VISIONING FUTURES

Improving infrastructure planning to harness nature's benefits in a warming world

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WWF

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EXECUTIVE SUMMARY

Seemingly every day around the world, new climate extremes are emerging that call into question the development paradigms of the 20th century and the fundamental ability of our existing infrastructure to meet the basic food, water, and energy needs of millions. There is perhaps no better recent example than yet another destructive fire season in California, where a stalled high-pressure system from a lethargic jet stream slowed by warming sent 70-90 mph winds for days across a tinderbox of vegetation and soil similarly dried out by new heat extremes. For the first time ever, the state's largest utility shut down large swaths of its power grid for days at a time until the winds subsided to reduce fire risk, stranding millions without basic energy. While the shutdown was the result of a multitude of factors, it is emblematic of just how poorly designed and managed the infrastructure of the 20th century is for the climate of the 21st.

$95 TRILLION

An estimated $95 trillion is expected to be invested in energy, transport, water, and telecommunications by 2030 alone to sustain economic growth and meet demand for basic services.

The estimates of future investment simultaneously demonstrate the enormous opportunity for change and the downside risk of failing to change: according to one estimate, more than 75% of the infrastructure to be built by 2050 does not yet exist today, with the large majority (60-70%) expected in developing economies. An estimated $95 trillion is expected to be invested in energy, transport, water, and telecommunications by 2030 alone to sustain economic growth and meet demand for basic services. If these investments happen, they would essentially double the total infrastructure on earth from that of 2012.

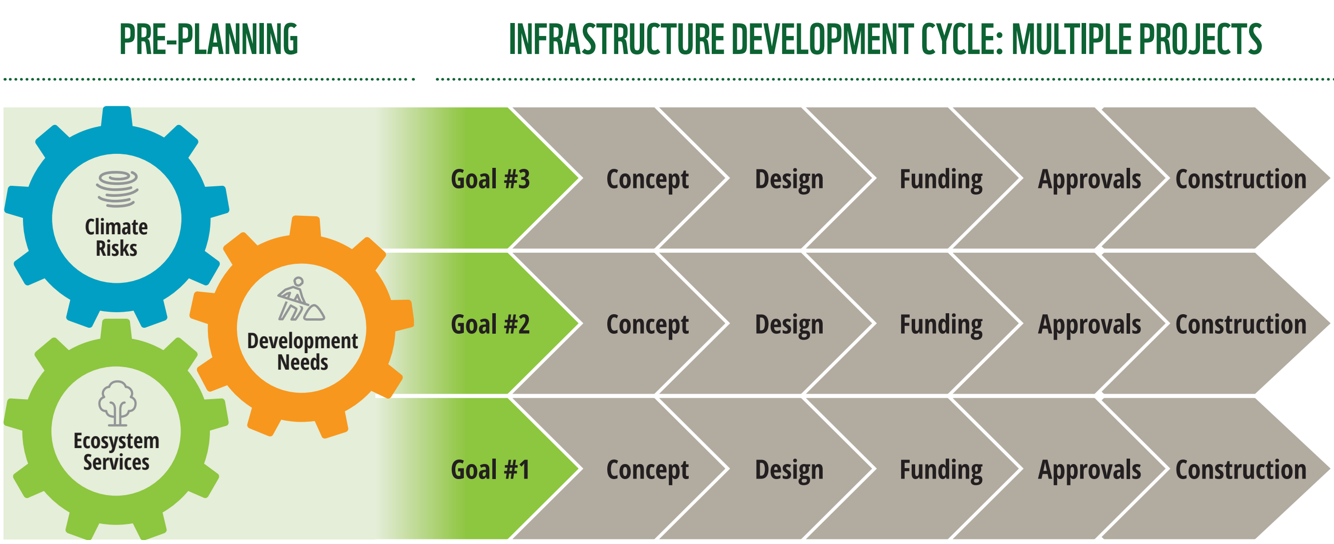
Recognizing the need for a new approach, institutions central to infrastructure finance and development have begun to work toward a shift to low-carbon, climate-resilient, "sustainable" investment. Driven in part to meet larger goals of the international agreements and national commitments—the Paris Agreement Nationally Determined Contributions (NDCs), Convention on Biodiversity (CBD) Post-2020 Framework, the UN Sustainable Development Goals (SDGs), and the New York Declaration on Forests (NYDF)—the paradigm shift has clear momentum. Influential institutions across sectors—from multilateral development banks to private sector developers and non-profits—have diagnosed the many challenges and necessary changes across the infrastructure development cycle to reorient current and future investments toward these goals. So far, however, this push toward sustainable infrastructure has largely been driven by—and largely understood in terms of—low-carbon investments and continuing reduction of social and environmental impacts.

While essential to avoid the long-term worst-case scenarios of climate change, this focus on low-carbon options and social and environmental frameworks to reduce negative impacts has left some critical gaps that risk compromising equally important needs to maintain and build resilience to the impacts of an already warming planet. This does not mean that positive progress is not underway: examples of efforts to plan at the appropriate scale around nature and the benefits it provides for people and economies, and to plan for the physical risks to large-scale investments of an increasingly erratic climate, do exist. Thousands of projects have been built following best-in-class social and environmental safeguards, for example. But these were largely developed following a social and environmental safeguards framework designed to *reduce impacts* on people and the natural world, rather than to explicitly maximize integrated, mutually enforcing social and environmental systems in a future of increasing climate change.

