MULTILATERAL
COOPERATION CENTER
FOR DEVELOPMENT FINANCE

CLIMATE-SMART CONNECTIVITY INFRASTRUCTURE

BEST PRACTICES AND CASE STUDIES

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Foreword

The world faces two formidable challenges that have caused economic bottlenecks and devastated people's lives: climate change and a lack of adequate connectivity infrastructure. The intensity and frequency of extreme drought and rainfall have sharply increased over the past 20 years due to global warming. China — where Multilateral Cooperation Center for Development Finance (MCDF) is located — has experienced both drought and flooding this year, mirroring a similar reality across several regions worldwide. More frequent and intensified natural disasters widen the chasm between the investments needed to achieve the United Nations' Sustainable Development Goals (SDGs) and the resources available. Urgent action is required to bridge this gap.

MCDF aims to help promote the SDGs through high-quality and sustainable connectivity infrastructure. We seek to facilitate such urgent action and believe enhancing infrastructure quality and connectivity can empower countries to better adapt and increase their resilience to climate shocks. To combat climate change, carbon emissions can be reduced by improving trade efficiency, transmitting green energy across borders and digitalizing data flows. For investors, this presents more sustainable — and therefore more attractive — prospects.

However, the linkage between connectivity investment and climate action requires more focus. For this reason, MCDF and our partners — the Egyptian Ministry of Finance, Asian Infrastructure Investment Bank (AIIB), Islamic Development Bank (IsDB), Vulnerable Twenty (V20) Group, World Bank and the World Resources Institute — co-organized a five-part workshop series. Through 45 case studies and thematic analyses, we have discovered how to expand regional connected networks in climate-smart ways and provide co-benefits. This publication summarizes the key messages from the workshops.

The culmination of the workshop series was a high-level event at the Climate Conference COP27 in Egypt. The heads of delegations of our partners (including China, Egypt, Liberia, AIIB, IsDB and the World Bank) spoke passionately about the importance of climate-smart connectivity infrastructure and their desire to continue working with MCDF. Fueled by their support, MCDF is committed to applying the lessons in this publication to help partner countries and organizations integrate climate action in connectivity infrastructure projects.

We hope governments, investors and communities adopt and replicate these lessons to reduce the emissions associated with connectivity infrastructure and prepare these projects for the growing impacts of climate change.

Zhongjing Wang
Chief Executive Officer
Multilateral Cooperation Center for Development Finance

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Workshop 1

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Workshop 2

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World Bank. Waleid Gamal El-Dien, Vice-Chairman, Investment and Promotion Affairs, General Authority of the Suez Canal Economic Zone (SCZONE). Kushaal Raj, Acting Head of Climate Change and International Cooperation Division, and Ocean Specialist, Ministry of Economy, Fiji. Dzung Huy Nguyen, Senior Disaster Risk Specialist, World Bank.

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Workshop 4

Monika Merdekawati, REE Department, ASEAN Center for Energy. Su Han, Head, East Asia and Pacific, NDB. Danwei Zhang, NDB. Claire Nicolas, Senior Energy Economist, Energy Sector Management Assistance Program, World Bank. Madeline Macmillan, Advanced Energy Systems, Colorado School of Mines and the National Renewable Energy Laboratory. Matthew Wittenstein, Chief of Energy Connectivity Section, Energy Division, UNESCAP. Hussein Mogaibel, Lead Global Energy Specialist, IsDB. Michael O. Sinocruz, Director, Energy Policy and Planning Bureau, Department of Energy, Philippines. Tilana De Meillon, Senior Operations Officer, Upstream, International Finance Corporation (IFC). Ms. Marwa Khalil, Operations Officer, IFC. Dr. Dimitris Mentis, Lead, Energy Access Explorer, WRI.

COP27 Finance Day Event

H.E. Dr. Mohamed Maait, Minister of Finance, Egypt. H.E. Xie Zhenhua, China Special Envoy for Climate Change. Hon. Ruth Coker-Collins, Minister of Public Works, Liberia. Dr. Muhammad Sulaiman Al Jasser, President, IsDB. Jin Liqun, President, AIIB. H.E. Ahmed Kouchouk, Vice Minister of Finance for Fiscal Policies and Institutional Reform, Egypt. Axel van Trotsenburg, Managing Director of Operations, World Bank.

Abbreviations

AI	artificial intelligence
AIIB	Asian Infrastructure Investment Bank
AGV	automated guided vehicle
ASEAN	Association of Southeast Asian Nations
CHEC	China Harbour Engineering Company
CO_2	carbon dioxide
COVID-19	coronavirus disease
EIP	equal industrial park
EV	electric vehicle
GCF	Green Climate Fund
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
LNG	liquified natural gas
M	meter
MCDF	Multilateral Cooperation Center for Development Finance
MW	megawatt
MWh	megawatt hour
NDB	New Development Bank
NDC	Nationally Determined Contribution
PDR	People's Democratic Republic
R$	Brazilian Real
SDG	Sustainable Development Goal
SCZONE	Suez Canal Economic Zone
TEU	twenty-foot equivalent unit
USD	United States Dollars
WRI	World Resources Institute

Executive Summary

Climate change is a pressing issue that requires immediate action. Climate change has emerged as a critical global issue, necessitating immediate action and unwavering commitment. Its impacts are already being felt worldwide, resulting in increasingly frequent and intense extreme weather events that surpass earlier predictions. This unparalleled phenomenon endangers human lives and infrastructure and acts as a catalyst, exacerbating underlying societal challenges such as poverty and inequality. In order to meet the Paris Agreement goals it is imperative to eliminate emissions and enhance infrastructure resilience and adaptability across countries.

Connectivity infrastructure is poised to be pivotal in enabling countries to realize their commitments under the Paris Climate Agreement and achieve their net-zero targets. This significance stems from the fact that sectors reliant on connectivity infrastructure, such as energy and transport, presently account for over 70 percent of global greenhouse gas emissions.* These types of infrastructure have a long-life span, meaning that decisions taken today will have an impact for decades to come.

The link between connectivity infrastructure and climate change mitigation and adaptation is multifaceted. First and foremost, the transition to low-carbon and sustainable energy systems necessitates the development of robust and efficient energy connectivity infrastructure capable of facilitating the integration of renewable energy sources and smart grid technologies. By optimizing energy transmission and distribution, connectivity infrastructure can minimize energy losses and enhance overall energy efficiency, consequently reducing emissions.

Similarly, deploying connectivity infrastructure in transportation can revolutionize mobility patterns and contribute to decarbonization efforts. Smart transportation systems, encompassing intelligent traffic management, electric vehicle charging networks and multimodal connectivity, can optimize traffic flow, reduce congestion, and promote the adoption of cleaner transport alternatives. Such advancements curb emissions from the transport sector and enhance accessibility and efficiency, fostering sustainable urban development.

However, connectivity infrastructure faces increasing vulnerabilities and risks as climate change progresses. Rising sea levels, extreme weather events, and changing climatic patterns pose substantial threats to the resilience and functionality of these assets. The lifespan of connectivity infrastructure demands careful consideration of climate-related risks, ensuring that the design, construction and maintenance of these systems incorporate adaptive measures. This entails factoring in anticipated changes in temperature, precipitation patterns and sea levels to safeguard the longevity and effectiveness of connectivity infrastructure.

To achieve the goals outlined in the Paris Climate Agreement and meet their net-zero commitments, countries must prioritize developing and integrating climate-resilient connectivity infrastructure. This requires collaborative efforts between policymakers, industry stakeholders and financial institutions to channel investments toward sustainable and climate-smart projects. Additionally, fostering

* Hannah Ritchie, Max Roser and Pablo Rosado (2020) - "CO_2 and Greenhouse Gas Emissions." Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/co2-and-greenhouse-gas-emissions' [Online Resource]

innovation and technological advancements will be crucial in enhancing connectivity infrastructure's efficiency, resilience and environmental performance.

The Multilateral Cooperation Center for Development Finance (MCDF) and its partners organized a Workshop Series on Climate-Smart Connectivity Infrastructure to analyze these issues and enhance global capacity to implement solutions. MCDF's partners included the Egyptian Ministry of Finance, the Asian Infrastructure Investment Bank (AIIB), the Islamic Development Bank (IsDB), the Vulnerable Twenty (V20) Group, the World Bank and the World Resources Institute (WRI). The workshop was designed to share practical lessons from global experience and policy options for climate-smart connectivity infrastructure projects. The workshop series is also intended to build capacity and support the development of a pipeline of climate-smart connectivity infrastructure projects. This publication summarizes the key messages from the presentations and discussions, including the need to harness various solutions, such as **avoiding** and reducing the need for motorized travel, **shifting** to more environmentally friendly modes of transport and **improving** the energy efficiency of transport modes. Most transport mitigation interventions under nationally determined contributions (NDCs) are only in the "improve" category.

The workshop series was organized around connectivity infrastructure sectors and concluded with a high-level panel at the climate conference COP27 in Egypt. An overview workshop introduced key cross-cutting issues and concepts around climate change mitigation, adaptation, and finance and their relation to connectivity infrastructure. The following workshops included deep-dive discussions on coastal infrastructure and maritime transport, roads and railways, and energy. The report follows the workshop series structure, but some case studies have been moved to ensure the best fit. The report summarizes the workshops and presents various case studies that exemplify several essential lessons in practice.

The workshop series and COP27 event provided several key lessons, as outlined below. These are discussed in more detail within the report:

Lesson 1: Getting the Basics Right

Enforcing regulations, ensuring high maintenance standards and adequate funding are critical for infrastructure projects to withstand climate change impacts. Maintenance planning and addressing existing infrastructure vulnerabilities improve resilience and provide a four-fold return on investment.

Lesson 2: Designing for Uncertainty

Designing infrastructure to withstand a range of potential future scenarios is crucial. Robust design approaches, such as scenario planning and flexible infrastructure design, enhance adaptability and resilience in the face of uncertain climate impacts.

Lesson 3: Innovative Financial Models

Innovative financial models and public-private partnerships, exemplified by green bonds and private sector engagement, support climate project implementation while benefiting communities. Integration of climate risks and environmental protections into contracts promotes successful outcomes.

Lesson 4: Coordination is Key

Strengthening governance and institutional frameworks, including cross-ministry committees, enhances coordination and skill development for managing climate risks. Integration of climate objectives into medium-term national development plans fosters private sector involvement. Regional cooperation and incentivized public-private collaboration further promote equitable resource access and identify infrastructure needs.

Lesson 5: Improving Decision-Making through Data

Access to data and modeling improves decision-making for infrastructure projects. Adequate financing for master planning and climate risk assessments enables informed choices that enhance resilience and withstand climate change impacts. Providing clear information to the private sector reduces investment risks and yields economic and social benefits.

Lesson 6: Investing in Climate-Smart Infrastructure Makes Good Business Sense

Incorporating climate-smart methods into new infrastructure projects reduces avoidable costs and disruptions caused by climate impacts. Resilience investments yield a significant return on investment, protect industries and communities, and foster trade and congestion reduction. Meanwhile, investments in adaptation and mitigation can create efficiency, cost benefits and possible alternative income streams.

Lesson 7: Private Sector Finance Should be Leveraged

Leveraging private sector finance can reduce costs and speed up the delivery of projects. This can be done through public-private partnerships, changing procurement processes and innovative financial instruments. Additionally, leveraging private sector finance can enable governments to utilize technical knowledge that the private sector has developed to implement similar projects in other jurisdictions.

By implementing these lessons, countries can develop climate-resilient infrastructure, minimize costs, and protect communities and economies from the impacts of climate change. Collaboration between the public and private sectors, effective data utilization and robust planning are vital to achieving climate-resilient infrastructure worldwide.

1 Climate Change Challenges and Opportunities for Connectivity Infrastructure

1 Climate Change Challenges and Opportunities for Connectivity Infrastructure

1.1 Overview

Global warming is one of the most critical challenges in the world. The Intergovernmental Panel on Climate Change's (IPCC's) latest analysis indicates that the world will hit 1.5°C by 2030 and reach between 2.1°C and 3.5°C for intermediate greenhouse gas emissions (GHG) scenarios.[1] The projections are much worse in high GHG emission scenarios, with warming levels between 3.3°C and 5.7°C. The Paris Agreement warming goals are achieved only under the lowest emission scenario. This calls for decisive climate mitigation action and proactive climate adaptation measures. An integral part of the solution is decarbonizing and adapting the physical and digital systems that facilitate the transportation of goods, people and energy, or connectivity infrastructure.

Connectivity infrastructure plays a crucial role as part of the solution. The case studies and research findings illustrated the opportunity, technology, planning and policies for climate-smart connectivity infrastructure projects — that is, infrastructure resilient to damage caused by extreme weather, which reduces GHG emissions to the maximum extent possible. The discussion highlighted three lessons for emerging economies. First, focus on infrastructure programs with significant local benefits like reduced congestion or air pollution and reduced GHG emissions. Second, find better ways to target subsidies for greater economic efficiency. Third, consider new lower-carbon technologies with rapidly decreasing installation and operation costs.

Four key elements for climate policies in connectivity infrastructure sectors were identified. The workshop discussions highlighted these critical features needed for climate-smart connectivity infrastructure policies:

- Solid sector diagnostics must be explicitly integrated into medium-term national development plans
- Climate-compatible connectivity infrastructure strategies must involve several ministries, with coordination critical for success
- National connectivity infrastructure public investment programs must include all climate-related costs
- Incentive and subsidy policies may be required for specific and targeted support actions

1 IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-33, doi:10.1017/9781009325844.001.

1.2 Climate Mitigation

Connectivity infrastructure sectors offer several solutions for addressing climate issues. Climate mitigation actions in transport connectivity infrastructure include electric vehicles and trucks, renewal and expansion of electric railways, innovation in aviation fuels, multimodal transfer efficiency, and innovation in logistics and inland waterways as a lower-carbon freight transport alternative. In the energy sector, connectivity infrastructure actions include regional power pools, smart grids and hydropower on international waters. This section will draw on many of these technology options, highlighting their climate and economic and social benefits.

A key frame of reference on climate mitigation actions in connectivity infrastructure is Avoid-Shift-Improve by the World Resources Institute. Under this framework, climate mitigation actions can start by avoiding infrastructure investments that lock in countries and regions in high-carbon services, like highways or coal-fired power plants. Second, mitigation would involve gradually shifting modes of transportation and energy generation options to lower-carbon solutions at a pace commensurate with national commitments. And third, actions would improve the efficiency of existing high-carbon solutions while replacements are developed, for example, by improving the efficiency of fossil fuel-based transportation and energy efficiency of producers and consumers.

The cost of renewable energy has decreased rapidly in recent years, making it an increasingly attractive investment. As presented by IRENA, the adoption of renewable energy across the world has been a game changer, causing the cost of renewable energy production to become more economical than fossil fuels.[2] For example, the global price of photovoltaic technologies has fallen by 85 percent while other renewable energy, such as wind, has been reduced by up to 50 percent (footnote 2).This illustrates a clear opportunity for countries to simultaneously reduce costs and their emissions, transitioning to zero-carbon renewable energy sources. Case Study 1 illustrates how China has used these energy sources to increase capacity and decarbonize its electricity grid.

Although renewable energy has become more economically attractive than fossil fuels, it still faces major intermittency challenges; therefore, energy storage technologies are required. Despite the advantages of renewable energy, such as lower operational and maintenance costs, the energy generated from these sources is subject to fluctuations caused by the inconsistent availability of natural resources like wind and sunlight. To address this challenge, energy storage facilities and smart grid technologies, including demand-side management and distributed energy resources, need to be deployed.

Alternative zero-carbon fuels produced from renewable energy will also be a key solution to overcome renewable energy's intermittency constraints. Green hydrogen, ammonia and methanol are all emerging alternative zero-/low-carbon fuels that show promise as viable alternatives to traditional polluting fuel sources. These fuels can be produced from excess renewable energy and generate only water as a byproduct, provided that high standards and regulations are adhered

2 The Recent Evolution of Renewable Technology and the Implications for Connectivity Infrastructure (Video) Mr. Binu Parthan, Head of Regions of CEP, IRENA

to. However, the cost of producing alternative fuels from renewable sources is significantly higher than traditional fuel sources. As a result, initial analysis suggests that alternative fuels will likely be used in domestic applications or hard-to-abate sectors, such as shipping and steel production.

Robust national strategies combined with a clear regulatory framework will be required for these solutions to be adopted and decarbonization targets met. As discussed by WRI at the workshop, to ensure that the Paris Agreement temperature goals are met, ambitious visions will need to be adopted by countries with an accompanying policy and regulatory framework.[3] These policies and regulations must be clear and strive for common standards across territories. Furthermore, to ensure that the appropriate technologies are adopted and that costs continue to be reduced, the right institutions must be in place to implement policies that support the development and deployment of green transport technologies. This will include ensuring that countries coordinate globally to ensure that common standards are adopted where feasible — as without these, it can reduce the ability of broad supply chains and economies of scale to be developed in the electric vehicles industry.

The connectivity infrastructure sectors have meaningful opportunities to leverage climate action. For example, the World Bank presented a recent study showing how early combined planning of the highways, renewable energy, and IT sectors can yield even greater benefits. Actions such as the installation of solar panels in the right of way of highways, the development of an "Internet of Vehicles" (the equivalent of the Internet of Things for highways), and an advanced charging network for electric vehicles will reinforce the benefits of this "Tri-Network."[4] Furthermore, connecting renewable energy sources with consumers through regional and national interconnection networks is critical for climate action in the energy sector.

