a high initial financial and resource investment. The capital-intensive nature of adopting and scaling innovative technologies is especially challenging to companies operating in sectors undergoing transformational changes, such as the energy or manufacturing industry, since they need to balance between allocating innovation funds amidst other operational costs. This financial requirement becomes particularly difficult in the context of developing countries, where economic resources may be limited.

- **Infrastructure Challenges:** Numerous countries and industries may have inadequate and outdated infrastructure that can inhibit the implementation of innovative solutions. As such, the infrastructure would either require to be updated or rebuilt to accommodate the modern technologies and operational practices, which would be financially burdening and time-intensive, requiring strategic, long-term planning. For example, the traditional setup of energy infrastructures can limit the deployment of renewable energy technologies, whether it be hydropower, offshore wind, or solar panels.

- **Technology Transfer:** The topic of developing and implementing innovative solutions often highlights the international disparities between countries. While developed countries often spearhead the research and development of technological solutions that can optimize their resource utilization, cut costs, and mitigate climate impacts, developing countries usually lack in resources and technology to adopt large-scale innovations. Moreover, the transfer of innovative technologies from developed to developing countries can be challenging due to issues related to intellectual property rights, knowledge sharing, and the capacity of recipient countries to effectively adopt and integrate new technologies.

- **Workforce Capacity Constraints:** Beyond successfully financing innovation applications, developing needed infrastructures, and transferring effective technologies, many countries may lack the technical expertise and capacity required to implement and manage innovative solutions. As such, companies in different sectors would need to train their employees and expand their skills and knowledge sets to be able to operationalize the new technologies. This requires both time and resources, and they may incur short-term costs for companies to improve their employee capacity.

Recommendations for Implementing Innovative Solutions

1. Multifaceted Approach to Overcoming Resistance to Change
To overcome the challenges associated with resistance to change in implementing innovative solutions for climate change mitigation, it is crucial for governments to adopt a multifaceted approach. Initially, governments should develop and implement targeted awareness campaigns and educational programs to address the internal limitations stemming from fear of experimentation, skill incapacity, and a lack of motivation. These awareness campaigns would foster a comprehensive acknowledgment of the importance and benefits of innovative solutions across diverse stakeholders, including individuals, communities, and industries. In Qatar, collaboration with institutions like the Qatar Environment and Energy Research Institute (QEERI), the Qatar National Research Fund (QNRF), and Earthna can enhance the development of these targeted awareness campaigns and educational programs and tailor them to suit the local audience. While events like the QNDCC are great examples of enlightening local industries and communities about national targets, initiatives, commitments, and progress, more systematic educational programs are needed to actualize real and long-lasting sustainable change within Qatar.

Simultaneously, the government can address external limitations through the development of supportive policies, regulatory frameworks, and clear sector-specific guidance to help develop and implement sustainable solutions. In Qatar, collaboration with the Ministry of Municipality, and the Qatar General Electricity and Water Corporation (KAHRAMAA) is crucial to align national targets and develop clear and comprehensive sustainability policy frameworks. Sectors can also benchmark internationally recognized guiding frameworks to understand where they stand in terms of sustainable performance, how they can improve to align themselves with up-to-date, best practices, and how to report their progress. Such frameworks and standards include the Carbon Disclosure Project (CDP), the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and the Greenhouse Gas Protocol.

In addition to guiding frameworks, the government can explore different ways, both financial and non-financial, to incentivize its sectoral stakeholders to embrace sustainable change and implement innovative solutions. Financially, the state can offer to subsidize parts of the transitioning process or administer tax cuts to companies implementing sustainable solutions. Entities such as Qatar Financial Centre (QFC), the Ministry of Finance (MOF), and Qatar Development Bank (QDB) can collaborate to develop funding mechanisms to help alleviate costs of sustainable transitions and implementations. Non-financially, the state can develop acknowledgment and award programs to celebrate the most progressive companies that have applied and reported on their sustainability transition. Overall, overcoming such resistance to change requires effective communication, stakeholder engagement, and influential incentivization.

2. International and Local Innovation Financing
To address the financial barriers associated with implementing innovative solutions for climate change mitigation, countries can foster international cooperation to mobilize financial resources and facilitate knowledge-sharing. Developed countries can especially help developing countries by financially supporting the innovative sustainability transition, either through direct financing, providing equipment, or offering technical assistance. In Qatar, leveraging the expertise of institutions like the Qatar Investment Authority (QIA) and the Qatar Financial Centre (QFC) can help mobilize and allocate local financial resources and facilitate cooperation with international financing institutions. Moreover, countries can explore partnership programs where mutual benefit is acquired as a result of enhancing industry operations relevant to their economic and environmental needs.

Locally, national entities such as Qatar Central Bank (QCB) and Qatar National Bank (QNB) can promote innovative financing mechanisms within the country by exploring the issuance of green bonds, establishing public-private partnerships, and setting up climate funds that can attract private-sector investments for climate-friendly technologies. Additionally, the government can offer to partially carry the cost of sustainability transitioning and technological implementation through a sustainability subsidization program, coordinated by entities like MOCI. This program can offer companies incremental subsidies based on the degree of operational transformation and its level of impact on sustainable climate mitigation. This can motivate companies in different sectors to explore transformational sustainability strategies and lead the initiative to innovate their operational and corporate practices. Through these collaborative efforts, countries like Qatar can effectively address financial barriers and stimulate a transformative shift towards sustainable and innovative climate solutions.