More explicit consideration of natural capital, intact biodiversity habitat, ecosystem services, and the numerous benefits they provide—increasingly referred to as nature-based solutions—to surrounding communities and economies, especially in conveying resilience, is needed. Forests that stabilize hillsides, slow water flows, or filter sediments under intense rainfall, and wetlands that absorb and diffuse flood waters, are just some examples of the many "resilience services" that must be better integrated throughout the infrastructure development cycle. As is increasingly evident, these systems provide the most benefits at larger scales; while still useful in many cases—e.g., urban environments, or as parts of hybrid "green infrastructure" approaches—isolated patches do not provide the same value as large, well-managed ecosystems. This is one of many reasons why it is most essential they are planned for at the "upstream," pre-feasibility stages of strategic spatial or regional land use planning, well before any single infrastructure project is proposed, designed, and financed (Figure 1).

Nature-based solutions are increasingly seen as either essential complements to "grey" engineered approaches or cheaper, more robust alternatives. They are also recognized as important to the world's most vulnerable populations, especially in marginalized

Figure 1. *An improved planning process, where consideration of natural capital and ecosystem services (including biodiversity), climate change impacts and risks, and infrastructure needs to support development are analyzed in advance of any individual infrastructure project development cycle.*



rural communities with few options for costly engineered adaptation. Nature-based solutions are, however, largely considered too late in the project planning cycle to most effectively balance trade-offs in managing social, ecological, and infrastructure systems resilience. Deeper understanding of the benefits of intact ecosystems—natural capital—must be a part of land use planning processes that precede the inception of sector-specific master plans and infrastructure projects. Key decision makers in ministries of economy, finance, planning, transport, and construction, and regional and local governments, need to be able to make development planning and investing decisions based on more holistic evaluations of

1) **the totality of services provided by ecosystems** and the reliance upon them by surrounding or downstream populations and economies,
2) **current and future infrastructure needs based on these dependencies** and other critical trends like population growth, migration, and projected economic development, and
3) **current impacts and likely future risks to 1 and 2 from continued warming** and the necessary pathways and planning steps to facilitate adaptation and resilience-building.

A process of assessing such dependencies and climate change impacts under varying scenarios—e.g., through detailing possible development trajectories under alternative climate change scenarios—has become an increasingly essential step in planning within various sectors given the uncertainties posed by climate change. Achieved through long-standing and increasingly proven methods like decision-making under deep uncertainty, scenario planning, and back-casting, these approaches are critical tools to facilitate planning for robustness, where plans prioritize options equally likely to function under multiple possible future scenarios of additional warming and resulting impacts. These approaches have, however, rarely holistically included potential changes to landscape scale ecosystems and resulting cross-sectoral impacts, or the benefits ecosystems provide as part of strategic or regional infrastructure planning processes.

This report seeks to at least partially fill this gap, proposing a revised regional- and landscape-scale planning framework, Visioning Futures, based on integrated, participatory assessments of ecosystem services and their values and current and future infrastructure needs under alternative climate scenarios. The goal is to fill these essential information gaps to support improved land use planning and decision-making in the “Avoid” stage of mitigation hierarchy, where critical ecosystems, habitats, and their services are identified, all to ultimately reduce risks for greater private sector investment and provide essential, necessary services that support poverty reduction and sustainable, resilient development.

Opportunities

To increase adoption of a more integrated approach, influential institutions operating internationally with power over infrastructure finance, regional development planning, conservation, and climate change adaptation and mitigation finance should seize the following opportunities to push for progress toward more integrated planning approaches. Relevant institutions include global environmental NGOs, bilateral aid agencies and other major funders including multilateral development banks (MDBs), and international intergovernmental organizations and country fora like the G7 and G20.

INTERNATIONAL POLICY, FINANCE, AND SCIENCE

1) **Develop explicit funding programs designed to support holistic, cross-sectoral landscape or regional scale planning** efforts in collaboration with existing international funding mechanisms like the Green Climate Fund (GCF), Global Environment Facility (GEF), and other major funders like the MDBs to support technical assessments and simultaneous capacity-building around a Visioning Futures or similar approach in-country to help de-risk potential investments, and thus to attract the private sector and explicitly meet country commitments under NDCs, CBD, and SDGs.
2) **Develop integrated regional or landscape scale planning standards** through cross-sector collaboration with landscape, city, and infrastructure planners; design firms; and major funders for a Visioning Futures approach or similar that explicitly considers ecosystem services and climate risks, connects to project level sustainability and resilience standards, and meets national NDC objectives, CBD post-2020 Framework, and SDGs.
3) **Expand existing and develop new open data access platforms to improve transparency and accessibility** to increase stakeholder knowledge and ownership in regional planning and infrastructure development processes, and to facilitate necessary technical assessments that inform planning.
4) **Update existing project screening and other "checklist" tools** commonly used by multilateral development banks and other funders when reviewing infrastructure projects (e.g., the Sustainable Infrastructure Foundation's SOURCE planning tool adopted by the major MDBs44) to explicitly include or require integrated, forward-looking assessments of ecosystem services, climate risks, and infrastructure needs.
5) **Create new procurement criteria for large-scale infrastructure funding** through collaboration with major funders—e.g., MDBs—and private sector developers, that require direct integration with existing regional, landscape, or watershed plans that have been developed based on integrated assessments that explicitly account for ecosystem services and climate risks.
6) **Increase investment in ecosystem service modeling science** to improve existing geospatial tools to allow greater flexibility, ease of use, and standardization, through collaboration with developers, funders, and academia, to improve accounting of climate change dynamics and risks explicitly tailored to regional development planning and infrastructure pre-planning contexts.
7) **Use existing climate and development policy support and coordination initiatives** (for example, the NDC Partnership, among others) to incentivize improved, holistic upstream infrastructure planning approaches and

investments in natural capital and ecosystem services in developing economies through technical support for more ambitious and integrated (adaptation, mitigation, biodiversity, SDGs) NDCs and other national commitments under global agreements.