The experience of utilizing green bonds in Egypt has provided valuable lessons for implementing mitigation projects.[5] It has highlighted the importance of early engagement with environmental consultants, allowing for comprehensive assessment and planning to integrate environmental considerations effectively. This proactive approach ensures that projects align with sustainability goals and optimize their impact in mitigating climate change. The successful use of green bonds in financing diverse climate initiatives also demonstrates the potential of innovative financial mechanisms to mobilize resources for sustainable development and drive the transition to a greener economy.

3 Decarbonizing China's Road Transport Sector – Strategies toward Carbon Neutrality (Video) Ms. Lulu Xue, China Urban Mobility Manager, WRI

4 Integration of Tri-network for Decarbonizing Transport Connectivity (Video) Mr. Yanqin Song, Senior Energy Specialist, World Bank

5 Egypt's Experience with Green Bonds, Ms. Eman Abdel Azeem, Manager of Capital Markets and Debt Management Unit, and Ms. Noha Ahmed, Senior Analyst, Ministry of Finance, Egypt

Case Study 1

Supporting Offshore Wind Power Projects in China

(presented by the New Development Bank)[6]

Background

This case study examines the New Development Bank's (NDB's) approach to supporting clean energy projects in China, specifically focusing on offshore wind energy. It looks at two wind energy projects in Fujian Province and Guangdong Province. Both aim to decarbonize the local power mix through wind capacity expansion. These projects exemplify NDB's commitment to sustainable development and its role in supporting China's renewable energy goals.

Problem Statement

Offshore wind projects face weather, marine and geological risks, requiring thorough assessment for site selection and project optimization. Government approvals from multiple agencies are necessary, leading to potential schedule delays. Turbine reliability and foundation quality determine a project's success to a large extent. Vessel dispatch often experiences difficulties during construction peak. Offshore wind development is prone to policy change, particularly subsidy reduction and cancellation.

Methodology

Offshore wind projects face risks like weather, marine and geological complexities, necessitating thorough assessments for site selection and layout optimization. Government approvals from multiple agencies are necessary, leading to potential schedule delays. Reliable wind turbines and quality foundations are crucial, requiring qualified contractors through competitive bidding.

To support energy projects in China, NDB provided long-term project loans with favorable interest rates. The Bank also promoted project design and operation knowledge sharing through expert recruitment and workshops. At the country level, subsidized feed-in tariffs for offshore power also contributed to a significant increase in cumulative installations since their adoption in 2014.

Credit: Fujian Zhongmin Offshore Wind Power Co., Ltd

Putian Pinghai Bay Offshore Wind Power Project

The Putian Pinghai Bay Offshore Wind Power Project is a 246 megawatts offshore wind project on the west coast of the Taiwan Strait that addresses regional power demand using domestically manufactured wind turbines. Over four years of construction, the project overcame challenges such as complex geological conditions, weather restrictions and limited construction vessels.

6 NDB's Experience in Supporting Offshore Wind Power Projects in China, Ms. Su Han, Head, East Asia and Pacific, New Development Bank and Ms. Danwei Zhang, New Development Bank

Credit: Guangdong Energy Group Co., Ltd

With a power purchase agreement and an RMB850/megawatt-hour (MWh) tariff, the project generated 755 million kilowatt-hour of power in 2021, contributing to meeting Fujian's increasing power demand. The project serves as a model for future regional offshore wind projects, with a development potential of 27 gigawatts.[7]

Guangdong Yudean Yangjiang Shapa Offshore Wind Power Project

The Guangdong Yudean Yangjiang Shapa Offshore Wind Power Project is an offshore wind farm with 300 MW of installed capacity located on the northern coast of the South China Sea. It has optimized resilience to extreme weather and complex seabed conditions. With a power purchase agreement and an RMB850/MWh tariff, the project generated nearly 400 million kilowatt-hour of electricity in the first half of 2022. The Guangdong government aims to install 2 gigawatts (GW) by 2020 and 30 GW by 2030, highlighting the importance of wind resource assessment, turbine reliability and foundation quality. The project exemplifies innovation and adaptation in renewable energy development, reducing carbon emissions and promoting sustainability.

7 Along Fujian coastline within water depth of 20 meters.

Lessons Learned

The development of wind energy projects requires careful planning and coordination. Developers should carefully choose capable contractors, implement a digitalized vessel management system, have strong implementing agencies to coordinate with multiple government agencies and mitigate policy uncertainties for foreign projects. Several initiatives have been undertaken to encompass knowledge exchange and dissemination, project financing, policy support and technology innovation.

Conclusion

The NDB's approach to supporting clean energy projects in China, particularly in wind energy, has supported China's long-term strategy of decarbonizing its energy mix. The NDB's experience illustrated that long-term project loans, knowledge sharing and workshops provide crucial support to developers and help ensure the success of these projects. The lessons from the Pinhai Bay and Guangdong wind energy projects can be applied to future clean energy projects worldwide.

1.3 Climate Adaptation and Resilience

Given the rapidly changing climate and the projected impacts, connectivity infrastructure must consider adaptation and resilience measures in its design and operation. The main cost incurred from natural disasters is not the repairs to the infrastructure itself but also the expenses incurred by businesses and households from consequential closures, travel disruption and the need to backup power generation technologies. The workshop discussion highlighted three main points. First, many climate impacts are happening faster than models predict. Second, the uncertainty of ultimate climate mitigation achievements is essential in designing resilient infrastructure. Third, when analyzing the vulnerability of connectivity infrastructure assets, it is important to look at the individual assets and the entire network's ability to sustain shocks and maintain operability.

Climate risk must be integrated into designs to overcome many preventable costs associated with climate shocks (See Case Study 2 for details). The World Bank presentation outlined the Resilience Rating System toolkit they have evaluated to evaluate the resilience of new infrastructure projects to aid in the decision-making process of transport and connectivity infrastructure.[8] The Resilience Rating System is being piloted on 20 World Bank projects across different sectors and regions. The assessments that integrate community benefits and include climate risks and extreme events are rated higher. Together this will lead to an increased understanding of climate change and better and more resilient projects.

Adapting to climate change requires network thinking and model solutions to make resilience investments more effective. The resilience of roads and railways must be engineered into the infrastructure's full lifecycle — from planning to maintenance. Modeling can be used to understand the resilience requirements better and help reduce damage and trip disruptions. When doing this, it is important to think of the road as a network to be maintained instead of individual segments that need to be maintained. This should consider who the main users are to analyze better the impact on different segments of society and the economy. It is crucial to understand which parts of the road should be prioritized because disruption of 10 percent to 20 percent of a country's road network can paralyze a whole country.

Integrating climate disaster risk evaluation into the project cycle beyond the design phase can help make plans flexible and adaptive to new information. This can be done by incorporating a range of scenarios into implementation contracts and government monitoring frameworks. Together this will ensure the project is well-resourced throughout its lifetime, accounting for uncertain events that may arise under high climate temperature models. Adopting a lifecycle reserve account will better prepare stakeholders to plan for adequate long-term maintenance. This can make projects cost-effective in the long run and enable easier access to financing after a disaster.

Ensuring that the infrastructure functions effectively and efficiently means getting the basics right. According to the World Bank, this involves introducing and enforcing

8 World Bank Resilience Rating System for Investment Projects, Dr. Jia Li, Senior Economist, World Bank; World Bank Group. 2021. Resilience Rating System: A Methodology for Building and Tracking Resilience to Climate Change. © World Bank, Washington, DC. http://hdl.handle.net/10986/35039

regulations, construction codes and procurement rules to ensure that infrastructure is designed, built and operated safely and reliably. Additionally, systems must be established for appropriate infrastructure operation, maintenance and post-incident response to ensure that infrastructure is resilient and can withstand natural disasters and other disruptions. Providing appropriate funding and financing for infrastructure planning and maintenance is also essential. This includes ensuring that adequate financial resources are available to invest in infrastructure and that proper mechanisms are in place to pay for ongoing maintenance and repair. Overall, getting the basics right is critical to building and maintaining sustainable infrastructure that can support economic growth and improve the quality of life for citizens.

Implementing a whole-of-government approach to resilient infrastructure by building institutions is recommended. This approach should build on existing regulatory systems to identify critical infrastructure and define acceptable and intolerable risk levels. It is important to ensure equitable access to resilient infrastructure. Building institutions for resilience requires strong governance frameworks and coordination between different government agencies to achieve the desired outcomes. Establishing clear guidelines and standards for infrastructure development and maintenance is essential to ensure that infrastructure is designed and built to withstand natural and human-made hazards. Building institutions for resilience requires a long-term commitment from governments, stakeholders and the public. This will require establishing various mechanisms, including regulations, funding, capacity building and institutional frameworks supporting resilient infrastructure development and maintenance. Ultimately, a whole-of-government approach will help ensure that infrastructure development is sustainable and resilient, as recommended by the World Bank (footnote 8).

To improve decision-making related to infrastructure resilience, investing in freely accessible natural hazard and climate change data is recommended. This data can help inform infrastructure planning and maintenance decisions and post-incident responses. In addition, making robust decisions that consider potential risks and account for climate change can minimize the potential for catastrophic failures and regrets. To achieve this, it is important to have skilled personnel who can use data and models effectively and mobilize the knowledge and expertise of the private sector. By doing so, infrastructure planning and decision-making can be more informed, effective and resilient.

To improve the resilience of infrastructure systems, it is critical to move from optimal designs to robust designs that allow for flexibility and adaptation to changing conditions. This will require financing climate data and promoting its transparency so investors and decision-makers can make more robust decisions that minimize the potential for catastrophic failures and ensure the longevity of infrastructure investments. Improving infrastructure resilience will ultimately require a whole-of-government approach that builds on existing regulatory systems, identifies critical infrastructure, defines acceptable and intolerable risk levels, and ensures equitable access to resilient infrastructure. By creating regulations and incentives that account for climate change and promoting innovative technologies and strategies, infrastructure systems can become more resilient, sustainable and able to withstand the challenges of an uncertain future.

Nature is often the best buffer, especially when dealing with great uncertainty. It is essential to recognize that there is a limit to how much cement and steel can be used to ensure that infrastructure is adapted to all potential future climate change scenarios. Hence, integrating nature-based solutions into infrastructure planning is crucial. In Case Study 2, trees were used to slow down coastal and road erosion. These solutions become more robust over time and may include planting mangrove trees to mitigate the impact of coastal natural hazard events and sea level rise.

The Global Center on Adaptation discussed the need to mainstream climate adaptation in Public-Private Partnerships.[9] Globally, only a few PPP contracts have incorporated climate change risks in their clauses. It is important to consider these risks up front and allocate them cost-effectively between the private party, the public agency and other parties such as insurance companies. Not being explicit on who is responsible for these risks could mean the PPP contract could fail or face enormous pressure on both parties after a climate disaster. The toolkit provides a valuable framework for developing PPPs,[10] while Case Study 8 provides examples of where PPPs have been effectively implemented to drive down costs.

Enhancing the resilience of roads can also support other sustainable development goals, such as gender equality. The International Fund for Agricultural Development (IFAD) presented its project on enhancing the resilience of roads in India. Here the program worked with Labour Contracting Societies to hire women that would receive training to construct roads and boat landing places. In an area where employment opportunities are scarce, and women traditionally do not work outside the house, this was a rare opportunity to earn some money. They earn both profit and income from the work.[11]

9 Climate Adaptation and Resilience in Connectivity Infrastructure PPPs, Mr. Ebere Ihetu, Consultant, invited by the Global Center on Adaptation

10 The Climate-Resilient Infrastructure Officer (CRIO) Handbook. 2021. Global Center for Adaptation. Available at: https://gca.org/reports/climate-resilient-infrastructure-officer-handbook/

11 Connectivity Infrastructure, Regional Rural Economies and Adaptation to Climate Change, Mr. Daniel Martin, Global Technical Specialist - Renewable Energy & Rural Infrastructure, IFAD

Case Study 2

Resilient Coastal Infrastructure Projects in West Africa

(presented by the Islamic Development Bank)[12]

Overview

The Avepozo-Aneho road project in Togo, implemented by the Government of Togo and six partners,[13] is an example of a successful project that aimed to reduce coastal erosion while increasing accessibility and connectivity across Togo. This has had the knock-on effect of promoting sustainable economic growth across Nigeria, Ghana and Cote d'Ivoire. This case study will discuss the challenges and risks associated with the project and how they were addressed through a refined methodology of climate adaptation.

Background

The Avepozo-Aneho road was at growing risk from climate change, with increasing flood damage, landslides and temperature increases in recent years. The risk was so significant that the damage could clearly be seen without a detailed assessment (See image below). Before the project's launch, the area suffered from annual coastal erosion at a rate of 15-20 meters (m) year. With some parts of the road only 100 m from the coastline, there was a clear urgency to address the road's climate risks. Furthermore, the road's location meant it had a 20 percent chance of potentially damaging coastal flooding within five to 10 years.

Figure 1: Trans-West African Coastal Highway from Dakar to Lagos

Source: Wikipedia

Coastal Erosion near Avepozo-Aneho Road

Panarama Solutions

Problem Statement

Clearly, the highway's vulnerabilities were causing longer travel times and impacting regional connectivity and trade. However, any upgrade or investment in the road also required its underlying climate change risks to be addressed. Failure to do so would lead to insufficient support for the range of climate impacts, resulting in congestion and accidents with significant financial and environmental consequences.

12 Resilient Coastal Infrastructure Projects in West Africa, Mr. Olatunji Yusuf, Senior Climate Change Specialist, Islamic Development Bank IsDB

13 African Development Bank, Islamic Development Bank, European Union, Global Environment Facility, West African Economic and Monetary Union, Banque Ouest Africaine de Développement

Table 1: Climate Change Risks to Avepozo-Aneho Road

Project Risks	Sea/Coastal Flooding - High	Increased Precipitation River Flooding – High	Temperature Increase - Medium
Systems Impact	Stronger wave action and increased coastal erosion Rising relative sea levels and saltwater intrusion	Increased flood risk Increased runoff and erosion	Increased hot days
Project Vulnerabilities	Exposure to salinity can deteriorate/corrode roadway surfaces and base layers, culverts or metal bridge components Increased weather-related traffic accidents, traffic disruption and congestion	Increased risk of land/mudslides, which can damage roads and make them temporarily impassable Deterioration of pavement and road foundations, increasing repair costs and decreasing service life of infrastructure Increased weather-related traffic accidents; traffic disruption and congestion	Reduced pavement integrity and possible cracking due to ground shrinking, subsidence

Source: Presentation by Resilient Coastal Infrastructure Projects in West Africa, Mr. Olatunji Yusuf, Senior Climate Change Specialist, Islamic Development Bank IsDB

Methodology

The project undertook different approaches to ensure that various risks across the road network were addressed. This involved going beyond the normal road improvement programs by addressing coast flooding risks along the traffic corridor through shore enhancement against coastal erosion. To do this, the project undertook an awareness session for stakeholders from the relevant government ministries. This provided information on how the road was and will be impacted by climate change. As a result, a range of climate risks was identified, with bespoke solutions, such as the integration of a star structure design along the road to enhance drainage in areas with increased flood risk, along with using sand to restore the coastline, constructing 28 groyns and planting over 14,700 trees to slow coastal soil erosion.

Lessons Learned

The project has provided valuable lessons that can inform future investments in transport infrastructure facing similar climate risks. It highlights the need for each infrastructure investment to have tailored solutions due to the unique nature of climate-related risks and uncertainties. Likewise, it illustrates that enhanced capacity and skills are necessary to understand and manage climate risks in traditional sectors like transport. Additionally, ownership is vital for clinical benefit, and evidence-informed project development plays a crucial role in making a case for addressing risks and building infrastructure. Finally, building resilience in infrastructure and communities is crucial, and strong government ownership is necessary for successful investment. These lessons learned can serve as a guide for future investments in similar regions.

Conclusions

The Avepozo-Aneho road project in Togo is a successful example of how to integrate climate risks into traditional infrastructure improvement programs. The project provides a refined methodology of climate adaptation that is essential for promoting sustainable economic growth while considering the future impacts of climate change on infrastructure.

1.4 Climate Finance

Climate finance must be scaled up dramatically to meet climate mitigation and adaptation technologies. This includes debt, equity, green bonds and carbon markets, which have grown considerably from USD364 billion in 2009-2010 to USD632 billion in 2019-2020.[14] However, this growth does not match the necessary climate finance required to meet the 1.5°C warming target, estimated to be around USD3,000 billion by 2021 and USD6,000 billion by 2040 (footnote 14).

National climate funds can be developed to support overcoming the financing gap. The development of Rwanda's national green fund has provided valuable insights and advice here. One crucial lesson is ensuring the fund's longevity, as establishing it and implementing projects requires time and concerted efforts. To achieve this, it is essential to prioritize coordination among departments and promote information sharing, thereby enhancing overall capacity. Additionally, a key consideration is the fund's ability to attract private finance, as relying solely on public sector funding may impose limitations. By diversifying funding sources, the fund can unlock greater opportunities for sustainable initiatives and drive impactful environmental projects.[15]

Likewise, national green bonds can help encourage finance into climate solutions and projects. These have been utilized in Egypt to support the development of its renewable energy sector (footnote 5) and in Georgia, as presented by EBRD, to decarbonize its railway sector.[16] These innovative financial instruments have attracted both overseas public and private finance and are likely to continue as the demand increases and the likelihood of a positive return increases.