3. Revising Strategic Objectives and Planning Infrastructural Upgrades
To diminish the challenges associated with inadequate and outdated infrastructure hindering the implementation of innovative climate solutions, countries and industries should prioritize the modernization and upgrade of their existing company infrastructures to align with their objectives and requirements for innovative applications of new technology, machinery, or sustainable materials. In Qatar, national entities such as Kahramaa and the Public Works Authority (Ashghal) can help different companies and organizations comprehensively assess their current infrastructure capabilities, short-term and long-term, state objectives and targets, and strategic planning to guide national industries toward initiating the necessary updates. Local governments can help sectors facilitate this process by publishing clear policies, regulations, and incentives that require and promote the integration of innovative technologies into infrastructure development plans.

Moreover, national policies and regulations can easily target newer establishments by requiring them to build their infrastructures with the latest sustainability guidelines able to accommodate newer technologies. International collaboration and knowledge-sharing can also help industries identify best practices for infrastructure upgrades, allowing nations to learn from successful experiences. In sectors where infrastructure requires significant transformation, such as the energy sector, government political and financial support are fundamental for the successful upgrade, and heavy subsidization might need to be introduced to actualize and protect the national interests within these sectors. Through a coordinated effort involving such national entities and initiatives, countries can address infrastructure challenges and create a conducive environment for the successful integration of innovative technologies, successfully advancing their commitment to sustainability.

4. Global Cooperation and Partnerships
To alleviate the international discrepancies in developing and implementing innovative climate solutions, global cooperation is crucial to facilitate the technological transfer to developing countries lacking in research and development capabilities. This can involve establishing mechanisms that streamline the sharing of knowledge, expertise, and innovations between countries with mutual sectoral interests and bilateral partnerships. In Qatar, the QNRF, QEERI, and Earthna can play pivotal roles by fostering regional and international cooperation, knowledge and technology exchange, and innovative research. Countries can also explore developing a framework that balances the protection of intellectual property and the free flow of innovative technologies for the overarching goal of mitigating climate change. In addition to these governance and sectoral collaborations, the collaboration between academia and industry plays a pivotal role in the development, promotion, and transfer of sustainability solutions and technologies. This cooperation serves as a crucial bridge between theoretical knowledge and practical applications, and it facilitates the transfer of academic research into real-world solutions.

Locally, the Qatar Science & Technology Park (QSTP) can function as a collaborative hub enjoining academia and industry research to provide a platform for knowledge exchange and facilitate joint research projects. Academic partnerships can also be formed between institutions in different countries to enable diverse perspectives, expertise, and resources to address complex sustainability challenges. As such, countries can consider establishing or cooperating with the Centers for the Fourth Industrial Revolution (C4IR), founded by the WEF. These centers serve as a global platform to help countries improve their technological governance and digitally transform their industries, economies, and societies. Establishing such a center can greatly aid in the actualization of national goals through the access to a large set of expertise and networks that can focus on themes directly affecting national interests and continuously enhance present national strategies to reflect ongoing technological, social, and economic changes. Ultimately, a cross-industry and inclusive approach is key to overcoming disparity obstacles in technological access and ensuring the widespread implementation of sustainable innovations.

5. Collaborative National and Sectoral Capacity Building
To overcome the challenges associated with capacity building for the implementation of innovative solutions to mitigate climate change, governments and industry stakeholders should prioritize investing in educational and training programs to enhance the technical expertise of the national workforce, especially in fields crucial to the national interests and economy. Such programs should

Recommendations for Implementing Innovative Solutions

be developed in collaboration with academic institutions, industry associations, and government bodies to note specific skill gaps in the workforce, research optimal capacity development methodologies, and establish training resources and mentorship programs. Companies can incentivize their employees to expand their knowledge and skill sets by introducing special promotion programs that increase the remuneration and benefits of newly skilled employees. Additionally, internal recognition systems that highlight exemplary employees can incentivize them to continuously learn and develop their capabilities.

Governments can also motivate companies to invest in employee training and national capacity development through similar incentivization programs: offering tangible benefits such as tax discounts and project-tender prioritization, or non-tangible benefits such as national recognition and certification programs. Moreover, public-private partnerships can further enhance employee sustainability skills and knowledge sets by organizing sector-specific conferences and workshops that teach and train employees within a specific sector on the latest practices and technological operations. By addressing national and sectoral capacity constraints through strategic investments, collaborative programs, and learning initiatives, a skilled workforce can effectively implement and manage innovative solutions for climate change mitigation.

In Qatar, entities such as the Ministry of Labor, MOCI, and the Qatar Chamber of Commerce and Industry, in conjunction with academic institutions such as Qatar University, Hamad Bin Khalifa University, and Georgetown University in Qatar, can take the lead in developing targeted educational and training programs to enhance the technical expertise of the national workforce, particularly in fields crucial to national interests and the economy. The Social and Economic Survey Research Institute (SESRI), a social scientific survey research initiative of Qatar University, can help administer national surveys and analyze data related to such labor gaps to support the formation of data-based insights for policy recommendations.

Conclusion

In conclusion, this White Paper emerges from the insightful discussions of the third annual Qatar National Dialogue for Climate Change (QNDCC) panel session on “Innovations in Climate Change.” The extensive exploration undertaken in this analysis reflects a meticulous examination of sustainable innovations, offering prescriptive recommendations aligned with Qatar’s national sustainability objectives and national interests. Emphasizing the immediate need for a paradigm shift in adopting innovative solutions, the paper focuses on key sectors-Energy, Industrial, and Agricultural-highlighting technological implementations for renewable energy, resource-efficient manufacturing, and advanced agricultural methodologies. The outlined recommendations, ranging from fostering international and local innovation financing, strategic infrastructure planning, global and intersectoral cooperation, and collaborative capacity building, pave a path for Qatar to emerge not only as a climate-conscious global player but also as a pioneer in sustainable development, aligning seamlessly with its ambitious QNV 2030.

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Contributors

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