DOMESTIC ACTION

These same relevant institutions operating in international fora should similarly seize directly related opportunities in-country to ground the shifts in policy and finance to affect actual landscapes, watersheds, regional plans, and ultimate infrastructure investments:

8) **Collaborate with relevant ministries and departments (planning, finance, public works, environment) to access global funds to support integrated planning approaches** in landscapes with urgent infrastructure needs to create the de-risking conditions necessary to crowd in private sector developer investment. Develop model case studies to replicate and scale nationwide, and contribute additional "business cases" that demonstrate the benefits of a Visioning Futures-like approach.
9) **Expand and develop national regulatory frameworks** enshrining holistic consideration of natural capital, ecosystem services, and climate risks in national policies, laws, and regulations governing spatial or strategic planning process, including procurement requirements, whether driven by large-scale infrastructure investments or otherwise.
10) **Create and expand existing financial, technological, and human resource investments** in cross-sectoral, inter-ministry, and academic natural capital programs that support modeling teams to provide regular technical support for regional planning efforts, including explicit partnership with relevant climate risk assessment departments and agencies; and train the next generation of political leaders to improve national planning and decision-making using such information.
11) **Institutionalize cross-sectoral collaboration and integration in planning processes** via designated official bodies like an inter-agency/ministerial working group or commission with direct oversight and decision-making power in regional and sub-national planning efforts for large-scale infrastructure. Participation should include leaders and support staff in planning, finance, economic development, environment, public works, and other essential ministries.
12) **Expand existing programs and establish accredited integrated regional planning degrees in national universities**, integrating curricula across schools of engineering, ecology, earth science, and economics around ecosystem services, natural capital, climate risk assessment and scenario planning, back-casting, decision-scaling, and other scenario planning approaches to train the technical experts necessary to manage and implement cross-sectoral planning processes.
13) **Increase ambition in NDCs through holistic mitigation and adaptation goals and programs**, achieved through the use of Visioning Futures or similar planning frameworks that can improve planning for both nature-based solutions and decarbonization in major infrastructure sectors like transportation, energy, and water supply, among others.

PART 1: DEFINING THE CHALLENGE

Seemingly every day, new climate extremes emerge that challenge the fundamental ability of our existing infrastructure to meet the basic food, water, and energy needs of millions around the world. There is perhaps no better recent example than yet another destructive fire season in California, where a stalled high-pressure system from a lethargic jet stream slowed by warming sent 70-80 mph (112-130 kph) winds for days across a tinderbox of vegetation and soil similarly dried out by new heat extremes. For the first time ever, the state's largest utility shut down its power grid for hundreds of thousands of customers for days at a time until the winds subsided to reduce fire risk, stranding millions without electricity in the state driving global technological innovation. While the result of multiple factors, including decades of deferred maintenance, mismanagement, and incentives for people to live in fire prone areas, this shutdown is emblematic of just how poorly the infrastructure of the 20th century is adapted to the climate of the 21st.

First
EVER

California's largest utility shut down large swaths of its power grid for days at a time until the winds subsided to reduce fire risk, stranding millions in the state driving global technological innovation without electricity.

Faced with these now regularly recurring extremes, ambition and global agreement to tackle the dual challenges of climate change—reducing greenhouse gas emissions and building resilience to the increasingly damaging impacts and future risks of a changing climate—are increasing. While there was some progress by signatories to the Paris Agreement to ratchet up ambition on both mitigation and adaptation at the Convention of the Parties to the UN Framework Convention on Climate Change (UNFCCC) in Katowice, Poland (COP 24), the subsequent UN Climate Action Summit in New York and COP 25 in Madrid demonstrated a continuing enormous gap between the level of ambition necessary and current country commitments. A series of recent UN and Intergovernmental Panel on Climate Change (IPCC) reports have rung alarm bells about just how essential increased action is, showing nearly every biome and its biodiversity in varying stages of crisis, from the oceans and cryosphere to essentially all life on land.[1,2]

Although the growing climate crisis has inspired global action—however insufficient—for decades, the similar crisis of decreasing biodiversity in nearly every habitat on the planet has not yet motivated global efforts to stem biodiversity declines on a comparable global scale. There are signs momentum is shifting toward progress, with a global push by many governments and NGOS for a "global deal on nature."[3] The SDGs attempt to address both trends while simultaneously bringing hundreds of millions out of poverty, but pose enormous challenges to governments that have historically failed to balance environmental and economic development trade-offs.

Perhaps no single issue better demonstrates the challenge of effectively managing these various trade-offs toward more sustainable and climate resilient development than infrastructure. Planning for the infrastructure of the 21st century creates perhaps the single most important opportunity to integrate these various global agreements, country commitments, and fundamental science-based needs to maintain biodiversity, reduce emissions, build resilience, and bring millions around the world out of poverty. As yet more calamities driven by a warming planet demonstrate—from the California and Amazon fires to more cyclones and hurricanes that are the most damaging in a given nation's history—the need to balance these trade-offs is becoming pressingly urgent.

The Problem

The global statistics are staggering: according to one estimate, more than 75% of the infrastructure to be built by 2050 does not yet exist today, with the large majority (60-70%) expected in developing economies.[4] An estimated $95 trillion is expected to be invested in energy, transport, water, and telecommunications by 2030 alone to sustain economic growth and meet demand for basic services, representing annual spending of $6.3 trillion, a 43% increase over 2016 spending.[5] If met, this goal would essentially double the total infrastructure on earth as of 2012,[4] On a planet already enveloped by 21 million km of roads (13 million miles), 25 million km more paved roads are needed by 2050 to meet basic demand, enough to wrap entirely around the earth 600 times, representing a 60% increase in total rail and roadways on earth as of 2010.[6]

95%
FOREST LOSS
95% of forest loss in the Amazon, for example, occurs within 5km of a road.