Climate and other development funds can also provide financial support. Development banks, such as the Green Climate Fund (GCF), can provide finance for climate-related projects. The GCF has approved over 200 climate adaptation and mitigation projects. However, this funding can support both government and private sector-operated projects. Almost 35 percent of these projects have involved the private sector at a total of USD3.6 billion dollars in equity and guarantees (footnote 14).

However, disaster recovery finance will become increasingly important, requiring increased coordination across various policy and finance measures. Coordination between national infrastructure policies and financial instruments will be increasingly important to fund efficient and fast disaster recovery. This will require funding in the aftermath of a disaster and investment in data and analytics to make informed decisions on recovery and reconstruction needs, especially as climate impacts move from being a distant risk to an annual one.

UNESCAP discussed ways to address the financing gap for climate-smart connectivity infrastructure (footnote 14). There is an enormous need for more investment in grids within and across countries. The session discussed different

14 Addressing the Financing Gap for Climate Smart Connectivity Infrastructure, Mr. Matthew Wittenstein, Chief of Section, Energy Connectivity, UNESCAP

15 Creating a Favorable Institutional Framework: The Case of Rwanda, Mr. Thierry Watrin, Green Economy and Climate Change Advisor to the Minister of State in Charge of Economic Planning, Rwanda

16 EBRD Approach to Climate-Smart Rail: Case study on Georgia Railways Green Bond (Video) Speaker: Ms. Elena Gordeeva, Associate Director, Infrastructure Eurasia, Sustainable Infrastructure Group, EBRD

models to attract private investment to the power transmission sector. For example, the Independent Power Transmission model is like the Independent Power Producer model, which is well-known in Asia. This model can be piloted on a single transmission line, requiring less upfront regulatory reform. UNESCAP highlighted the need for stronger legislation, a solid institutional setup and capacity, and a stable power sector as pre-conditions to attract the private sector financing needed.

The Coalition for Climate Resilient Investment (CCRI) described the solutions it is developing to integrate climate risks into infrastructure project financing.[17] CCRI is a coalition of 126 institutions representing USD25 trillion of financial assets. Their products include systemic resilience metrics, a national resilient infrastructure prioritization tool, a methodology for physical climate risk assessment, a review of resilience credit quality drivers and a set of principles for climate-resilient investment.

The Asian Development Bank presented the Shandong Green Development Fund in China.[18] This Fund was designed to attract private sector and commercial capital to climate-smart investments. The Green Investment Framework of this operation included an analysis of the level of reduction of GHG emissions or adaptation benefits; the potential to scale up and replicate the sub-project innovations; the economic, social and environmental co-benefits; a demonstrated need and implementation capacity; as well as efficiency and effectiveness. The USD350 million financing of the ADB, the French Development Agency, KfW and the Green Climate Fund mobilized about USD1.5 billion in this public-private financing facility for climate-related investments in the province of Shandong.

1.5 Harnessing Private Finance

Overcoming the climate finance gap will require public and private sector collaboration. Decarbonization solutions can require high upfront capital costs; however, operational costs are often lower than traditional sources. Blended finance products from governments can reduce barriers for private sector entrants, such as high initial capital costs and risks associated with new technologies. This can take the form of green taxes and subsidies to reduce costs or adopting carbon markets to incentivize zero-carbon innovation more directly. Specifically, studies have found that to limit global warming to 2 degrees warming, one ton of carbon dioxide should be priced at between USD40-USD80 within a carbon market (footnote 14). By providing financial support and creating favorable conditions for investment, the private sector can be incentivized to contribute to climate-smart connectivity infrastructure projects.

Case Study 1 also highlighted how providing information, such as Wind Atlas, to the private sector can help overcome knowledge gaps on where low-carbon technologies could best be placed. Details on how integrating climate risks and

17 Innovations in Adaptation Infrastructure Finance, Mr. Carlos Sanchez, Executive Director, Coalition for Climate Resilient Investments

18 Shandong Green Development Fund, Mr. Kang Hang Leung, Principal Infrastructure Finance Specialist, Asian Development Bank

resilience measures into the design and operation of connectivity infrastructure can reduce costs are crucial. Combined, this can ensure that private sector finance supports resilience, reduces damage-related costs and maintains operability in the face of climate shocks.

Case study 2 on the Avepozo-Aneho road project in West Africa highlights the importance of addressing climate risks in infrastructure projects. It demonstrates the need to go beyond traditional approaches and implement bespoke solutions to mitigate climate impacts. Stakeholder engagement, risk assessment and customized design can help address vulnerabilities and promote sustainable economic growth. Along with clear national strategies, regulatory frameworks and common standards can facilitate the adoption of climate-smart technologies and enhanced resilience.

2 Climate-Smart Coastal Connectivity Infrastructure

2 Climate-Smart Coastal Connectivity Infrastructure

2.1 Overview

Coastal areas are some of the Earth's most highly populated yet climate-vulnerable locations. Over 40 percent of the global population lives within 100 kilometers of the coast, resulting in a significant concentration of urban development susceptible to sea level rise and natural disasters like cyclones.[19] Unfortunately, the frequency and severity of these events are projected to increase, further compounding the risks coastal populations face. In addition to this, the ocean itself is threatened by unmitigated climate change, which could have devastating consequences for the world's economies and ecosystems. Specifically, coral reef tourism revenue could decrease by over 90 percent, while certain West African countries may experience an 85 percent decline in fish stocks.[20]

Coastal connectivity infrastructure has a crucial role in climate mitigation and adaptation. From the climate mitigation perspective, coastal connectivity infrastructure and services are also vital. Maritime transport, for example, is responsible for about three percent of global greenhouse gas emissions and is projected to increase by as much as 40 percent by 2050.[21] If nothing is done, shipping emissions could climb to 17 percent of global emissions by 2050 (footnote 21).

Coastal connectivity infrastructure will be highly affected by climate impacts. The risks to this infrastructure from sea level rise and storm surges, combined with significant economic activity in coastal areas, make this discussion quite relevant for coastal countries, as outlined in Case Study 3. However, as Infrastructure Development Consultants presented, integrating climate adaptation into infrastructure costs adds only three percent to the total project costs.[22] This can result in substantial long-term cost savings as rerouting capacity and the disruption level increase.[23]

Coastal connectivity infrastructure covers a variety of sector investments. As part of the workshop discussion on coastal connectivity infrastructure, practical experiences were shared on green ports, decarbonizing maritime transport, eco-industrial parks connected to ports, resilient transport in coastal areas and small island states, and transforming maritime transport corridors into green innovation hubs.

19 Joel E. Cohen, Christopher Small, Andrew Mellinger et al. Estimates of Coastal Populations.Science278,1209-1213(1997). DOI:10.1126/science.278.5341.1209c

20 A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis, Ms. Eliza Northrop, Senior Associate, Sustainable Ocean Initiative, World Resources Institute

21 Fourth IMO Greenhouse Gas Study. International Maritime Organization. 2020.

22 Climate Resilient Design in Roads: The Case of India Madhya Pradesh Rural Connectivity Project, Mr. Subhash C. Nigam, Managing Partner, Infrastructure Development Consultants

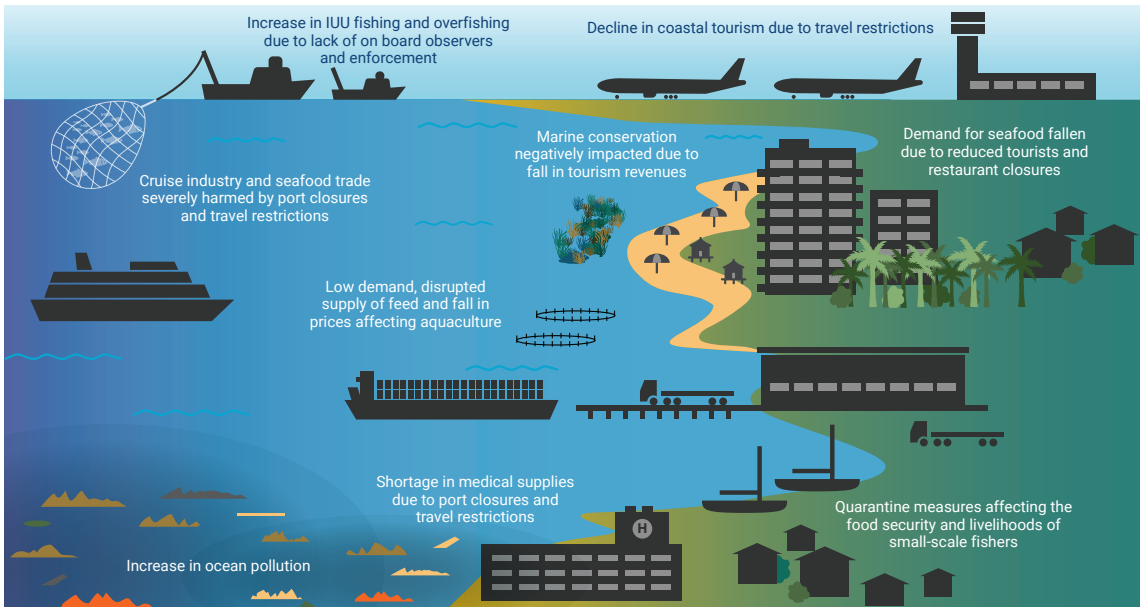
23 Climate Change Risk Analysis of Argentina's Land Transport Network, Ms. Veronica Raffo, Senior Infrastructure Specialist, World Bank

2.2 Resilience of Coastal Connectivity Infrastructure

Investing in sustainable infrastructure is crucial as it has long-term implications that can shape the trajectory of coastal society for the next 10-20 years. Major maritime ports are particularly vulnerable to the impacts of sea level rise, with estimates suggesting that up to 14 percent of these ports could be at risk of flooding and erosion (footnote 19). This highlights how many countries are at risk from a disruption in importing necessities such as medicine and foodstuff, particularly to small island developing states.[24] However, this risk also presents an opportunity to drive sustainable and equitable development while enhancing resilience in the face of climate change.[25]

Economic diversification must be considered as a strategy to prepare for future crises. This is particularly relevant for coastal areas, which were among the hardest hit by the coronavirus disease (COVID-19) pandemic due to factors like travel restrictions, overfishing and pollution (See Figure 2). Despite these impacts, areas were often overlooked in recovery stimulus programs. Supporting economic diversification can create new opportunities for vulnerable groups such as women, youth, indigenous communities and small-scale fishers, thereby strengthening their resilience to future crises. Additionally, investing in sustainable ocean industries like decarbonized shipping and renewable energy presents significant opportunities for long-term economic growth and stability, as the High-Level Panel recommends for a sustainable ocean economy.[26]

Figure 2: Impact of COVID-19 on Coastal Areas



COVID-19 = coronavirus disease, IUU = illegal, unreported and unregulated

Source: Ocean Panel (2022)

24 Resilient Transport in Small Island Developing States: From a Call for Action to Action, Mr. Frederico Ferreira Fonse Pedroso, Disaster Risk Management Specialist, World Bank

25 Experiences of Pacific Islands on Resilient Coastal Infrastructure, Mr. Kushaal Raj, Acting Head of Climate Change and International Cooperation Division, and Ocean Specialist, Ministry of Economy, Fiji

26 High Level Panel for A Sustainable Ocean Economy. Available at: https://oceanpanel.org

Many small island developing states are at the forefront of these investments and understand the ocean's importance to the local and global economies. Furthermore, many national governments that heavily depend on the ocean are implementing policies that require consideration of climate risks throughout the government. The presentation by Fiji highlighted how their government is doing this through the Climate Change Act, whereby legislation mandates that climate change risks must be considered across budget and infrastructure planning (footnote 25).

Investing in response facilities is necessary to increase resilience in the aftermath of natural disasters. The World Bank's presentations outlined how they have identified four key strategies for enhancing resilience.[27] The first strategy is to conduct spatial and sector planning to identify vulnerable areas and prioritize interventions. The second strategy involves investing in climate-resilient infrastructure to minimize the damage caused by natural disasters. The third strategy is to create an enabling environment, including policies and regulations, which incentivizes private sector investment in measures that promote resilience. The fourth strategy is to provide post-disaster recovery support to help communities rebuild and recover after a disaster. By implementing these strategies, the resilience of vulnerable communities can be enhanced along with mitigating the impacts of natural disasters on people, economies and the environment (See Case Study 3 for details).

27 Pacific Climate Resilient Transport Program (PCRTP): MICRO and MICRO2, Ms. Nana Soetantri, Senior Transport Specialist, World Bank and Resilient Shores: Vietnam's Coastal Development Between Opportunity and Disaster Risk, Mr. Dzung Huy Nguyen, Senior Disaster Risk Specialist, World Bank; Rentschler, Jun; de Vries Robbé, Sophie; Braese, Johannes; Nguyen, Dzung Huy; van Ledden, Mathijs; Pozueta Mayo, Beatriz. 2020. Resilient Shores: Vietnam's Coastal Development Between Opportunity and Disaster Risk. ©World Bank, Washington, DC. http://hdl.handle.net/10986/34639License: CC BY 3.0 IGO

Case Study 3

Resilient Shores - Vietnam's Coastal Development Between Opportunity and Disaster Risk

(presented by the World Bank)[28]

Overview

The Vietnamese government undertook a coastal risk analysis to address Vietnam's many disaster risks and is launching a five-phase coastal resilience program over the next 15 years. The program aims to strengthen the anti-coastal region, focusing on natural base solutions, integrated coastal resilience planning, insurance, social safety net development, mobilizing financing resources and improving emergency preparedness. The program will consider natural hazards that have occurred over five to 500 years and their historical impacts.

Background

Vietnam's coastal areas face increasing yearly damage due to natural disasters such as coastal erosion, storm surges and saline intrusion. This is significantly impacting key sectors such as agriculture, aquaculture, tourism and industries; obstructing people's access to jobs, education and health care; and damaging the competitiveness of firms. In particular, the Mekong Delta, a major producer of rice, is vulnerable to natural hazards like flooding and intrusion, resulting in significant economic losses.

Methodology

Vietnam undertook a coastal risk analysis that looked at the physical climate risks and the interactions these will have on industries, demographics and macroeconomics. This enabled it to develop a clear five-point plan to enhance resilience.

Coastal Risk Analysis

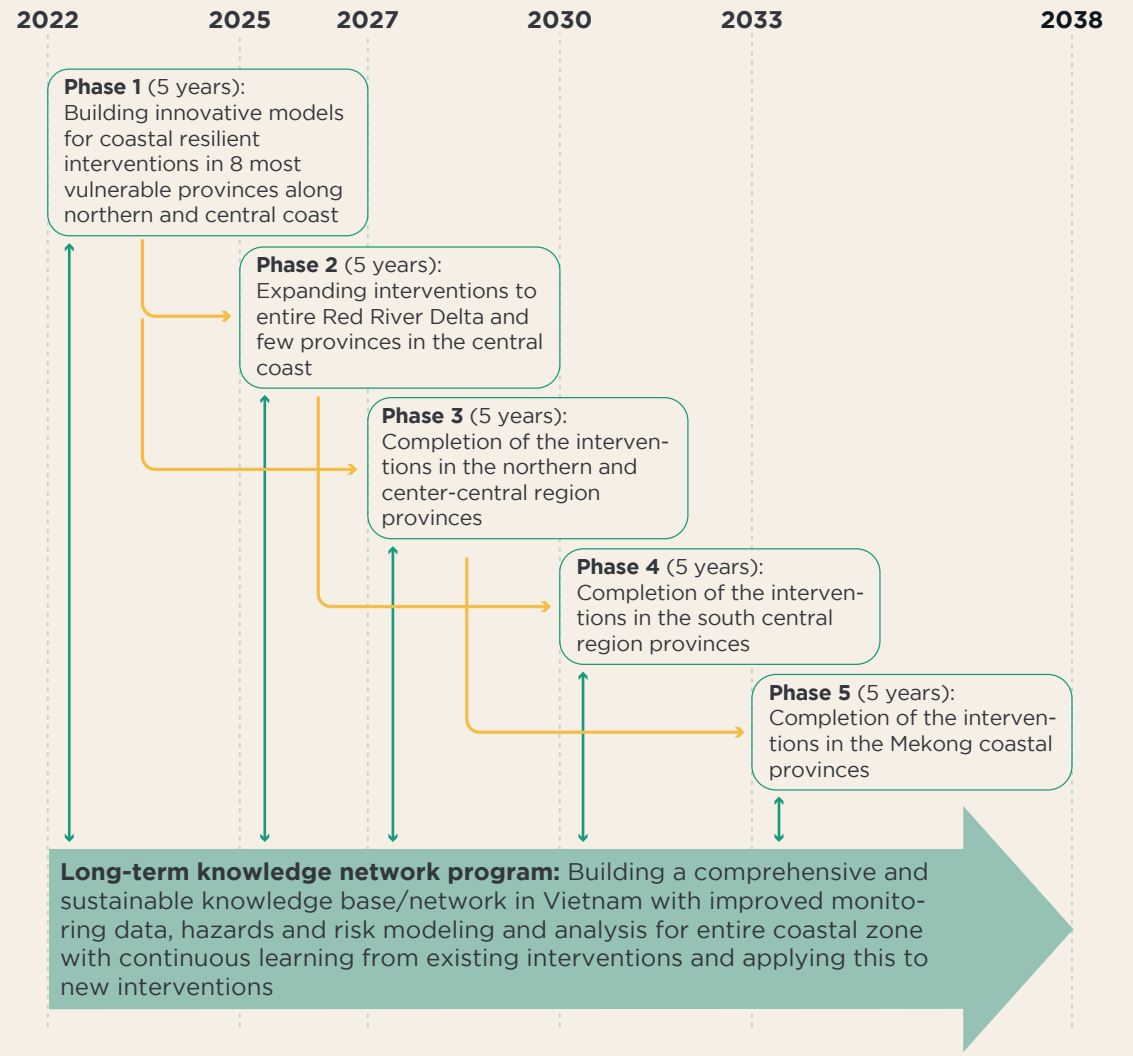
According to a resilience strengthening report, Vietnam faces significant coastal risks due to climate change impacts. These risks directly impact 12 million people who live by an eroding coastline. In addition, Vietnam's energy infrastructure and transportation systems are also at risk due to coastal flooding causing a three percent gross domestic product (GDP) loss and unemployment for 7.15 million people. Furthermore, the impacts on other key sectors, such as agriculture, brick production and tourism, are significant. For example, 43 percent of hotels and 45 percent of healthcare facilities are likely to be flooded when looking at a 100-year period.

Key Findings

Vietnam is a low-middle-income country vulnerable to natural shocks, with 60 percent of annual GDP losses caused by disasters occurring in coastal areas. Despite this, the country is one of the largest exporters of rice and other agricultural products. Over the last decade, Vietnam's economy has moved closer to the coast, increasing the risk of considerable economic losses from underestimated natural hazards. In addition to flooding, sea level rise, storms and coastal

28 Resilient Shores: Vietnam's Coastal Development Between Opportunity and Disaster Risk, Mr. Dzung Huy Nguyen, Senior Disaster Risk Specialist, World Bank

Figure 3: Vietnam's Five-Year Plan



Source: Resilient Shores: Vietnam's Coastal Development Between Opportunity and Disaster Risk (worldbank.org)

erosion, saline intrusion in the Mekong Delta, which produces 50 percent of the country's rice, is also a significant issue due to sea level rise and sand mining. Natural hazards also impact aquaculture, and health care facilities face significant flooding risks.

Furthermore, 22 percent of Vietnam's coastline is eroding, and 35 percent of settlements are on eroding coastlines. With 65 percent of Vietnam's dikes failing to meet the prescribed safety standards, delaying action on coastal resilience by 10 years could expose an additional 4.3 billion of economic growth to natural shocks. Therefore, Vietnam must focus on coastal resilience programs, with a 15-year, five-phase plan being recommended. Implementing recommendations in pilot projects and programs and expanding these to more areas will be essential in mitigating the risks posed by natural hazards to essential services, coastal urbanization, and essential sectors such as tourism, aquaculture and agriculture.

Lessons Learned

The project has provided essential key lessons as outlined below:

a) **Spatial Planning:** To integrate risk information into development and investment planning, spatial planning must be prioritized. This requires ensuring the availability of robust hazard data and analysis tools and supporting provincial and city government planning processes to identify and prioritize climate risks.

b) **Donor Coordination Platform:** A donor coordination platform must be established to facilitate investments from multiple sources, including both private and public. This will reduce duplication of work and align recommendations across all levels of the project.

c) **Disaster Risk Financing:** Formulating financing instruments and insurance models for DRM and post-disaster recovery is essential while there is a need to review and strengthen relevant laws and decrees regarding financing, DRM, asset management and social safety nets to improve financial inclusion. Together, this will ensure that a country is better prepared for disasters.

d) **Strengthening Emergency Response:** An emergency command center can be established to improve the risk-based forecast and early warning system in combination with a coastal disaster monitoring system. Improving the coordination of response capacity across departments through policies and tools can further strengthen emergency response.

Conclusion

The Vietnamese government's five-phase coastal resilience program is a comprehensive and integrated approach that aims to strengthen the country's coastal areas against natural hazards, protect its key sectors and ensure the well-being of its people. By adopting a multi-phased approach and incorporating innovative solutions, Vietnam can build its coastal resilience sustainably and effectively.

2.3 Climate Mitigation in Coastal Infrastructure and Services

Decarbonizing the shipping industry is critical to achieving global emission reduction targets. International shipping accounts for about 80 percent of global merchandise trade and is expected to increase by about 40 percent by 2050.[29] Yet it represents close to three percent of global emissions and is on track to represent 17 percent of global emissions by 2050 under a business-as-usual scenario.[30] The International Maritime Organization has recognized the significant role of shipping in global greenhouse gas emissions and air pollution and has committed to reducing emissions by at least 50 percent by 2050 compared to 2008 levels.[31]

Decarbonization in the shipping industry is technologically feasible but will require significant finance. According to the World Bank's presentation, the shipping sector can be decarbonized rapidly through various existing technical, operational and economic solutions (footnote 30). However, it requires a significant investment of at least USD1 trillion in the next two decades to reduce shipping emissions by 50 percent by 2050, making it a financially challenging sector to abate. The investments will need to be made in both on-shore and off-shore infrastructure, including a transition from highly polluting heavy fuel oil to a new zero-carbon bunker fuel alternative and a substantial increase in energy efficiency.

Developing new zero-carbon bunker fuels, such as green hydrogen and green ammonia, is crucial to decarbonize shipping. Alternative marine fuels such as green hydrogen can be produced using renewable energy, with the only by-product being water. These can be transported easily as green ammonia, an already commonly traded commodity worldwide. However, strategic public policies are needed to get the scale of these solutions and implement the energy transition. These can range from targeted subsidies and carbon pricing policies since zero-carbon bunker fuels are estimated to be around 40 percent to 60 percent more expensive than conventional fuels.

Liquefied natural gas (LNG) will likely have a limited role as a feedstock and for niche routes, while biofuels are unlikely to play a significant role. Considering the entire lifecycle of proposed alternative fuels is important to ensure they deliver real emission reductions. By doing so, it becomes clear that LNG will not become a zero-/low-carbon bunker fuel alternative due to its methane leakage. However, they could be a feedstock to support the production of 'blue hydrogen,' that is, hydrogen produced from LNG using carbon capture and storage. Likewise, the role of biofuels will be limited due to supply constraints and cost.

Inland waterways transport can play a critical role as a lower-carbon option compared to freight transport by roads. In China, for example, by the end of 2021, the country had more than 128,000 kilometers of navigable inland waterways. Furthermore, the country has accelerated the development of intermodal transport facilities between railways and ports to reduce the need for container movement by truck, as discussed in the China Harbour Engineering Company Case Study 4.[32] Some

29 Englert, Dominik; Losos, Andrew. 2021. Charting a Course for Decarbonizing Maritime Transport: Summary for Policymakers and Industry. © World Bank, Washington, DC. http://hdl.handle.net/10986/35436 License: CC BY 3.0 IGO

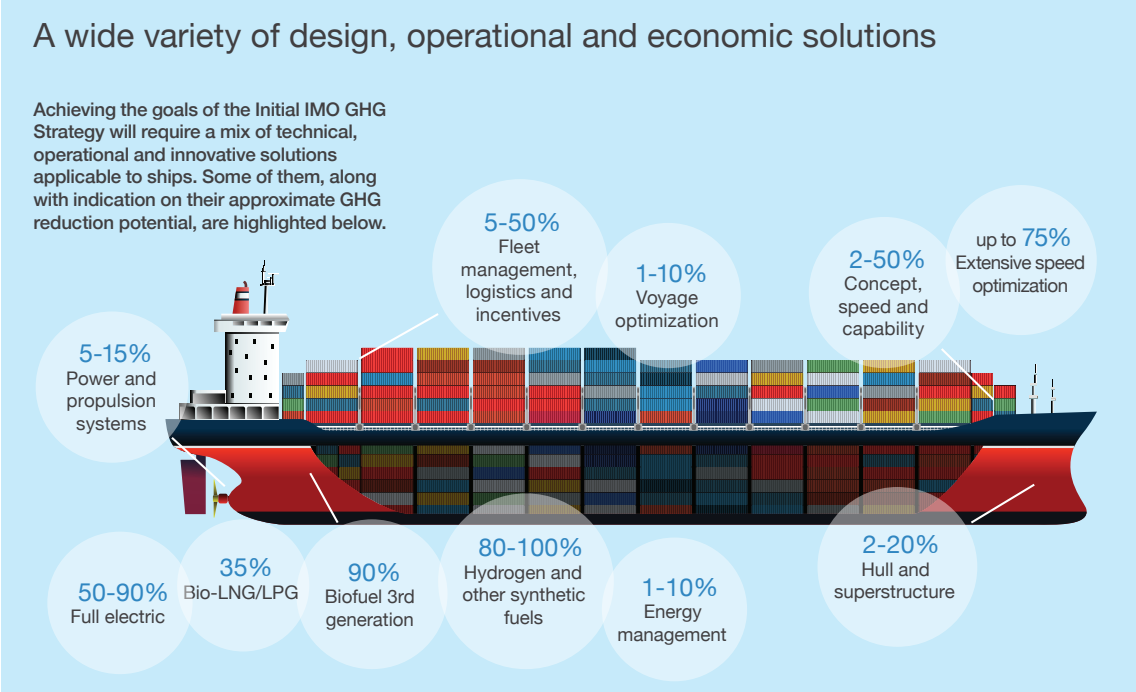
30 Decarbonizing Maritime Transport: The Potential for Zero-carbon Bunker Fuel Production in Developing Countries, Mr. Dominik Englert, Economist, Global Knowledge Unit, Transport Global Practice, World Bank

31 Initial Greenhouse Gas Strategy. International Maritime Organization. 2018

32 A Green, Digital, Information, Efficiency Revolution Delivering by CHEC: 4th Phase Shanghai Yangshan Deep Water Port, Mr. Claude Peng, Project Financing Senior Consultant, China Harbour Engineering Company

provinces like Jiangsu have created pollution management systems that combine ships, ports and surrounding cities. China has also issued several new advanced regulations on green ports to bring consistency to infrastructure development in the sector. While in Vietnam, it has been demonstrated that the increased use of inland waterways can lead to reduced emissions, costs, road accidents and congestion costs.[33]

Figure 4: Operational and Economic Decarbonization Solutions for Shipping



GHG = greenhouse gas, IMO = International Maritime Organization.

Source: 26620IMO_ACTION_TO_REDUCE_GHG_EMISSIONS_FROM_INTERNATIONAL_SHIPPING.pdf (un.org)

Small Island Developing States (SIDs), such as the Pacific and Cabo Verde, have recognized the benefits of decarbonizing their maritime sector and have implemented a coordinated approach across the sector through partnerships like the Pacific Blue Shipping Partnership. These regions and countries rely heavily on maritime transport to import daily necessities and ensure that communities can undertake essential activities — from work to attending school (footnote 24). However, the region is highly vulnerable to climate change, meaning that the sector it depends on increasingly negatively impacts its economy. That is why a group of countries across the region has developed the Pacific Blue Shipping Partnership to decarbonize the maritime transport sector while unleashing several social, environmental and economic benefits aligned with the SDGs. The idea is that investing in shipping and scaling renewable energy supports diversification and innovation to deal with the impacts of COVID-19, climate change and other economic shocks.

33 Facilitating Inland Waterways Transport in Vietnam for Sustainable Logistics Connectivity, Ms. Yin Yin Lam, Senior Trade Logistics Specialist, World Bank

Case Study 4

A Green, Digital, Information, Efficiency Revolution Delivered by CHEC: 4th Phase Shanghai Yangshan Deep Water Port

(presented by the China Harbour Engineering Company)[34]

Background

China Harbour Engineering Company (CHEC), a prominent infrastructure construction company, has implemented a green digital information and efficiency revolution at the Shanghai Yangshan Deep Water Port in response to an evolving maritime industry. This case study focuses on the project undertaken by CHEC to improve the port's efficiency, promote sustainable practices and create new job opportunities. The project was aimed explicitly at the Yongshan deep water port in Shanghai, which handles over 1,000 twenty-foot equivalent (TEU) per day and has a gross capacity of 150,000 TEU or around 5.7 million TEU per year. Through this case study, we will examine the strategies and technologies implemented by CHEC to achieve its goals and the project's outcomes (footnote 34).

Problem Statement

The Shanghai Yangshan Deep Water Port faced several challenges before the project's implementation. The manual operations led to high human costs, limited efficiency and safety concerns. Likewise, using diesel fuel for equipment resulted in significant emissions, negatively impacting the environment. These challenges hindered the port's growth and efficiency, making it less competitive globally. The project aimed to address these challenges by adopting innovative technology and sustainable practices to improve efficiency, reduce human costs and promote environmental sustainability.

Methodology

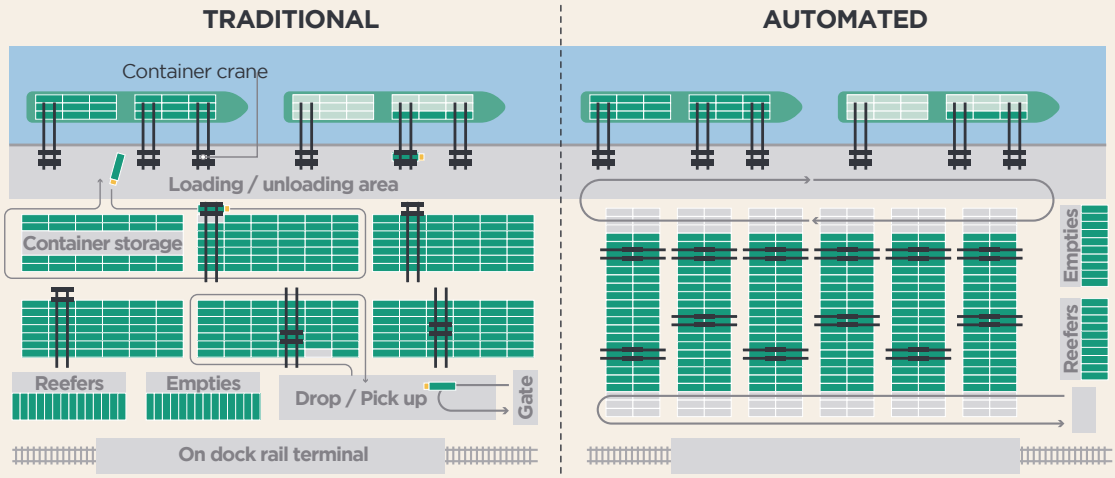
The project integrated digitization and automation technologies to transform yard equipment and increase efficiency. Electric-powered and more automated systems like automated guided vehicles (AGVs) and AI management were introduced, making the shift to clean energy possible. While operational systems integration further enhanced efficiency and reduced emissions. The details of these technologies and systems implemented are outlined below:

Efficiency Improvements with Automated Equipment

The adoption of magnetic nails and 5G technology has led to a groundbreaking transformation in equipment automation at the port. Real-time guidance for automated guided vehicles and remote control from a control room has become possible, improving efficiency. Automated

34 A Green, Digital, Information, Efficiency Revolution Delivering by CHEC: 4th Phase Shanghai Yangshan Deep Water Port, Mr. Claude Peng, Project Financing Senior Consultant, China Harbour Engineering Company

Figure 5: Traditional vs. Automatic Port Layout



Source: Author

equipment, such as production route planning, ship and yard planning systems, storage planning systems and sensor technology, work together to streamline the movement of containers from ships to storage yards. The switch to electric-powered and more automated systems like AGVs and AI management has become possible through the shift from semiautomatic to fully automatic systems.

Integration of Operational Systems for Efficiency and Emission Reduction

Several operational systems were integrated into the port's operations to enhance efficiency and reduce emissions. These systems include a new gate control system and an electronic data interchange system, which provide real-time updates and ensure safety.

The port also optimized its electricity usage through smart power exchange technology, dynamically balancing power exchange between different energy sources and the power grid. This reduces waste, lowers costs and enables efficient distribution. Additionally, automatic fault diagnosis technology is employed to detect and diagnose electrical system faults using machine learning and AI algorithms, ensuring timely corrective action and minimizing disruptions. Moreover, electricity monitoring technology measures and analyzes consumption, identifies inefficiencies, reduces energy usage and enables preventative measures for potential issues. These innovative technologies collectively enhance the port's energy efficiency, reliability and operational sustainability.

Lessons Learned

The project has provided valuable insights into the potential of technology to advance the transition toward clean energy. These lessons include:

1. Cost-Effectiveness of Clean Energy: Technological advancements and algorithms have made clean energy sources more cost-effective, particularly by adopting smart power exchange systems.

2. Integration of Automated Equipment: Integrating advanced automated equipment, such as production route

planning and sensor technology, improves operational efficiency and safety, and reduces emissions.

3. Computer Systems for Power Shift: Computer systems enable the transition from diesel to electric power, optimizing energy resources and reducing GHG emissions.

4. Fully Automated Systems for Enhanced Efficiency: Shifting to fully automated systems powered by electricity improves overall efficiency and reduces costs.

Conclusion

The transformation of Shanghai's Yangshan Deep Water Port through CHEC's green digital revolution has yielded impressive results by reducing costs, increasing efficiency and adopting cleaner energy sources while creating jobs. Integrated systems have enhanced safety, allowing the port to handle more containers and contribute to China's economic growth. This project showcases the potential of technology and sustainability to transform the maritime industry, serving as a model for a sustainable and efficient energy future.