Much of this development will be in developing economies rightly trying to pull millions of their citizens out of poverty to a quality of life middle classes in the developed world have been enjoying for decades. It is also clear, however, that the development approach of the 19th and 20th centuries—where vast swaths of intact natural habitat and the highly valuable ecosystem services provided by them were sacrificed for economic growth and development, thus creating the emissions driving climate change—cannot be the model of the 21st. The data make this starkly clear: 60% of vertebrate biodiversity has been lost since 1970, more than a million species are at risk of extinction, and 40% of the world's forests have been cut down since the start of the Industrial Revolution.[1,7] According to the IPCC's latest report on climate change and land, human use of natural resources now directly affects 70% of all land surface, excluding the cryosphere, which is indirectly and rapidly experiencing the effects of warming.[8]

This development and the resulting impacts have contributed substantially to global greenhouse gas emissions: according to analysis of 2017 forest loss data, deforestation in the tropics contributed 8% of total global carbon emissions, enough to make it the third highest emitter if it were a country, behind the U.S. and China. While infrastructure is a relatively minor cause compared with the largest drivers of deforestation (agriculture commodities and small-holder slash and burn still contribute the lion's share of loss), it is nonetheless an important cause of deforestation in the developing world, especially in the loss of intact primary forests,[9] and likely an underestimate given how central roads are in driving deforestation for other sectors, including agriculture expansion. Ninety-five percent of forest loss in the Amazon, for example, occurs within 5 km of a road.[10]

In part due to incremental impacts occurring over years and decades, such developments rarely consider their cumulative environmental impacts over sufficiently large spatial and long-term temporal scales unless they're considered in spatial and strategic planning processes, which still often fail due to weak enforcement and oversight capacity. This is in part due to the gradual nature of the impact: the recent Amazon fires, for example, mostly occurred on farmland, but many were to clear forests for expanding crop area and grazing (partly due to new incentives and lax oversight from changes in federal policy). Any one fire on one farm isn't impactful: it's the gradual impact over subsequent years and decades, clearing marginally more forest every year, that ultimately leads to wide swaths of loss over the long run.

These same trends have begun to compromise the capital investments of the past 100 years, feeding back to disrupt the actual services they were built to provide. Infrastructure and asset damages from climate change and extreme weather topped $300 billion globally in 2016.[11] Subsequent years haven't been as economically costly as the highly destructive hurricane season of 2016 in the U.S., which was responsible for most of these losses (partly due to the high value of the damaged assets in urban areas). Losses have nonetheless continued into 2019 around the globe, with the most damaging fire season in U.S. history in 2018 and enormous increases in fires across Brazil, Bolivia, and Paraguay in August and Australia in December 2019; devastating flooding on a global scale; and cyclones in the tropics and east Africa—including two of the strongest cyclones to hit Mozambique in its history, back to back in a six-week period in March 2019—among numerous other examples. In many cases, the climate system feedback is much more direct, especially in large tropical forests, where deforestation can lead to very immediate changes in weather and climate. Scientists have discovered, for example, the importance of "atmospheric rivers" created through evapotranspiration in the Amazon that then drive rainfall patterns in neighboring watersheds or in urban areas like Rio De Janeiro and the cities of neighboring countries.[12] Deforestation thus not only contributes to global warming, but directly causes local changes in climate.

New flooding extremes are challenging infrastructure service delivery, due to designs and subsequent operations manuals that were created for a climate that no longer exists. Flood zone maps in the United States produced by the Army Corps of Engineers and used to determine insurance payouts—and thus incentives to build in vulnerable areas—are largely based on historical data and thus nearly useless in an increasingly variable climate.[13,14] A dam in Oroville, California, relying on operations manuals dated to the 1970s to manage for unusually high rainfall, was forced to release excess water at such a rapid rate over the spillway that it threatened the integrity of the entire dam and thousands of people downstream. This is just one example among many of the challenges of a non-stationary climate.[15]

Already significant declines in biodiversity are compounded by a climate changing too fast for many species to realistically adapt, leading to further declines, extinctions, and extirpations.[1] These numbers are also likely conservative, especially given current global emissions trajectories that track to some of the worst-case emissions scenarios—not including the pledges of the Paris Agreement, which would only limit warming to more than twice the already destructive goal of 1.5 degrees—that would result in catastrophic warming and massive ecosystem loss, uninhabitable swaths of the planet, hundreds of millions of refugees, and many similarly apocalyptic impacts of unabated warming.[16–18]

One of the most important drivers of these trends is an insufficiently holistic understanding of investment risk and costs and benefits. In developing economies around the world, planners and engineers are still proposing perceived least-cost, shortest-path designs (in the case of linear infrastructure like roads, rail, pipelines, and transmission lines), which are often routed directly through protected areas and other important habitats like wildlife migration corridors, or ecosystems that provide important but regularly undervalued benefits.[19–22] As a recent study of infrastructure financed in Latin America over the past 40 years demonstrates, projects often turn out to be far riskier and more costly than initially planned for or analyzed in feasibility and cost assessments. Reviewing 200 projects affected by conflict, the authors found that 80% were delayed, 20% canceled entirely, more than half over budget, and roughly only

20% unaffected by social and environmental factors (with many projects impacted by multiple factors, e.g. over budget and delayed or canceled).[22] Perceived low costs often turn out to be higher over the life of a project if social and environmental risks aren't as comprehensively considered at the earliest stages of development.