2.4 Harnessing Private Finance

Cooperation is crucial for unlocking the benefits of zero-carbon fuels in the maritime sector. As ships frequently visit ports in different countries or regions and may depend on fuel sources located in other countries, cooperation is necessary. Furthermore, many players are involved when a ship makes a delivery, including the ship owner, charterer and manufacturer of goods being transported. Furthermore, the coordination between a new and emerging fuel industry involves an even broader range of stakeholders, from port operators to those across the maritime fuel value chain. Given the breadth of stakeholders involved and global nature of the shipping industry, cooperation at every level is required across countries. Steps are being taken to establish green corridors across the world whereby an agreement between two ports to supply green hydrogen allows a ship to travel between the two ports with the knowledge that they can bunker at either of them with zero-carbon bunker fuels.

Eco-industrial parks can support cooperation among stakeholders and incentivize green shipping. The United Nations Industrial Development Organization (UNIDO) presentation outlined how these parks aim to enhance environmental, social and economic benefits in communities of manufacturing and service businesses.[35] Today, industrial parks have been greening globally, with UNIDO undertaking a project to help eight pilot countries—from Vietnam to Egypt to Colombia—mobilize finance, reduce transition costs and enhance global knowledge. This has resulted in 20 tools

35 EIP Framework, UNIDO Concept Plan and EIP Master Plan Review Tools, Mr. Rana Pratap Singh, Industrial Development Officer, Energy and Cleaner Production Branch, United Nations Industrial Development Organization (UNIDO)

to measure the environmental, social and economic park performance parameters.[36] A key lesson of their experience is that synergies are critical for the success of these parks. Examples include co-location and clustering of companies in the supply and value chains, use of by-products and waste exchange, and linkages between companies in the park and cities close to them to leverage joint green infrastructure development and use.

While Special Economic Zones are another model that can be used to incentivize green shipping and provide benefits to the broader community. The presentation by the General Authority of the Suez Canal Economic Zone (SCZONE) outlined how Panama has implemented a range of such zones, providing another example of promoting sustainable economic growth while addressing climate change challenges.[37] It includes incentives for businesses that invest in the zone and comply with specific sustainability and climate resilience requirements. To support climate resilience, SCZONE incorporates green technologies and sustainable infrastructure, such as renewable energy, low-emission transportation and water management systems. The zone also supports creating green jobs and promoting sustainable business practices through partnerships with local communities and civil society organizations.

The Suez Canal Economic Zone is an example of a low-carbon transformation process. The SCZONE has embarked on a change process from being only a maritime transportation channel to becoming a global hub for green products. They have invited the private sector to produce green hydrogen, leveraging the tremendous solar power resources in the area, the supportive regulatory environment for private investments in the energy sector, and the privileged location for the sale and distribution of green hydrogen for the maritime transport industry.

Likewise, private sector investment is vital for achieving global emission reduction targets. The private sector, including shipping companies, must invest in technological advancements, such as zero-carbon bunkers and artificial intelligence (AI), to reduce emissions. However, significant financial investments and supportive public policies are necessary to accelerate the adoption of these technologies. The Shanghai Yangshan Deep Water Port case study demonstrates the effectiveness of integrating digital and automated systems to enhance efficiency and reduce emissions. Leveraging AI, smart power exchange and automation can significantly improve operational efficiency and sustainability.

36 An International Framework for Eco-Industrial Parks, World Bank. Accessed on: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/429091513840815462/an-international-framework-for-eco-industrial-parks; Eco Industrial Parks. Tools. Knowledge Hub UNIDO. Available at: https://hub.unido.org/eco-industrial-parks-tools

37 Transformation of SCZONE from a Transit Area to An Innovation Hub, Mr. Waleid Gamal El-Dien, Vice-Chairman, Investment and Promotion Affairs, General Authority of the Suez Canal Economic Zone (SCZONE)

3 Climate-Smart Roads and Railways

3 Climate-Smart Roads and Railways

3.1 Overview

Efficient roads and railways are essential to supporting sustainable development and growth. Roads and railways comprise around 80 percent of the global land transport network, enabling people and goods to move effectively within and between countries.[38] Yet, these modes of transportation must be decarbonized as transport currently makes up around 17 percent of emissions globally, projected to go up to 30 percent by 2050 if no action is taken.[39] The workshop discussed practical experiences worldwide on electric mobility in developing countries, road traffic digitization and greening of the sector, and innovations in climate resilience in the roads sector.

Given the linear nature of roads and railways, their climate risks are substantial and growing. Natural disasters cause USD8 billion in annual damage to roads and railways in low- and middle-income countries (footnote 38). More importantly, the annual cost of transport infrastructure disruptions on firms in developing countries is USD107 billion to their economies. Therefore, road and rail decarbonization must be combined with concrete adaptation measures.

3.2 Climate Adaptation and Resilience in Roads and Railways

Roads and railways are critical components of the global transport network, enabling the effective movement of people and goods. However, as the World Bank explained in their presentation, these assets are vulnerable to natural hazards, with annual damages amounting to USD15 billion, more than half of which occurs in low and middle-income countries (footnote 38). The real cost, estimated at around USD107 billion, is borne by firms and households in the form of business closures, higher fuel costs and loss of time (footnote 38). Therefore, there is a need to invest in resilient infrastructure assets that are less costly to maintain and repair. This includes building the resilience of infrastructure services to provide more reliable services and resilience of infrastructure users to better cope and recover from shocks. Case Study 5 details how critical road and railway infrastructure resilience can be integrated at every stage of the project lifecycle. It should also be noted that there is a need to focus on understanding the system and user needs to invest in high-priority areas.

Bangladesh has several good practices on engineering measures for resilient roads. To face climate risks, the Government of Bangladesh issued new road design standards in 2021.[40] To minimize climate impacts on infrastructure, it has implemented vertical fire breaks to reduce the impact of fires, revised surface

38 From A Rocky Road to Smooth Sailing: Building Climate Resilience in the Roads Sector, Ms. Julie Rozenberg, Senior Economist, World Bank

39 AIIB's Experience of Promoting Climate Resilience in the Roads and Railways Sector, Ms. Jin Wang, Senior Investment Operations Specialist – Transport, AIIB

40 Climate Resilience and Adapted Road Projects, Mr. Md. Jasim Uddin, Superintending Engineer and Project Director, Climate Resilient Infrastructure Mainstreaming Project, Local Government Engineering Department, Bangladesh

drainage and discharged mechanisms for flooding and sea level rise while conducting detailed investigations for slope protection to mitigate landslide risks. This can all be done while incorporating climate-friendly aspects such as solar panels, water harvesting and dedicated space for green vehicles to reduce the carbon footprint and promote environmental awareness.

Case Study 5

Promoting Climate Resilience in the Roads and Railways Sector

(presented by the Asian Infrastructure Investment Bank)[41]

Overview

This case study provides an overview of how the Asian Infrastructure Investment Bank (AIIB) has promoted climate resilience in the transportation and rural sectors to reduce greenhouse gas emissions and align policies with the Paris Agreement. It draws on examples from the road and railway sector across Asia, namely Bangladesh, India, Indonesia and Lao PDR (footnote 39).

Background

The transport sector is highly vulnerable to climate change impacts and the increasingly extreme weather events it brings, which means that infrastructure in these sectors must be designed and constructed to withstand the impacts of climate change and reduce emissions. This has required the AIIB to alter its traditional models to consider the changing needs of transport infrastructure.

Methodology

Several AIIB-funded projects demonstrate how climate resilience can be incorporated into infrastructure projects. They have identified and analyzed the key risks associated with climate change, such as rising temperatures, sea-level rise, extreme weather events and changes in precipitation patterns. The AIIB then recommended climate-adaptive design/measures to minimize and implement these risks into the project.

41 AIIB's Experience of Promoting Climate Resilience in the Roads and Railways Sector, Ms. Jin Wang, Senior Investment Operations Specialist – Transport, AIIB; AIIB's disclaimer applies https://www.aiib.org/en/general/disclaimer/index.html

Key Findings

Bangladesh: Because 90 percent of its land is low-lying, Bangladesh faces many climate change risks. This will lead to extreme rainfall and heat waves across the country. The Sylhet to Tamabil Road Upgrade Project[42] aimed to improve intercity connectivity in Bangladesh and cross-border connectivity between Bangladesh and India by upgrading Bangladesh National Highway N2 between Sylhet and Tamabil. It did this by incorporating climate resilience features into the project design, such as improved surface drainage (road drains, curbs and gutters), improved design criteria for bridges and culverts to account for increased peak flows and floods, erosion control measures for embankment slopes and hillside cuts (e.g., increased tree planting and revegetation) and enhanced pavements and road base in areas prone to flooding.

India: The objective of the Chennai Metro Rail (phase 2 – Corridor 4) Project[43] was to provide increased capacity and efficiency of east-west connectivity by expanding the Chennai metro system. Chennai Metropolitan Area (CMA) is an earthquake-prone area, falling under moderate zone III as per the local seismic code. It is prone to cyclone risks within 20 kilometers of the coast, and few areas within the CMA are susceptible to

42 Project Document, 20200402-P000153-Sylhet-Tamabil-Road-Upgrade-Published-Document.pdf (aiib.org)

43 AIIB-P000301-India-Chennai-Metro-Rail-Phase-2-Corridor-4-APD-Published_20210924.pdf

flooding during heavy storms.[44] The project design adopts climate change resilience features to reduce vulnerability to the detrimental impacts of these climate-related events.

Indonesia: Under appraisal is a project (Trans-Sumatra Toll Road Project – Cinto Kenang to Sentjalang)[45] to improve the efficiency, safety and resilience of road connectivity in Sumatra by building a segment of the Trans-Sumatra Toll Road. To achieve the objective, a series of climate resilience measures will be incorporated into road design and implementation, including road elevation, adequate road structure, drainage and enforced embankment.

Lao PDR: The Climate Resilience Improvement of National Road 13 South Project's[46] objective was to improve the road condition, safety and climate resilience of the south section of the National Road 13 (section 3). To achieve this, the project will implement several measures, including upgrading the drainage systems and designing culverts, drains and ditches to ensure efficient water discharge. The project would minimize impacts to the road structure and adjacent surroundings protecting riverbanks and preventing erosion at bridge piers and abutments. These measures will help make the road more resilient to climate change, ensuring it remains accessible and safe, promotes economic growth and supports inclusivity.

Lessons Learned

The case studies presented demonstrate the importance of integrating climate resilience into infrastructure development to mitigate climate change risks and enhance adaptive capacity. Identifying the risks, vulnerabilities and opportunities associated with climate change and integrating recommended measures throughout the project development cycle is essential.

Conclusions

AIIB has already taken several steps toward promoting climate resilience in its projects, such as conducting climate risk analysis and implementing adaptation measures. However, there is still a long way to go to achieve international climate targets. AIIB can further promote climate resilience in transportation by investing in low-carbon and resilient infrastructure.

44 Key climate-related risk as per Second Master Plan for Chennai Metropolitan Area 2026, Chennai Metropolitan Development Authority, Government of Tamil Nadu.

45 Project Summary Information, AIIB-PSI-000556-Indonesia-Trans-Sumatra-Toll-Road-Project.pdf

46 Lao PDR: Climate Resilience Improvement of National Road 13 South Project (Section 3) - Projects - AIIB

3.3 Climate Mitigation in Roads and Railways

Comprehensive and coordinated implementation of innovative practices is needed to effectively decarbonize the rail and road sectors. Transitioning to zero-carbon transport requires a top-level design that includes science and technology innovation, regulations and standards, mechanisms, and institutions to achieve connection and security. Establishing interministerial coordination and linkage mechanisms between various government ministries is essential to promote collaboration between transport digitalization and green development planning. This will ensure that the emerging zero-carbon transport system supports both the economy and all groups across society.

China is an excellent example of a country that has implemented various initiatives to promote sustainable mobility. For instance, the government has widely adopted the Electronic Toll Collection system, which has significantly reduced air pollutants and CO_2 emissions.[47] They have also used Intelligent Signal Control to optimize signal timing and reduce carbon emissions at major road interchapters. By implementing these technologies, China has significantly reduced carbon emissions from the transportation sector.

Moreover, China is promoting the adoption of new energy vehicles in urban public transport, rental, logistics and distribution. They are also accelerating the development and application of high-level automated driving, which can further reduce emissions by optimizing vehicle routing and reducing empty trips. In addition, China is encouraging innovation in passenger transport service models based on the sharing economy and carrying out pilot demonstrations of carbon accounts for urban resident mobility. By incorporating electric vehicles into their broader plans for sustainability and implementing these innovative strategies, China is making great strides toward decarbonizing its transportation sector.

Furthermore, innovative financial models and private-public partnerships should be utilized to support the transition. One way to support the adoption of electric vehicles is through innovative financing strategies such as long-term financing or pooling demand, which can help manage the upfront costs of more expensive electric vehicles and charging infrastructure (See Case Study 6 for details).[48] Developing battery leasing and recycling models can also make electric vehicles more accessible and sustainable. Private-public partnerships can support rail infrastructure upgrading by supporting the capital costs, as seen with São Paulo by the Inter-American Development Bank and outlined in more detail within Case Study 7.

Green Bonds are other potentially important tools for decarbonizing the railways sector. The EBRD presented its innovative experience with a green bond for Georgia Railways (footnote 16). The project mobilized USD500 million through a seven-year green Eurobond issue list on the London Stock Exchange. The green bond was underpinned by a Green Bond Framework that defined the rules of the game.

47 Collaborative Development Path of Road Traffic Digitization and Greening in China, Mr. Hou Dezao, Professor/Director of Intelligent Transportation Research Center, Research Institute of Highway, Ministry of Transport, China

48 Regulatory and Policy Approaches Enabling the Transition to Transportation Decarbonization. Sharing the Barbados Net-Zero 2030 Experience, Mr. Mark Durant, Chief Planning Officer, Ministry of Transport, Works and Water Resources, Barbados

The green bond was issued with record-low pricing for Georgia's state-owned companies. There was an 8.4 times oversubscription for the green bond. Overall, it was a very successful bond issuance. The green projects financed by the bond included a new railway line developed without direct emissions saving 19,000 tons of CO_2 in one year. This was combined with freight and passenger rolling stock, energy efficiency improvement of existing electrified railway lines and modernization of trackside infrastructure. These investments avoided more than 19,000 tons of CO_2 equivalent in 2021 and increased speeds to 80 kilometers per hour. Capacity is expected to increase from 27 to 48 million tons of cargo annually.

Case Study 6

Transitioning Barbados to Zero-Carbon Transport through Electric Vehicles

(presented by the Government of Barbados)[49]

Introduction

Barbados, a small island nation with a population of 272,300 people, is committed to transitioning to zero-carbon transport through the widespread adoption of electric vehicles (EVs). This case study will examine the country's efforts to achieve this goal, focusing on key policies, challenges and results.

Background

Barbados commonly experiences climate change impacts, which are unsustainable annually. Yet, with its current transport fleet being 95 percent carbon-based, the country heavily relies on technologies contributing to these devastating impacts. The country faced many challenges in transitioning to zero-carbon transport, including high upfront costs of EVs, availability of EVs, road quality and maintenance, driver behavior and multiagency collaboration.

Methodology

Through its strong visionary leadership and stakeholder engagement, Barbados has implemented a swift decarbonization process through clear policy and financing. For example, the country has implemented several technological solutions, such as electric vehicle registration, vehicle black box technology, improved enforcement services, an electronic load management system, and transport augmentation and digitization of partnerships. Finally, power grid support systems such as transformers, photovoltaics, standby generators and enhanced technical expertise are crucial to the success of the transition.

However, due to limited charging capacity, Barbados realizes that it cannot replace all fossil fuel vehicles with EVs. To address this, the country has implemented a range of tax and duty incentives, such as reducing import duty on battery EVs from 45 percent to 10 percent, PPP for renewable solar projects and increasing loan limits for civil servants to purchase alternative fueled vehicles. The country has also installed solar charging stations for electric buses in the city and encouraged private and residential areas to become charging stations.

Barbados electric buses

Inter-American Development Bank (IDB)

49 Regulatory and Policy Approaches Enabling the Transition to Transportation Decarbonization. Sharing the Barbados Net-Zero 2030 Experience, Mr. Mark Durant, Chief Planning Officer, Ministry of Transport, Works and Water Resources, Barbados

Key Results

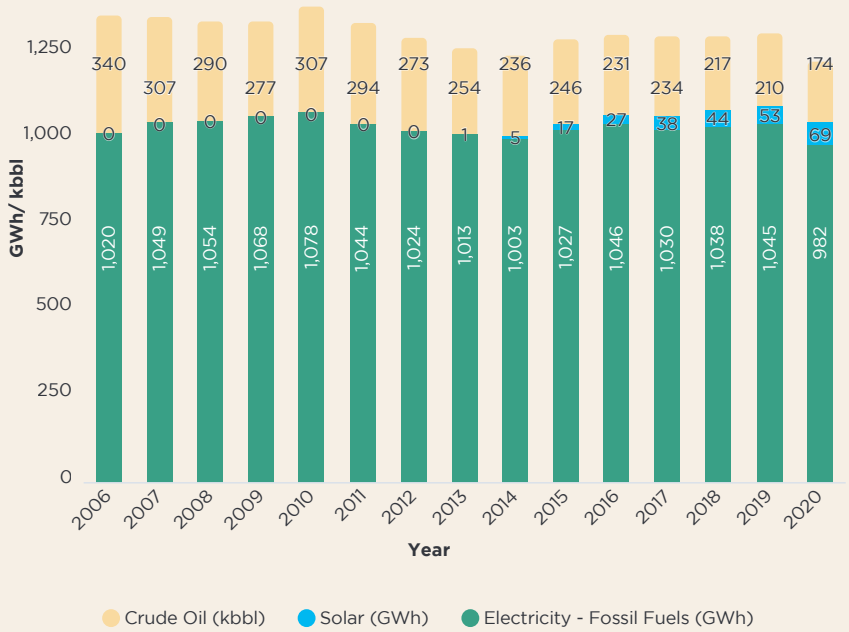
Barbados has seen significant progress in its transition to zero-carbon transport. The introduction of EVs and hybrid vehicles has enhanced physical and technological infrastructure, including GPS and online payments. The country's electric bus committee, comprised of local experts, has led to the deployment of 49 electric buses and 33 charging stations, as well as increased energy efficiency and air quality. As a result of these efforts, Barbados has enhanced its energy security due to a reduced dependency on imported fuel, increased inclusive mobility due to a reduction in operational and maintenance costs and provided many health and environmental benefits due to improved air quality and reduced CO_2 emissions by 14 percent to 43 percent.