Large-scale hydropower developers have been especially egregious in overselling benefits and underestimating risks, with cost overruns and construction delays so substantial they have been found to fundamentally challenge the projects' ultimate economic value around the world, *without* considering the continued impacts of a changing climate[23,24] Further analyses have found even fewer economic benefits and greater risks of large-scale hydropower investments when considering climate change.[23] Without significant updates to standard approaches to regional spatial development planning, the current and future infrastructure investment—including the 75% yet to be built—will further compound these trends, leading to even greater declines in biodiversity as further habitats are lost and deforestation-driven emissions increase. As noted by the authors of the recently released Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report showing global declines across populations around the world, this risks compromising the essential "safety net" provided by natural resources ecosystems and biodiversity.

Working Toward a Solution: Trends in Sustainable, Climate-Resilient Infrastructure

Recognizing the need for a shift to address these trends, especially given the continued rise in global carbon emissions, some of the world's most powerful institutions—from governments to multilateral development banks, funders like the GEF and GCF, and influential private sector developers—have begun to propose solutions through the larger umbrella of "sustainable infrastructure." The phrase has risen to global prominence in recent years across global policy fora, becoming an explicit focus of powerful funder country working groups like the G7 and G20 and in recent UN conventions on biodiversity and climate change, and as demonstrated by the publication of numerous white and grey papers from investor institutions and in the scientific literature.

Global financial institutions like the multilateral development banks and their funder countries, driven by both ongoing efforts to improve performance against social and environmental safeguards and, more recently, support for countries to meet their commitments under the 2015 Paris Agreement and 2030 Agenda for Sustainable Development, have been particularly influential in driving progress toward the next generation of infrastructure investment. Though following country-driven development priorities, they nonetheless provide critical guidance and capacity-building for recipient countries and set the conditions for loans and grants that ultimately determine what gets built. These conditions increasingly consider climate change, with substantial initiatives, programs, and real funding allocated toward sustainable, low-carbon, climate-resilient infrastructure and the various iterations therein to ensure that current investments not only reduce emissions (or are low carbon) but also account for the new realities and future risks of an increasingly warmer world.[25]

Shift
FUNDING
Some of the world's most powerful institutions have begun to propose solutions for sustainable infrastructure.

To crystalize a definition and create cohesion of so many influential institutions in the infrastructure development space—including the varying definitions between sustainability and climate resilience—the G7 agreed to the "Ise-Shima Principles for Promoting Quality Infrastructure Investment" during the Japanese presidency in June 2016, focused on effective governance, disaster resilience, job creation and capacity building, addressing of social and environmental impacts, alignment with economic development strategies including national and regional planning for climate change, and enhancement of funding through public-private partnership models.[26]

The Inter-American Development Bank (IDB) used these as a basis to further flesh out a definition of sustainable infrastructure as projects that "are planned, designed, constructed, operated, and decommissioned in a manner to ensure economic and financial, social, environmental (including climate resilience), and institutional sustainability over the entire life cycle of the project." While it leaves some aspects to be further defined, it is notable that "sustainable" is explicitly defined as a function not just of reduced impacts on the environment, but of "environmental sustainability including climate resilience," and of "preservation of the natural environment, efficient use of resources," both of which are also explicitly outlined in the G7 principles.[27]

The World Bank has similarly begun to shift investments toward financing low-carbon, climate-resilient infrastructure. Alongside explicit internal policies requiring screening for climate risk (both in terms of risks to physical assets and carbon emissions), it has also released a number of reports providing guidance to countries and investors for how countries and investors can meet their NDCs and the sustainable development goals.[28,29] A recent report co-authored with the Organization for Economic Cooperation and Development (OECD), "Financing Climate Futures: Rethinking Infrastructure," outlines the conditions necessary to shift global infrastructure development toward decarbonization and resilience. It highlights six key areas to align finance with low-carbon, resilient infrastructure, including improved planning, technical innovation, fiscal sustainability, resetting the financial system toward long-term risks, rethinking development funding to create enabling environments for climate investments, and empowering city governments to build low-carbon, resilient urban environments.[29] Another recently launched report clearly demonstrates the substantial benefits of investing in resilient infrastructure, highlighting the regular and substantial costs of disruption to transport, energy, and water infrastructure systems, especially in developing economies. It also demonstrates that there is still enormous progress to be made, especially in tackling the exact gaps this report highlights: capacity-building for resilience, the need to incorporate ecosystem services, and the opportunity presented by improvements in planning.[30]