Solar Plant in Lamert's St. Lucy Barbados

Conclusion

Barbados' efforts to transition to zero-carbon transport through the widespread adoption of EVs represent a significant step towards reducing the country's carbon footprint and promoting sustainable development. While challenges remain, the country's strong leadership, comprehensive policies, and commitment to stakeholder engagement and technological innovation provide a blueprint for other nations to follow in the transition to a greener, more sustainable future.

Figure 6: Barbados Energy Production (by type per year)



GWH = gigawatt-hours, kbbl = 1,000 barrels

Source: OSIE Barbados

3.4 National Long-term Strategies and Policies for Transport Decarbonization

To support decarbonization and enhance resilience within the road and rail sector, countries can take several steps that should all be integrated into a comprehensive plan. This chapter has identified that a whole-of-government approach is required to decarbonize the road and railway sector through a range of clear policies and laws. One way to enhance this is by integrating the roads and railways sector into a country's NDCs. This will allow the government to create a clear vision for the whole country and minimize emission misplacement, whereby emissions move from one sector to another. The World Resources Institute (WRI) presented the global experience of the transport sector in NDCs through data collated and presented by its Tracker of Climate Strategies for Transport tool.[50]

Increasing public transport is a key solution within NDCs, but there are also many others. Most countries prioritize public transport as a solution for transport sectorial mitigation, with 100 out of 142 mentioning it as a tool for reducing emissions. However, these tend to be teamed with vague and measurable actions/targets making it hard to create real change. Better efforts are needed for development and implementation. This could include clear guidelines for planning for compact cities with improved public transport, walking and cycling infrastructure.

The Avoid-Shift-Improve Framework can be a useful tool in transport decarbonization. This framework outlined in the presentation by the World Resource Institute[51] has three categories of activity: **avoid** and reduce the need for motorized travel, **shift** to more environmentally friendly modes of transport and **improve** the energy efficiency of transport modes. Most NDC transport mitigation interventions are only in the "improve" category.

There are three key areas for NDC enhancement in the transport sector. First, accelerate the electrification of transport modes. Second, amplify the "avoid" and "shift" solutions mentioned earlier. Third, address GHG emissions for freight transport.

A detailed analysis of transport electrification is required to define the best policies for a country. The presentation by the World Bank outlined the economics of accelerating electric mobility adoption for passenger vehicles in low- and middle-income countries and offered a useful methodology for policy design.[52] The adoption of electric vehicles can benefit areas such as health through improved air quality, inclusive mobility through affordable last-mile solutions and energy security if the country imports fuels. If electric vehicles are part of an integrated sustainable transport strategy, they can provide significant carbon reduction and climate mitigation benefits. The analysis showed that initially targeting the most promising market segments is important. This means electric two- and three-wheelers and buses; regular four-wheel electric cars are only cost-effective in a minority of cases.

50 Enhancing NDCs: Opportunities in Transport, Ms. Yiqian Zhang, Research Associate, Global eMobility, WRI; Climate Strategies for Transport: An Analysis of Nationally Determined Contributions and Long-Term Strategies. Available at: http://slocat.net/wp-content/uploads/2022/01/Climate-Strategies-for-Transport-An-Analysis-of-NDCs-and-LTS-SLOCAT-December-2021.pdf

51 Enhancing NDCs: Opportunities in Transport, Ms. Yiqian Zhang, Research Associate, Global eMobility, WRI; Enhancing NDCs: Opportunities in Transport, a guidance aiming to help countries incorporate ambitious, relevant, and tangible transportation solutions into enhanced NDCs for communication to the UNFCCC. World Resource Institute

52 Economy Wide Analysis of Financial and Economic Costs and Benefits of E- Mobility Adoption Speaker: Ms. Cecilia Briceno-Garmendia, Global Head / Lead Economist, Transport Economics and Policy, World Bank

3.5 Harnessing Private Finance

Private finance engagement in the road and rail sector should prioritize climate resilience measures. Road and rail infrastructure vulnerability to climate risks, such as natural disasters, highlights the need for resilient design and construction. Lessons from Bangladesh's road design standards and AIIB-funded projects in India, Indonesia and Lao PDR emphasize the importance of incorporating climate risk assessments and implementing adaptation measures, such as improved drainage systems, erosion control and bridge design to withstand future flood levels. Private finance can be harnessed to support these activities through guidelines and regulations.

Private finance can also be harnessed through innovative financial models and public-private partnerships to support the transition to low-carbon and resilient road and rail infrastructure. Private-public partnerships can be crucial in supporting capital investments for rail infrastructure upgrades, as seen in the São Paulo project funded by the Inter-American Development Bank (Case Study 7). These should draw on innovative payment and revenue models while integrating climate requirements into the contracting process. Furthermore, private finance can be harnessed for electric vehicles through long-term financing, pooling demand, and battery leasing models to manage upfront costs and make electric vehicles and charging infrastructure more accessible.

Decarbonization in the road and rail sector also requires comprehensive and coordinated government and private sector actions. Governments should establish interministerial coordination mechanisms that draw on private sector expertise to promote collaboration between transport digitalization and green development planning. China's initiatives, such as adopting electronic toll collection systems, optimizing signal timing, promoting new energy vehicles and exploring high-level automated driving, demonstrate the importance of integrating innovative practices and technologies for effective decarbonization.

National long-term strategies can provide certainty and clarity for private finance. This can reduce the risk associated with investing in climate solutions for the private sector. Private sector engagement should align with national long-term strategies and policies for transport decarbonization. Countries should promote this by integrating the road and rail sector into their NDCs and developing clear policies and laws to support decarbonization efforts. Emphasizing public transport, implementing the Avoid-Shift-Improve Framework, accelerating electrification and addressing freight transport emissions are key areas for enhancing NDCs in the transport sector and supporting innovative private investments.

Case Study 7

São Paulo Intercity Train – North: Public-Private Partnership

(presented by the Inter-American Development Bank)[53]

Background

The state of São Paulo is home to two of the largest metropolitan areas in Brazil, São Paulo and Campinas, with a combined population of over 25 million people. The demand for reliable and sustainable transportation services between these two cities is high, with many currently relying on cars and buses. To address this issue and promote a cleaner mode of transportation, the Brazilian government launched a project to develop metropolitan and express rail services connecting the two cities.

Methodology

The project involves the construction of a rail network that would replace trips currently made by cars and buses. With an estimated capex of around R$10.5 billion (about USD2 billion), the private sector needed to absorb the risk of the new service being built and fully execute the capital and operational expenditure. The project will leverage existing infrastructure to promote new transport services and alternatives, thereby generating opportunities for economic and local industry development with clean technologies. An overview of how the project will impact the three lines is outlined in Table 2.

Figure 7: Map of Southeast Brazil

hab = habitants, R$ = Brazilian real
Source: Map, Sistemas de Informação Metropolitanas do Instituto Geografico e Cartografico do Governo do Estada de São Paulo, 2021; Estimated Population, IBGE 2019; GDP (R$), IBGE

53 São Paulo Intercity Train – North: PPP, Mr. Gaston Astesiano, PPP Team Leader, Inter-American Development Bank

Table 2: Overview of Train Line Improvements

Express Service	Commuter Service: Line 7 - Rubi	Commuter Service: Intermetropolitan Train (TIM)
☐ 3 stations (São Paulo – Jundiaí – Campinas)	☐ 13 stations (Barra Funda to Francisco Morato)	☐ 9 stations (Francisco Morato to Campinas)
☐ New service/"Greenfield"	☐ Retrofit/"Brownfield"	☐ Expansion and Retrofit/"Yellowfield"
☐ 101 km of extension	☐ 35.19 km to be built	☐ 65.81 km to be built
☐ 64 minutes for the whole extension	☐ 50 minutes for the whole extension	☐ 55 minutes for the whole extension
☐ 42,416 passengers/day	☐ 414,323 passengers/day	☐ 98,258 passengers/day
☐ Maximum Tariff: R$0.63/km	☐ Metropolitan service basic tariff	☐ Metropolitan service basic tariff
☐ Full operation by year 7	☐ Full retrofit by year 7	☐ Full operation by year 5

km = kilometer
Source: São Paulo Intercity Train – North: PPP, Mr. Gaston Astesiano, PPP Team Leader, Inter-American Development Bank

Payment Mechanism

To make the project more efficient, an innovative payment mechanism was utilized to fund the improvements of the railway line. These included constructing payments by the government, express service revenue, availability payments, fixed periodic public payments and ancillary revenue. The revenues from these innovative schemes covered 75 percent of the project's capital expenditure. It also covered several taxes and operational expenditures for all lines, with a small proportion going to the railway's shareholders.

Reducing Project Impact and Enhancing Resilience

The public-private partnership contract had specific conditions to ensure that the project reduced its impact on nature while enhancing its resilience. It did this by implementing strict rules on impact assessment and conservation of biodiversity in the surrounding area. The private partner was obliged to perform a risk analysis of natural disasters and climate change to be used in the design of the engineering project. Specifically, the contract requires that future rain be considered based on the IPCC scenario RCP4.5, considered an intermediate scenario.

Lessons Learned

The project provides a clear example of how existing infrastructure and innovative private-public partnerships can create win-win opportunities for the environment, society and economy. The private sector's complete execution of capital and operational expenditure ensures that public resources are used efficiently to promote clean transport technology and reduce motor vehicle dependency. Likewise, this could all be done with a small impact on the environment due to strong contractual obligations that integrate future climate change risk and the need to minimize the impact on biodiversity.

Conclusion

The São Paulo and Campinas clean transport infrastructure project is a significant initiative that would provide reliable and sustainable transportation services to over 25 million people. It would reduce dependence on highways and urban roads, resulting in less automobile use and GHG emissions. Likewise, it would generate several business and job opportunities in the region while supporting compliance with strong environmental standards. It shows how innovative private-public partnerships and finance models can unleash several benefits.

4 Climate-Smart Energy Connectivity Infrastructure

4 Climate-Smart Energy Connectivity Infrastructure

4.1 Overview

The potential for renewable energy is enormous, but connecting sources and consumers must be part of the solution. These connections bring three key benefits. First, economic benefits, as consumers can access cheaper energy and countries can export their excess energy production. Second, security, as countries access diverse energy sources. Third, sustainability, as with better connectivity infrastructure, consumers have access to regions with high renewable energy potential, and countries can reduce the carbon emissions of their energy by accessing those renewable resources.

Furthermore, there is a need to ensure that connectivity infrastructure is prepared to handle natural disasters. The increasing costs of climate shocks and disasters are estimated at around USD15 billion annually. The impact is even greater when including extra costs — lost time, forced closures and the need for energy generation. This chapter will investigate how connectivity and resilience across the energy sector can be enhanced, along with deep diving into energy equity.

In addition, decarbonizing the transport and connectivity infrastructure will require the energy sector to decarbonize. This is due to many mitigation strategies and solutions requiring the electrification of vehicles. Therefore, true emission reduction may only result in the transport sector if the energy sector it depends on is decarbonized.

4.2 Climate Adaptation and Resilience in Connectivity Energy Infrastructure

Integrating climate resilience will minimize power disruptions, costs and impacts on users. The World Bank presented its work on resilience in the energy sector.[54] Improving power infrastructure resilience through asset, service and network resilience is crucial to ensuring uninterrupted power service during climate shocks or natural disasters without increasing liability or impacting users. It can be achieved through regular vegetation management, strengthening infrastructure against natural disasters, and integrating new technologies and automation. Together, these solutions will help reduce the estimated USD15 billion annual repair costs for private firms and households alike.[55] Reducing power outages can positively impact gender equality by lessening the disproportionately adverse effects on women's work and girls' study time compared to men.

54 Powering through the Storm: Climate Resilience for Energy Systems, Ms. Claire Nicolas, Senior Energy Economist, Energy Sector Management Assistance Program, World Bank; Lifelines: The resilient Infrastructure. World Bank. 2019. Accessible at: https://documents1.worldbank.org/curated/en/099854409132241342/pdf/IDU0e4e47d0c09d0a04bc10842b093ad71761b86.pdf.

55 Powering through the Storm: Climate Resilience for Energy Systems, Ms. Claire Nicolas, Senior Energy Economist, Energy Sector Management Assistance Program, World Bank

Resilience in power infrastructure involves three dimensions: asset resilience, service resilience and network resilience. Power infrastructure resilience is essential to ensure the delivery of uninterrupted power service during climate shocks or natural disasters. The first dimension includes asset resilience and is concerned with the ability of physical components such as power plants, transmission lines and transformers to withstand and recover from disruptions. The second dimension revolves around service resilience and refers to the power system's ability to deliver electricity to customers during and after a disruption, requiring backup power sources, prioritizing critical facilities and restoring service promptly. Finally, the third dimension refers to network resilience and focuses on maintaining stable and reliable operations under changing conditions, including those caused by climate change. These measures help ensure that power infrastructure can cope with various challenges and protect customers from climate shocks or natural disasters. Integrating resilience across the three levels can be difficult due to the varying vulnerability of assets, so flexibility is key to finding effective solutions.

Improving the resilience of power sector infrastructure assets is challenging due to the heterogeneity of assets and their varying vulnerabilities to different hazards. This was clearly illustrated in the highly exposed capacity of generation and transmission networks in some countries. However, integrating planning and increasing network flexibility through new technologies and automation can help improve the system's resilience during natural shocks, with users supporting its effectiveness. Reducing power during a shock through demand response and energy efficiency behavioral changes can limit the impact of blackouts caused by network congestion.

This flexibility can be integrated into energy system planning. Resilient energy systems and energy systems planning can help develop more resilient strategies against extreme weather events causing significant economic losses and physical damage. This requires a delicate balance to direct strategies and investments in specific threats, along with strong data, which often needs to be improved, especially given the large-scale uncertainties. However, one solution to enhance flexibility is implementing high levels of distributed solar, wind and battery storage. This can enhance resilience and overcome reductions in generation during natural hazards, as presented by the Colorado School of Mines.[56]

The risks can be reduced through environmental management and adaptation measures, as in the case of the Philippines. The country suffers from catastrophic cyclones, and energy infrastructure damage has been enormous in the past. The country has identified a series of priority actions designed to improve the whole value chain of the energy sector so that the system can withstand the impact of hazards and recover quickly from any energy supply disruption. The presentation by the Philippines outlined how it is critical to lessen the vulnerability of transmission networks to natural disasters by undertaking regular vegetation management to reduce wildfires and the likelihood of strong winds leading to felling trees.[57] Other

56 Exploring Acute Weather Resilience: Incorporating Resilience Concerns in Energy Decision Making, Ms. Madeline Macmillan, Advanced Energy Systems, Colorado School of Mines and the National Renewable Energy Laboratory

57 The Role of Energy Sector in Climate Action, Mr. Michael O. Sinocruz, Director, Energy Policy and Planning Bureau, Department of Energy, Philippines; 2020-2040 Philippine Energy Plan: Towards a Sustainable and Clean Energy Future. Accessible at: https://www.doe.gov.ph/sites/default/files/pdf/pep/PEP_2020-2040_signed_01102022.pdf

measures include physical changes to the sector, such as elevating infrastructure and using concrete blocks to improve infrastructure resilience to floods.

4.3 Climate Mitigation through Energy Connectivity and Regional Cooperation

Increased electricity cooperation and trade between countries will yield numerous advantages as the world addresses the climate crisis. Regional energy connectivity will support energy security and lower costs, accessibility and sustainability through diverse renewables by creating a fully integrated and low/zero-carbon power grid. The ASEAN Center for Energy provided an overview of how many countries within their region have begun to do this and are benefiting from reducing costs and enhancing the reliability of electricity for their economies and citizens.[58] This has focused on increasing knowledge, energy access, renewable energy generation and energy efficiency.

Regional road map development and collaboration with stakeholders across all sectors can facilitate enhanced connectivity. The ASEAN Center for Energy discussed how 10 ASEAN countries have developed a strategy to implement increased regional energy connectivity that covers planning, financing, development, operational issues and cross-cutting areas, including building trust, intergovernmental agreements, capacity building and sharing data. It also acknowledges and aims to overcome the risks associated with power sector investment since these investments are capital-intensive, long-term and high-risk. Governments and stakeholders should learn from this road map and work together to increase capacity, coordinate joint procurement tenders and harmonize standards to reduce cost (footnote 58). This includes utilizing innovative common financial instruments and developing clear long-term policies and frameworks overseen by robust institutions to unlock private climate finance.