Plan
FOR CHANGE

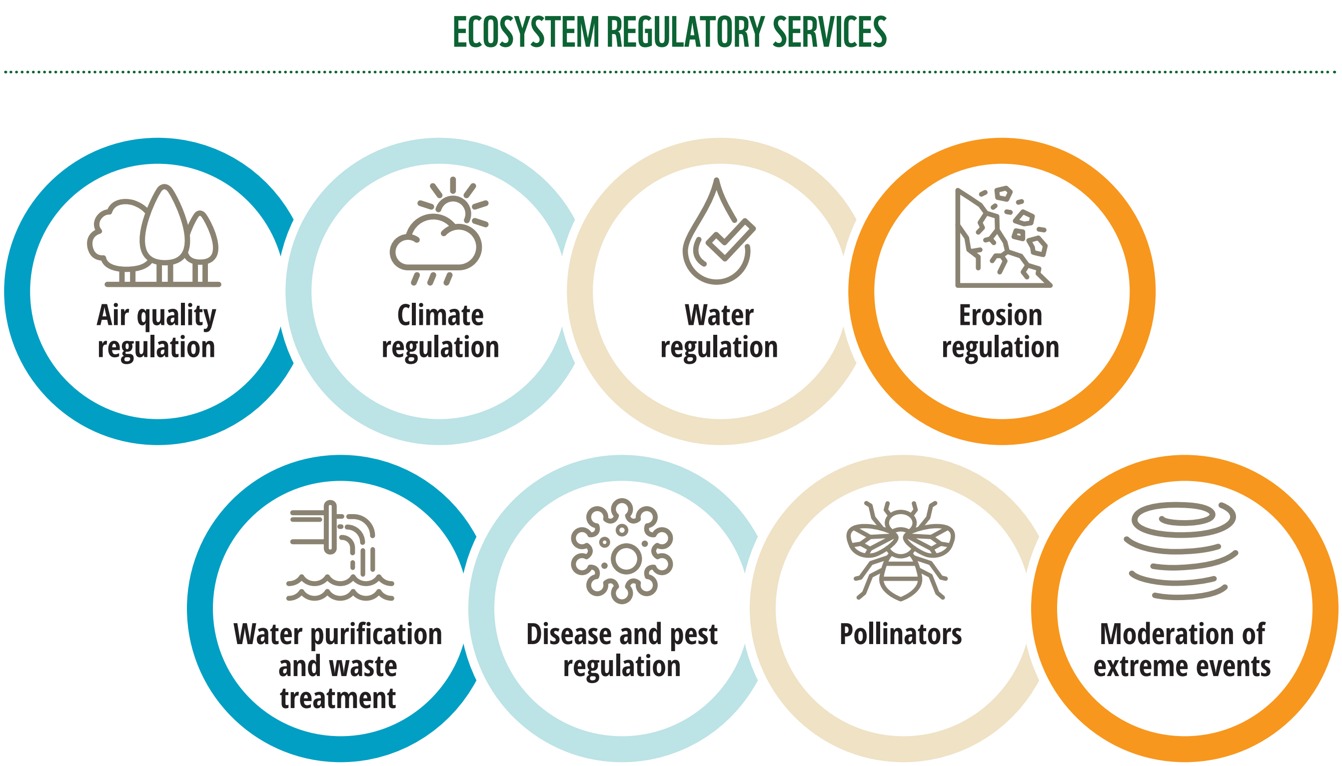
Sufficiently addressing climate risks, including true integration with planning efforts to maintain natural capital, is still not happening in many planning contexts around the world.

Nearly every large funder of infrastructure, especially those channeling public government funding, is screening projects based on "climate risks"—defined by the risk of their becoming stranded assets as the world shifts away from fossil fuel energy sources (transitional); and the impacts of climate change (physical)—alongside longer-standing social and environmental safeguards criteria that have evaluated potential project impacts for decades.[25] Combined, these two steps in the project preparation and appraisal process—an initial climate screening and the application of performance standards throughout (e.g., those developed by the International Finance Corporation)—have largely been deemed sufficient for evaluating project sustainability and climate risks or resilience. Substantial gaps where MDB requirements meet country implementation remain: as of 2017, no OECD country and a set of major emerging economies had incorporated climate resilience into their frameworks for Public Private Partnerships for infrastructure development.[31] As this report further details, sufficiently addressing climate risks at necessary spatial and temporal scales, including true integration with planning approaches focused on maintaining ecosystems and natural capital and the many ecosystem services benefits they provide, including those that contribute resilience to climate change (Figure 2), is still not happening in many planning contexts around the world.

There is similarly increasing awareness of the benefits of planning and designing for ecosystem services in multiple fields and sectors, from urban stormwater management and coastal development to linear infrastructure like roads and railways. This is especially true of the past decade, as countries have embraced "green economy" development pathways built around the importance of valuing and maintaining their natural capital wealth.[32] It has become even more of a focus of late as countries, academic organizations, NGOs, and the private sector alike have begun to raise the importance of "nature-based solutions"—a catch-all term for various methods of reducing climate change impacts and risks like ecosystem-based adaptation (EBA), eco-disaster risk reduction, green engineering, and natural or ecological infrastructure—to help countries pursue more sustainable, resilient development in an effort to meet goals for global agreements like the CBD, Paris, and Sustainable Development Goals.[33] They are increasingly seen as either essential complements to grey engineered approaches or cheaper, sometimes more robust alternatives.[31] They are also recognized as important to reduce vulnerability for the world's most vulnerable populations, especially in marginalized rural communities with few options for costly engineered adaptation.[34]

These solutions are, however, still largely considered too late in planning—either as isolated, smaller-scale projects, or as marginal components of infrastructure design—to most effectively balance trade-offs in managing social, ecological, and infrastructure systems resilience. One indicator of just how rarely or insufficiently these larger-scale intact systems and the critical benefits they provide in supporting both resilience and mitigation are planned for in development is found in country commitments under the Paris Agreement NDCs. A recent WWF analysis showed that less than half (37%) of the parties to the agreement even mention Protected Areas (or other conserved areas) in their NDCs, and only eight of all 151 NDCs analyzed explicitly stated or implied that ecosystem services provided by such areas could reduce vulnerability for people to the impacts of climate change (i.e., ecosystem-based adaptation).[35]

Figure 2. *Regulating services are particularly critical to climate resilience for people and infrastructure, moderating extreme events, erosion, climate, and air quality. Source: WWF, 2018.*



Recognizing these larger trends and the central, cross-sectoral role that infrastructure development plays in the achievement of multiple global agreements, the G20 recently agreed to updated principles for "Quality Infrastructure" to the Ise-Shima principles originally defined by the Japanese government during its presidency in 2016:[36]