Green corridors can be a valuable tool to test initial regional energy connectivity collaboration. UNESCAP presented its work with Asia Pacific countries exploring ways to enhance the connectivity in the energy sector across the region. Collaboration and coordination have been crucial for identifying deployment opportunities and enabling cross-border integration in the field of connectivity.[59] However, with investments in these projects significant and risks, green power corridors can be established to overcome initial barriers and support pilot projects. These projects can increase the reserve margin and support energy exchanges between the two systems, saving a considerable investment in both countries. Furthermore, it can test whether issues relating to the synchronization of systems and regulations have been overcome effectively. In addition, greater transparency, harmonization of energy systems, innovative financing, more coordinated energy grid planning and stronger capacity across the region are fundamental factors in

58 Building Regional Energy Connectivity through ASEAN Power Grid and Renewable Energy Certificate (Video) Speaker: Ms. Monika Merdekawati, REE Department, ASEAN Center for Energy; ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. ASEAN Centre for Energy. Available at: https://aseanenergy.org/asean-plan-of-action-for-energy-cooperation-apaec-phase-ii-2021-2025/

59 Sustainable Energy Connectivity in APAC – Trends and Opportunities (Video) Speaker: Mr. Matthew Wittenstein, Chief of Energy Connectivity Section, Energy Division, UNESCAP; Attracting private finance to transmission in the Asia-Pacific Region. Escap. 2022. https://hdl.handle.net/20.500.12870/4560

achieving energy connectivity and integration.

Projects like the Central to South Asia Electricity Transmission and Trade Project show the benefits of cross-regional energy connectivity infrastructure. The Islamic Development Bank shared its experience with regional connectivity energy projects, of which they have more than USD2 billion in investments.[60] Their presentation discussed the Central Asia to South Asia Electricity Transmission and Trade Project and the Saudi-Egypt Electricity Interconnection Project. This latter project is an ideal example because it demonstrates the potential to leverage the differences in the two countries' energy load profiles. This project will connect the two largest power systems in the Arab region resulting in both countries saving 750 MW due to sharing their capacity or the equivalent of three power plant stations.

Box: Energy Connectivity for Equity, Livelihoods and Climate Action

The World Resource Institute has developed Energy Access Explorer (EAE), an open-source information system that aims to enhance energy equity:[1] EAE is an online platform developed by the World Resource Institute[2] that synthesizes granular data on energy demand and supply to identify high priority areas for expanding access to energy and linking it to socioeconomic development. With this information, governments can develop data-driven energy plans to support the expansion of clean energy markets. The platform allows users to group and customize data sets, generate customized analysis and present it in less than a day of training without requiring programming or GIS expertise. The program is available for seven countries[3] and aims to expand electricity access for all within those countries.

Satellite data is utilized to visualize where energy development would be most impactful. The service further provides visualizations on demand for energy services using data on demographics, population density, distribution, socioeconomic activities, education and healthcare facilities, electrification status and satellite imagery. Frequent satellite imagery updates provide critical information on energy demand and supply-related indicators, including energy resource availability and infrastructure, which can help identify high-priority areas for expanding access to energy services. The platform synthesizes and normalizes various data sets to generate high-resolution prioritization maps for decision-making, including environment data, protected areas data, finance access, service providers and microfinance institutions.

1 Energy Access Explorer, World Resource Institute. Available at: https://www.wri.org/initiatives/energy-access-explorer

2 Energy Access Explorer: An Integrated, Data-driven Approach to Achieving Universal Access to Energy for Equitable Development, Dr. Dimitris Mentis, Lead, Energy Access Explorer, WRI

3 The seven countries available on the platform are Ethiopia, India, Kenya, Nigeria, Tanzania, Uganda and Zambia

60 The Regional Energy Integration and its Role in Addressing the Energy Gap, Mr. Hussein Mogaibel, Lead Global Energy Specialist, IsDB

Case Study 8

Renewable Energy Transformation in Egypt

(presented by the Government of Egypt)[61]

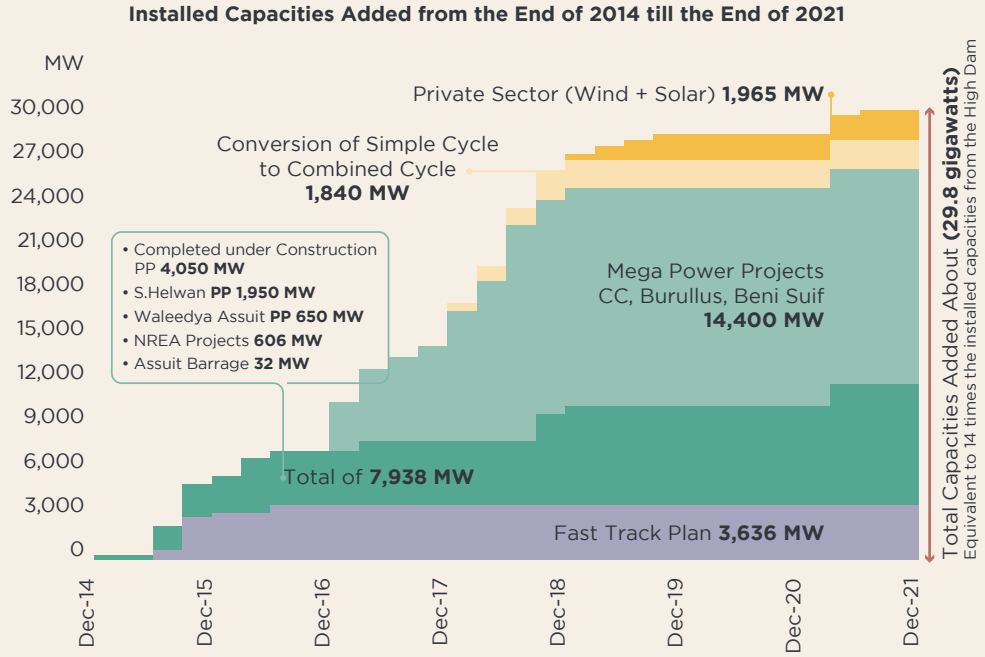
Overview

In 2014, Egypt experienced a series of power outages due to an energy supply gap of nearly 25 percent. This was due to various factors, including electrical power outages, transmission constraints and fuel shortages. However, through a combination of measures, the Government of Egypt overcame this shortage so successfully that it has been preparing to export electricity to neighboring regions, thereby providing additional income for the country.

Emergency Power Capacity Plan

To overcome its energy constraints, Egypt implemented a five-part plan. This consisted of fast-tracking the construction of eight power plants in the space of 8.5 months at the cost of USD2.7 billion to generate 3,636 MW. Likewise, it invested heavily in ensuring six energy projects under construction before 2014, representing 4,250 MW, were completed within the year by investing USD3.98 billion. Three additional mega power plants were created with local and international partners, such as Siemens, adding another 14,400 MW of electricity to the grid.

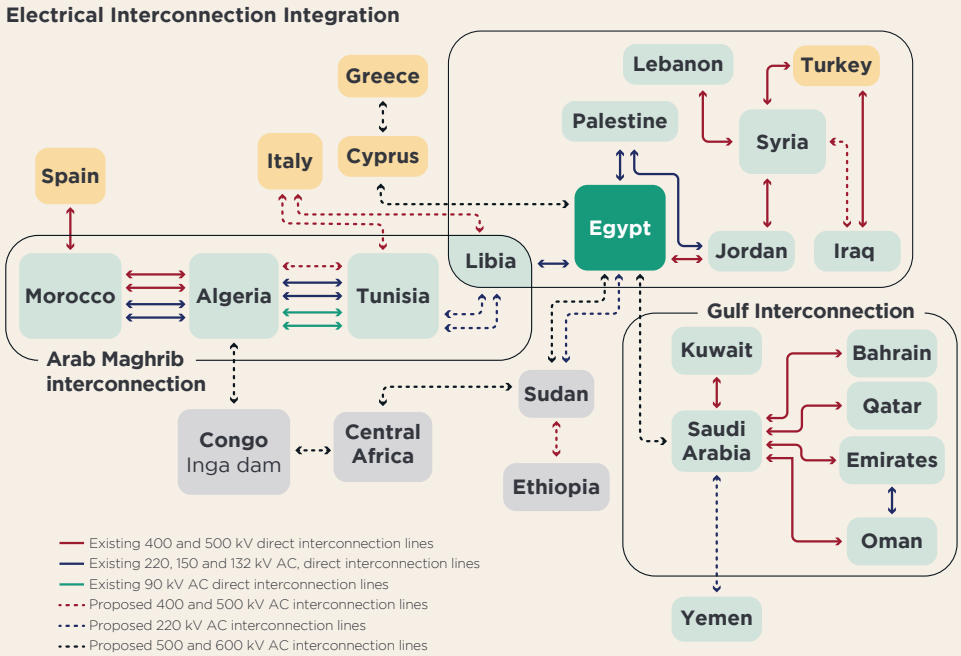
Figure 8: Total Added Capacity in Egypt in 2014



Source: Ministry of Electricity and Renewable Energy, 2023

61 Renewable Energy Transformation in Egypt, Dr. Eng Ahmed Mohina, First Undersecretary for Research, Planning & Authorities, Egypt, Ministry of Electricity and Renewable Energy, Egypt

Figure 9: Regional Interconnections



Source: Ministry of Electricity and Renewable Energy, 2023

Energy Efficiency

In addition, work was undertaken to enhance the energy efficiency of the plants by converting simple cycle power plants into combined power plants by adding 1,840 MW without using any extra fuel. The energy efficiency improvements reduced fuel use and, thereby, operational costs. Furthermore, it improved its transmission grids and established 47 distribution control centers and 31 substations.

Diversity of Renewable Energy Types

In addition to traditional electricity production methods, Egypt has embraced the diversity of renewable energy by constructing hydro, solar and wind projects. It has constructed solar parks and works with international companies to implement further renewable energy generation facilities. Additionally, 20 percent of municipal solid waste will be used to create energy, equating to around 300 MW in five years. The government will create a compensation tariff for purchasing electricity produced from solid waste to incentivize the private sector to reduce emissions. Furthermore, to overcome the intermittency issues associated with renewable energy, Egypt has adopted agreements with the private sector to produce green hydrogen and is constructing pumped hydro plants. This has enabled Egypt to surpass its expected energy production capabilities and create a surplus.

Policies to Support the Transition

The Government of Egypt adopted several policies to support this range of improvements. This included high renewable energy and efficiency targets and private sector incentives such as allocating 5,200 square kilometers of land for renewable energy generation projects. In addition, Egypt has ensured that a range of information is available to investors, including maps of each area's solar and wind potential and environmental impact assessments. It has also ensured long-term bankable power purchase agreements and sovereign guarantees and reduced customs duties for all materials and equipment.

Egypt as an International Energy Hub

Due to the program's success in enhancing electricity production and its abundance of solar and wind resources, Egypt is now producing a surplus of electricity to sell to other countries (See Figure 9). It has already begun to create memorandums of understanding with various countries across Africa, Asia and Europe, connecting Greece to Saudi Arabia. This enables a return on its investments and an additional income source for the government.

Conclusion

Egypt's leadership and implementation of its five-point plan have significantly increased its energy generation to 28,229 MW in six years. This has created a sustainable energy blueprint for many countries on how they can not only decarbonize their energy sector but also provide additional income benefits and enhance energy security.

4.4 Harnessing Private Finance

Private sector involvement in the energy sector is essential. Through public-private partnerships, innovative financial instruments and changes in procurement processes, private sector companies can bring managerial skills, know-how and investment capital to develop energy infrastructure more efficiently. Case Study 9 on Zambia and Peru showcases this and how it supported the development of transmission infrastructure can lead to the displacement and reduction of diesel generation, contributing to sustainable energy access.

Supporting offshore wind power projects in China exemplifies the role of private sector engagement in clean energy initiatives. By providing long-term project loans, favorable interest rates and knowledge sharing, the private sector contributes to expanding wind capacity and decarbonization efforts. Projects like the Pinhead Bay Wind Power Project and the Guangdong Wind Energy Project demonstrate the resilience and innovation required for successful offshore wind development and how leadership by the government to harness the private sector can help overcome these challenges.

Climate resilience is a critical aspect that the private sector needs to comprehend and incorporate into its operations. In particular, the energy sector must bolster its resilience to effectively navigate natural disasters and climate-related shocks. The repercussions of such events can be substantial, encompassing lost time, forced closures and amplified energy generation requirements. Enhancing resilience and fostering connectivity across the energy sector makes it possible to minimize power disruptions, mitigate costs and mitigate their adverse effects on users and profits. Enhancing the private sector's understanding of how climate resilience impacts it is necessary to ensure its integration into the project lifecycle to reduce costs.

Case Study 9

Private Sector Participation in Power Transmission

(presented by the International Finance Corporation)[62]

Context

The private sector has traditionally focused on renewable energy generation with limited involvement in transmission infrastructure. This has led to some developing countries having inefficient transmission infrastructure. Since the 1990s, the restructuring and liberalization of power markets in OECD countries have resulted in a shift in the financing of transmission infrastructure away from the public sector, with new business models created to encourage private sector participation. These models started in the developed world and Latin America — with Peru a success story where blackout was prevalent — before spreading to Asia. Experience in these regions shows that private players have brought know-how and capital in fiscally constrained markets where public funding was limited and more appropriately focused on other infrastructure sectors less capable of attracting the interest of private sector investors.

Africa suffers from a massive shortfall in transmission infrastructure (both in capacity and reach) and a prevailing philosophical perception that transmission is naturally the preserve of the public sector. There is a need for significant funding to close the energy access gap and support the substantial investments made and required in the future. The World Bank has estimated the funding required to expand and maintain Africa's transmission network at between USD3.2 and USD4.3 billion annually between 2015 and 2040. The case study transmission project presented shows how Zambia has an oversupply of electricity due to new hydropower plants coming online. The power is, therefore, largely of a renewable nature (up to 700 MW). Transmitting the supply of power from Zambia to the region defers the need for new generation to be developed, which would result in additional GHG emissions.

Case 1: Transmission infrastructure is a key enabler for energy transition in Africa

This case study highlights the importance of private sector involvement in developing power transmission infrastructure to facilitate the energy transition in Africa. An active transmission interconnector project between Zambia and the Democratic Republic of Congo highlighted how developing transmission infrastructure can be key enablers to a sustainable energy transition and allow for more capacity to connect renewable power, lead to the displacement and reduction of diesel generation, and defer the development of new generation. The project emphasizes the need to explore opportunities for private sector involvement in transmission infrastructure development in Africa and leverage policy measures and financial instruments to promote sustainable energy transition in Africa.

Case 2: Private sector success story of Peru (1998–2017)

Peru's experience between 1998 and 2017 demonstrated the effectiveness of public auctions in attracting private sector involvement in developing transmission infrastructure. The competitive bidding

62 Private Sector Participation in Power Transmission, Ms. Tilana De Meillon, Senior Operations Officer, Upstream, IFC and Ms. Marwa Khalil, Operations Officer, IFC

process resulted in the winning bids being, on average, 31 percent cheaper than the government's original price cap estimates. A total of 7,560 kilometers of new lines were implemented through USD2.6 billion invested (cost saving and line lengths are given in Figure 10). Winning bids help the government improve its ability to determine future price caps. Good tenders and competitive forces tend to force private bidders to optimize costs, which the government can leverage in future bidding rounds.

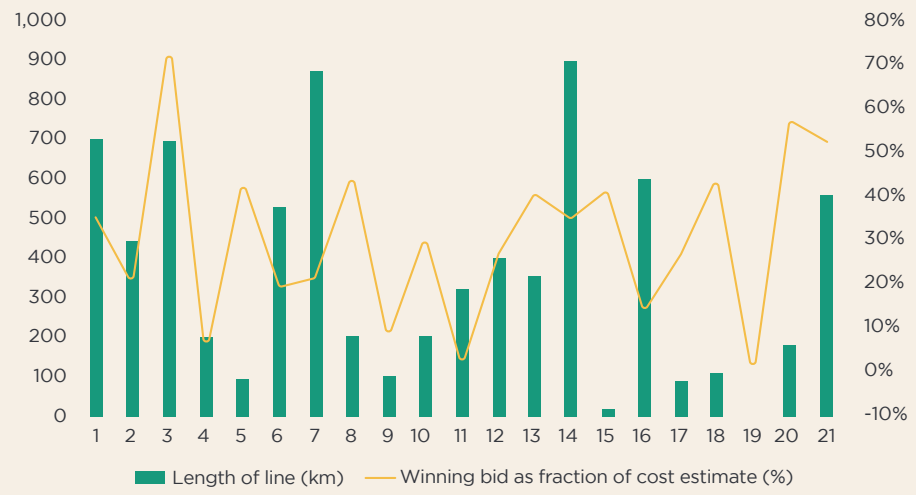
Case 3: Finance instruments - Super Green Loan Coelba, Brazil

Blended and concessional finance tools can be utilized to support renewable energy projects and fill funding gaps or provide risk mitigation to reduce costs. International Finance Corporation (IFC) Super Green Loan in Brazil is an example of using finance tools effectively, combining the more traditional "green" (climate-related) use of proceeds (energy efficiency and resiliency) with sustainability-linked pricing features. The corporate sustainability performance targets include reduced carbon intensity, improved gender metrics and external validation of emission reduction targets. The investment contributes to climate mitigation by supporting brownfield efficiency improvement and reduction of GHG emissions, with a climate finance portion of 82 percent. It also has identified gender benefits such as bringing more women into technical jobs, increasing productivity and promoting innovation in the company.

Lessons Learned

Combining public and private financing can complement social and energy infrastructure while developing viable transmission projects with higher capacity can enable the integration of renewable energies into the grid. Private sector companies can facilitate these projects by bringing skills, know-how and investment capital to develop transmission infrastructure efficiently and complement public finance to create projects that can lead to cost savings, greater efficiency and displacement of thermal generation. The models outlined illustrate how countries can develop different models to match a country's specific context and drivers. Pilot programs are essential to understand what adjustments need to be made (e.g., regulation changes) and how an innovative model will operate. It is important to leverage policy measures and financial instruments to facilitate the energy transition in Africa.

Figure 10: Length of Electricity Lines in Peru Against Winning Bid as a Fraction of Cost Estimate



Source: Privately Financed Transmission Projects: The Case of Peru. Pedro E. Sanchez. World Bank. March 2018

5 Connectivity Infrastructure Finance at COP27

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The Climate-Smart Connectivity Infrastructure Workshop Series concluded with a high-level event at the Climate Conference COP27 in Egypt. The event focused on the challenges and innovative experiences in financing climate action in connectivity infrastructure. This section summarizes the statements of the high-level panelists.

H.E. Dr. Mohamed Maait, Minister of Finance of the Arab Republic of Egypt, opened the event by highlighting how climate-smart connectivity infrastructure is crucial for economic growth and multilateral cooperation. He continued that infrastructure that both adapts to and mitigates climate change is an essential loss and damage strategy. In addition to mobilizing climate finance for these projects, sharing global knowledge on best practices and policies for these sectors is essential. Emphasis was put on the current macroeconomic climate and how many countries struggle with unprecedented debt burdens. To address the various crises in developing countries, it is equally critical to ensure that green climate finance becomes more attractive than traditional finance as part of the solution. However, this will need increased synergy between governments, development financiers and private investors to create de-risking instruments, such as incentivization frameworks, and diversifying the sources and types of climate financing available.

H.E. Mr. Xie Zhenhua, China's Special Envoy for Climate Change, reminded the audience of climate change's impact on the environment, the global economy, the livelihood of the poor, and the health and well-being of individuals. The impacts of climate change are now intertwined with the COVID-19 epidemic, geopolitical conflicts, energy and food shortages, and the global economic slowdown. Mr. Zhenhua emphasized that connectivity is the foundation of global business. The development of maritime, rail, aviation, transportation and infrastructure construction has contributed to economic prosperity. Connectivity infrastructure development can help countries address climate change and advance carbon neutrality or net-zero carbon dioxide emissions. For example, China's Global Energy Interconnection initiative provides a road map for meeting the world's rapidly growing energy demand with a globally interconnected grid that connects the production of renewable energy to consumers around the world. At the same time, developing countries alone cannot adequately afford to finance low-carbon resilient connectivity infrastructure. Developed economies, the private sector, banks and others need to play a role in providing financial and technical support for climate-smart infrastructure development.

Dr. Muhammad Sulaiman Al Jasser, President of the Islamic Development Bank, recognized the added economic value of regional connectivity and its role in addressing climate change challenges. However, infrastructure sectors require massive investments. Therefore, mobilizing finance for climate-smart infrastructure is paramount to support IsDB's member countries in achieving their NDC targets and 2030 agenda. In the last five years, an average of 55 percent of the IsDB's total commitments to climate action have been dedicated to climate adaptation, particularly building sustainable infrastructure. Examples in the bank's portfolio include resilient coastal infrastructure projects in West Africa, sustainable transport

system infrastructure finance in Türkiye, and an electricity interconnectivity project between the Kingdom of Saudi Arabia and the Arab Republic of Egypt.

The Hon. Ruth Coker-Collins, Minister of Public Works, Liberia, described how, with over 90 percent of the country's network of 13,000 kilometers of unpaved roads, precipitation and flooding are having significant impacts. Monrovia is one of the wettest cities in the world. Liberia is constantly rebuilding roads and repairing them. The breakdowns caused by climate change cause significant negative impacts on the economy, trade, livelihood and health. The constant cycle of repairing and rebuilding roads has strained Liberia's national budget leading to higher levels of debt. To face this reality, the country is taking fundamental steps such as climate stress testing of its roads, revisiting national standards and many other measures. Liberia and most other developing countries need alternative financing for infrastructure development. Together with the V20 Group, Liberia is looking forward to mobilizing a loss and damage fund to finance rebuilding the country's road network to climate-resilient standards.

Mr. Jin Liqun, President of the Asian Infrastructure Investment Bank, highlighted that the AIIB was created to deal with global challenges and connect people worldwide. To do this, the AIIB is working across Latin America, Africa and Asia with organizations with high standards and expertise to capture the minds and hearts of people globally and confront climate change in a beneficial way. Smart connectivity is based upon smart infrastructure, done in a cost-effective, environmentally sustainable manner and in a way that helps climate action and net-zero national goals. However, it cannot be approached in the same manner as 30 or 40 years ago. The AIIB believes that digital technology can substantially reduce the cost of building and monitoring the emissions produced by infrastructure. Climate-smart infrastructure requires out-of-the-box thinking, new approaches and new ideas. This requires drawing ideas from global partners and leveraging multilateral decision-making.

H.E. Mr. Ahmed Kouchouk, Vice Minister of Finance for Fiscal Policies and Institutional Reform of Egypt, reiterated that the workshop series has been developed to create a platform for everyone, everywhere to share experiences and learn. He recognizes that many lessons must be learned across all levels — from the local to regional and global levels. Mr. Kouchouk presented the enormous potential of the country to produce renewable energy, not only for its own needs but also for other countries, including neighbors in the Middle East and North Africa region and Europe. The private sector has played a vital role in this sector leading to the current production of more than 20 percent of Egypt's electricity generated from renewable sources, soon to reach 40 percent. However, there is still extensive demand for renewable energy worldwide. What is missing, especially in Africa, is connectivity. Current technology is still expensive, and solid multistakeholder partnerships are required to reduce these costs.

Mr. Axel van Trotsenburg, Managing Director of Operations of the World Bank, emphasized the massive investment needs for electricity in Africa, where only 40 percent of the population has access to this service. The Asian experience comes from countries like Vietnam, where energy access went from 20 percent

to more than 80 percent in 15 years. Climate-smart connectivity is a key part of the solution. Political commitment must be at the core of the solution. In addition, a regulatory and technology framework must be in place to allow financiers and investors to support the rapid development of the energy sector. Getting the energy pools in Africa requires solid regional cooperation and strong regulatory frameworks, ideally continent-wide. Finally, there is an urgent need for coordinated action by multilateral development banks, the private sector and local capital to finance larger climate-smart investments in the region, including in the most difficult, fragile and conflict-affected countries.

Mr. Zhongjing Wang, Chief Executive Officer of the MCDF, concluded the event by highlighting the importance of mobilizing financing for climate-smart infrastructure. He also outlined the need for creating the right policies and regulations, standards, and framework for environmental and social safeguards to ensure that the projects with the biggest impact could be invested in. The role of MCDF is to promote high-quality connectivity infrastructure investments. In 2020, 11 international financial institutions, including AIIB, IsDB, the World Bank and seven donor countries, including Egypt and China, set up MCDF. To date, USD8 million in grants have been provided to support seven regional and country project preparations in environmental and social safeguards, climate mitigation and adaptation. MCDF aims to mobilize USD500 million to USD1 billion dollars for those projects in the next five years.

6 Concluding Messages

6 Concluding Messages

Connectivity infrastructure projects play a crucial role in shaping the economic and social landscape of countries worldwide. With climate change presenting an ever-increasing threat, it is necessary to integrate climate thinking into every step of decision-making. The workshop series provided insights into how this is being done globally on various transport and connectivity projects. However, several key lessons existed across the work presented:

Lesson 1: Getting the Basics Right

Enforcing regulations and standards and ensuring high maintenance standards and adequate funding are critical aspects of infrastructure projects (footnote 8). Public policies and financial incentives should be clear and regulations and standards enforced to ensure that infrastructure projects can withstand the impacts of climate change.

As the World Bank illustrates, maintenance is a critical aspect of infrastructure projects that can impact their resilience and lifespan (footnote 8). Therefore, it is essential to incorporate maintenance planning to ensure that infrastructure can withstand the effects of climate change. This includes identifying and addressing vulnerabilities in the existing infrastructure and incorporating climate resilience into future maintenance plans. It also makes good business sense, with every dollar invested in maintenance yielding a four-dollar return (footnote 8).

In addition to focusing on maintenance, integrating climate risks into every stage of the infrastructure lifecycle is required. These stages include planning, design, construction and operation. This ensures that climate risks are considered at every stage of the infrastructure project rather than just during maintenance.

Lesson 2: Designing for Uncertainty

Designing for uncertainty is critical for infrastructure projects, as the full impact of climate change is still uncertain. Therefore, it is necessary to design infrastructure that can withstand a range of potential future scenarios. A “robust” design approach involves incorporating various possible future conditions into the design process, such as sea level rise, increased frequency of extreme weather events, or changes in temperature and precipitation patterns.[63] This approach ensures that infrastructure can adapt to a range of potential future scenarios.

To implement robust design, scenario planning can be used to develop different future scenarios based on a range of possible climate impacts. This approach can help infrastructure planners identify potential vulnerabilities and plan for them in advance, ensuring that the infrastructure can withstand a range of possible future conditions and has been successfully used to increase adaptative capacity, as seen in Case Study 4 (footnote 28) and Case Study 5 (footnote 41). Flexible infrastructure

63 Kalra, N., Hallegatte, S., Lempert, R., Brown, C., Fozzard, A., Gill, S., & Shah, A. (2014). Agreeing on Robust Decisions: New Processes for Decision Making under Deep Uncertainty. World Bank. https://doi.org/10.1596/1813-9450-6906

design is another approach incorporating robust design, which involves designing infrastructure that adapts to changing conditions. This approach can include features such as adjustable height or modular design, which can be adjusted as conditions change.

Overall, designing for uncertainty is a critical aspect of infrastructure planning that can help ensure that infrastructure projects can adapt to the impacts of climate change and remain functional for years to come. By incorporating a robust design approach, infrastructure planners can identify potential vulnerabilities and plan for them in advance, ensuring that infrastructure can withstand a range of potential future scenarios (footnote 63).

Lesson 3: Innovative Financial Models

Innovative financial models and public-private sector arrangements can enhance the ability of countries to implement climate projects. This is clearly seen by the use of green bonds by Egypt (footnote 5) and Georgia (footnote 16) to decarbonize their energy and rail sectors, respectively. While Case Study 7 (footnote 53) effectively demonstrates how public-private partnerships can be utilized to provide better results than if the public sector implemented a project alone by integrating climate risks and environmental and social protections into contracts and using innovative revenue models, the implementation of climate projects can have more comprehensive benefits without harming the wider environment (footnote 9). This can provide much-needed support for communities affected by climate change.

Lesson 4: Coordination is Key

Governance and institutional frameworks should be strengthened to coordinate between ministries and agencies. This includes cross-ministry committees and additional skills to manage climate risks. Such frameworks should be integrated into visionary medium-term national development plans that target both climate and other development objectives, including private sector involvement, as illustrated in Case Study 6 (footnote 49).

Furthermore, ASEAN (footnote 58) and the Islamic Development Bank (footnote 60) illustrated how enhanced regional cooperation could improve equitable access to resources across all communities and facilitate identifying which aspects of infrastructure need the most support. This coordination should include the private sector and can be incentivized by implementing special economic zones (footnote 60) and eco-industrial parks (footnote 35).

Likewise, the tri-network example showed how combined planning across sectors such as renewable energy, IT and highways can yield greater results than if done separately (footnote 4). Actions such as the installation of solar panels in the right of way of highways, the development of an “Internet of Vehicles” (the equivalent of the Internet of Things for highways) and an advanced charging network for electric vehicles have reinforced the benefits of this.

Lesson 5: Improving Decision-Making through Data

Access to data and modeling is critical for improving decision-making for infrastructure projects. Adequate financing is necessary to gather and understand the data, including master planning and climate risk assessments. By integrating climate risks into infrastructure projects, it is possible to enhance their resilience and ensure they can withstand the effects of climate change.

Egypt's transition of its energy sector is a clear example of this (footnote 61). By providing clear information, such as areas to be developed for renewable energy along with data on renewable energy resource maps (e.g., Global Solar Atlas),[64] the private sector was able to reduce costs and information gaps. This reduced the perceived risk of investing in climate solutions and resulted in economic and social benefits such as reduced environmental impact and operating costs.

Lesson 6: Investing in Climate-Smart Infrastructure Makes Good Business Sense

Climate impacts are and will continue to impact the movement of goods and people along with the deployment of electricity. By incorporating resilience into new infrastructure project planning, avoidable costs can be reduced, both in terms of repairing infrastructure and the disruptions climate impacts cause (footnote 8). It can also lead to an estimated 400 percent return (footnote 8). As Case Study 2 (footnote 12) illustrates, this can be because of additional benefits such as enhancing trade and reducing congestion in West Africa. While Case Study 3 illustrates how resilience investments will protect industries and communities across Vietnam (footnote 28).

Similarly, broader mitigation measures can yield additional benefits beyond reducing carbon emissions, such as enhanced energy efficiency measures that reduce costs and time associated with activities due to increased uptake in automatic systems linked to electric vehicles at ports (footnote 34). It can also result in additional income streams, as has been seen with Egypt exporting its excess electricity (footnote 61). Furthermore, shifting to electric vehicles reduces dependence on fuel imports (See Case Study 6).

Lesson 7: Private Sector Finance Should be Leveraged

Deploying climate-smart infrastructure comes with significant costs, demanding substantial upfront capital and technical expertise. However, these gaps can be bridged by harnessing private sector financing. São Paulo is a prime example of how public-private partnerships have successfully upgraded the trail network, incorporating explicit environmental benefits and climate requirements within contracts (footnote 53). Similarly, Peru has demonstrated how involving the private sector in energy projects has reduced development costs. In both these cases, pre-existing managerial and technical skills in the private sector were also leveraged to reduce government costs and direct project costs (footnote 62).

64 Global Solar Atlas. Available at: https://globalsolaratlas.info

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Annex 1 – JIGSAW

To access all of the presentations from the Workshop Series on Climate-Smart Connectivity Infrastructure that this publication is based upon, please join MCDF's JIGSAW platform.

What is JIGSAW?

JIGSAW, MCDF's digital solution for fostering high-quality infrastructure and connectivity investment, was launched in December 2021. It facilitates the flow of information on unfunded connectivity projects, and relevant knowledge to promote International Financial Institution (IFI) standards and best practices, to foster high-quality infrastructure and connectivity investments in developing countries.

What does JIGSAW consist of?

A Project Database (accessible for designated staff of organizations registered with JIGSAW as Organization Users): contains information about investment proposals seeking financing from IFIs and/or New Partners (including emerging market financiers) to facilitate communication between project owners and potential financiers. It also includes technical assistance (TA) proposals seeking grant support for project preparation and capacity development. The technical assistance project proposals will allow the MCDF Secretariat and MCDF Implementing Partners to see if MCDF's Finance Facility can support the requested technical assistance projects. The Project Database also allows organizations registered with JIGSAW including New Partners an opportunity to present themselves to other users of JIGSAW. Investment proposals and technical assistance proposals are accessed under the 'Projects' tab. Information on registered organizations is presented under the 'Partners' tab.

A Knowledge Database: hosts up-to-date information on: IFI standards, best practices, and projects; news and analysis related to high-quality and sustainable connectivity infrastructure and Investments; and all the material from MCDF events. These are all accessed under the 'Knowledge' tab that contains links to the following sections:

- **Knowledge Materials:** go here for access to the main knowledge database, which contains three types of materials: MCDF Event Materials that comprise materials related to MCDF knowledge events including presentations, links to video clips, and background reports; MCDF Knowledge Products that MCDF has produced itself on particular topics; and IFI Standards and Good Practices that have been produced by MCDF's IFI partners.
- **MCDF Briefs:** all back copies of MCDF's bi-weekly digest of news and analysis related to MCDF's themes of infrastructure Connectivity, Quality and Partnership.
- **IFI Historical Projects:** a searchable database of financed projects from IFIs.

How to participate?

If you or your organization are interested in joining JIGSAW, please email jigsaw@themcdf.org and we will guide you through the process.

The Multilateral Cooperation Center for Development Finance (MCDF)

The Multilateral Cooperation Center for Development Finance (MCDF) is a multilateral initiative designed to increase high-quality infrastructure and connectivity investments in developing countries through partnerships. With a central goal of encouraging the adoption of IFI standards, it is designed to reinforce the numerous existing global, regional and sectoral initiatives established in response to the worldwide need for more connectivity infrastructure. This includes supporting the implementation of the G20 Quality Infrastructure Principles, the UN Agenda 2030 and its Sustainable Development Goals, and the Paris Climate Agreement.

MCDF is unique in the way it pursues its goals by acting as a 'one-stop shop' for both developing country governments and new partners – sharing information, building capacity and assisting with project preparation.

For more information, please visit our website: www.themcdf.org.

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