1. Maximizing the Positive Impact of Infrastructure to Achieve Sustainable Growth and Development
2. Raising Economic Efficiency in View of Life-Cycle Cost
3. Integrating Environmental Considerations in Infrastructure Investments
4. Building Resilience against Natural Disasters and Other Risks
5. Integrating Social Considerations in Infrastructure Investment
6. Strengthening Infrastructure Governance

Further details in each of these presents a clear understanding of the central role of infrastructure in meeting multiple international agreements and the need for an integrated social-economic-environmental approach, calling for investments that account for "economic, environmental and social, and governance aspects…guided by a sense of shared, long-term responsibility for the planet consistent with the 2030 Agenda for Sustainable Development, national and local development strategies, and relevant international commitments…"

Principle 3 also directly acknowledges the importance of considering environmental aspects at all stages of the project development cycle:

> "Both positive and negative impacts of infrastructure projects on ecosystems, biodiversity, climate, weather and the use of resources should be internalized by incorporating these environmental considerations over the entire process of infrastructure investment..."

It further calls for alignment with "national strategies and nationally determined contributions" and consideration of ecosystem-based adaptation. Ecosystems or nature-based solutions are, however, interestingly not included in principle 4 on resilience against natural disasters, indicating that the value of nature-based approaches to reducing risk is either still not well understood or not prioritized for the infrastructure sector.

GAPS AND OPPORTUNITIES IN CURRENT APPROACHES

This progress toward more sustainable investments is beginning the necessary transformational shift toward a future of climate-resilient, low-carbon, and sustainable infrastructure. Key gaps remain, especially in insufficiently addressing aspects of ecological and climate resilience. The lack of progress in closing them is rooted in both technical limitations in addressing the increasing uncertainties and impacts of climate change and environmental governance failures, especially in (but not limited to) developing economies. The lack of technical progress can be organized into three larger, overarching causes:

1) insufficient "upstream" strategic planning across multiple projects and sectors, limited by insufficient data and analysis of key climate risk, ecological integrity, and ecosystem services factors;
2) the limited spatial scope of environmental and other impact and feasibility assessments; and
3) insufficient consideration of the risks and likely future impacts of ever-increasing climate change.

Improved planning for more sustainable, resilient infrastructure development is not solely an information-deficit challenge: even with the right information and optimal plans, more integrated, nature-based planning is still not occurring. The same governance and capacity limitations that have plagued natural resource governance in developing economies for decades—from historically limited resources and decision-making power over major economic strategy and investment in environmental departments and ministries responsible for oversight, to political patronage, rent-seeking behavior, and corruption—are just as important here, and perhaps even more so in the face of the added complexity of climate change. There is rich literature assessing and proposing solutions to these particular political economy challenges to more sustainable, resilient infrastructure development that this report does not aim to replicate; see, for example, Watkins et al., 2017, Hallegate et al., 2019, and Granoff et al., 2016, among others.

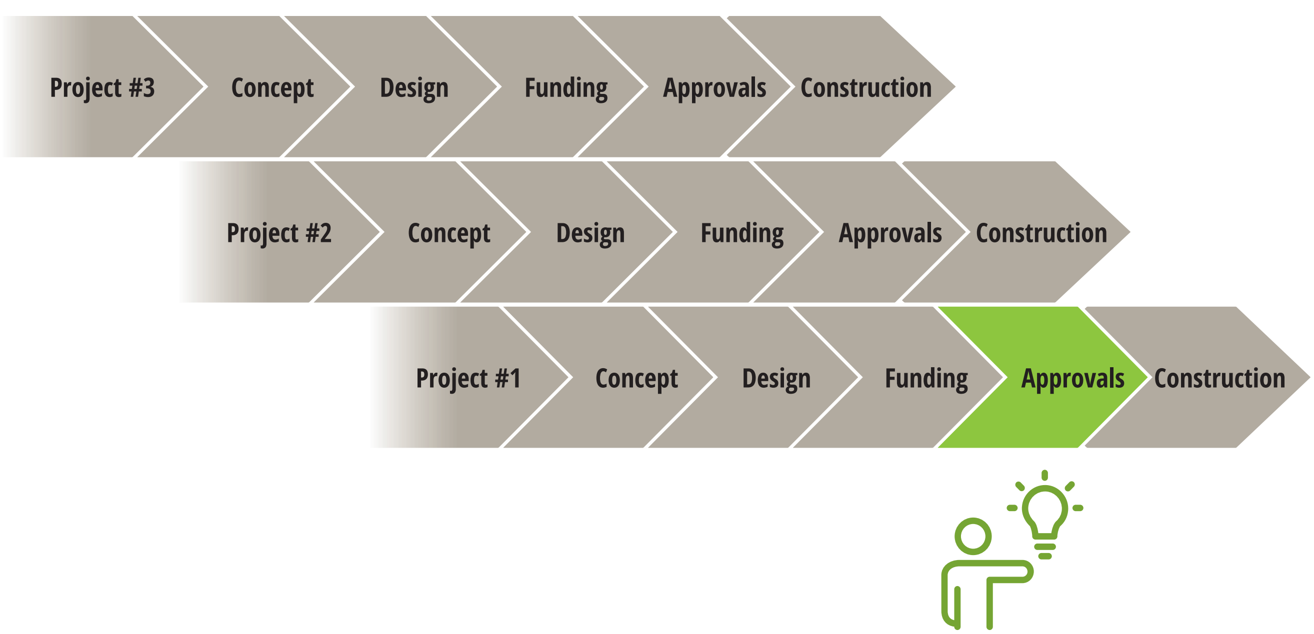
SPATIAL PLANNING

The most fundamental limitation to the current infrastructure development process (Figure 3) is the lack of strategic spatial and land use planning both early enough and at a sufficiently large enough spatial scale to adequately consider the costs, benefits, and optimal mix of multiple projects in any one geography.[22,30] When planning does occur, it is often driven by single projects with unique funding, priorities, and time lines, without larger national or regional spatial plans to evaluate potential trade-offs among multiple sectors or projects. The cost of uncoordinated hydropower infrastructure development, for example, has rarely been considered in basins around the world.[37] This is a standard collective action failure common to natural resource management, where funding is limited for processes that would benefit all projects and the public good rather than any particular investment. A recently launched World Bank report on resilient infrastructure states:

> "...it remains difficult to mobilize resources for infrastructure sector regulations, risk-informed master plans, infrastructure risk assessment, or early stage project design. More resources tend to become available when infrastructure projects are mature, but at this stage most strategic decisions have already been made, and most low cost options to increase resilience are no longer available."

Or as is often the case, even when integrated plans do exist, they are rarely used to guide actual investments. The same challenges that plague intersectoral or inter-ministerial coordination in many countries across a multitude of issues—but that are especially limiting in developing economies where environmental impact or spatial planning departments are often underfunded—are even more problematic in the context of organized economic development planning.

Figure 3. *The current siloed infrastructure planning process, where each project in a landscape or region is designed to meet a specific goal, but projects are not planned in coordination with one another, and environmental considerations are mostly evaluated at the approval stage for each individual project rather than comprehensively across them.*

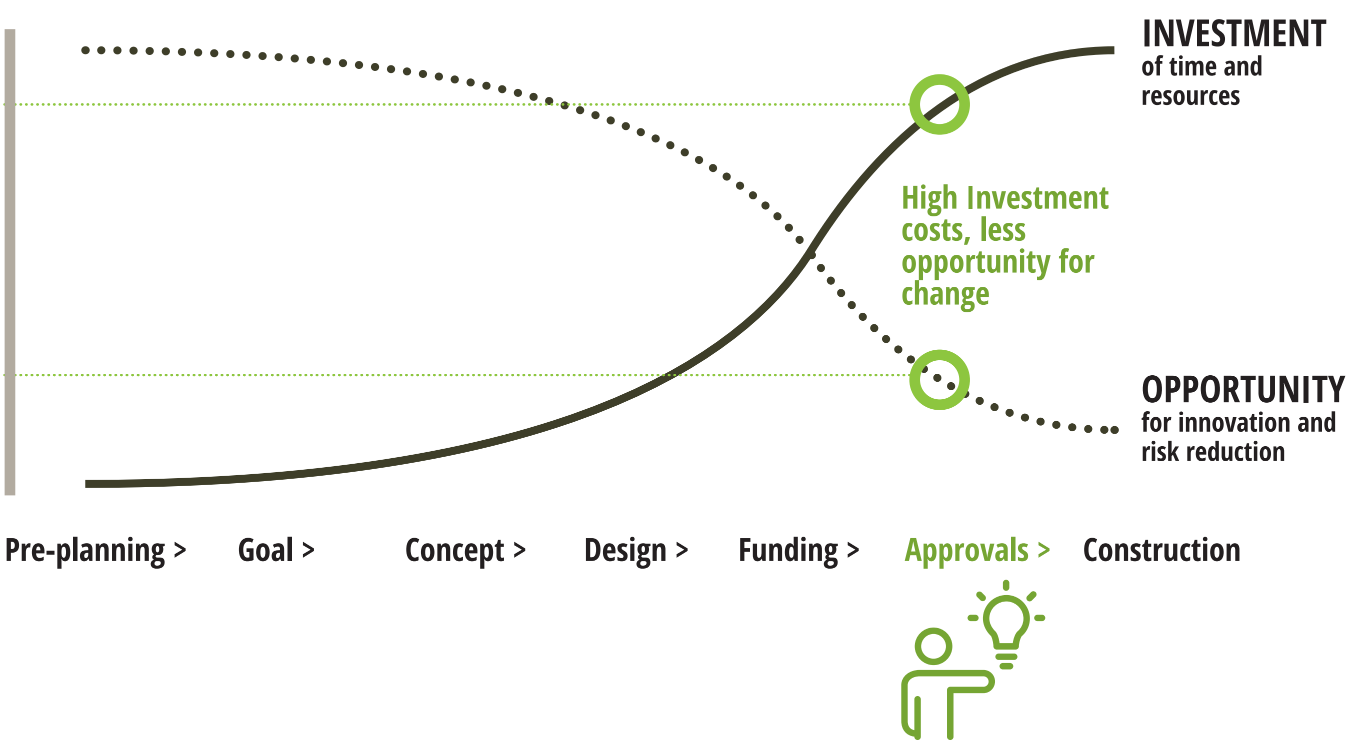


This results in unplanned or unintended consequences, particularly for surrounding ecosystems and their services, whose costs and benefits for surrounding economies and the larger region are rarely considered, or only minimally considered at earlier stages of concept and design. By the time key stakeholders like environmental or social civil society organizations are engaged as part of standard consultation processes, projects are already well past the design and funding stages, seeking final approvals, which results in protracted battles between governments and contractors and civil society about whether something as designed should be built, or what marginal design compromises might be possible to appease the most vocal outcry. In the mitigation hierarchy, this leaves few options for only minimizing or reducing, rather than truly avoiding, the most substantial risks that could arise over the life of the investment (Figure 4), leading to costly delays, cancellations, or increased maintenance costs when those risks manifest into impacts, delays, and cancellations.[22,24]

LIMITED SPATIAL AND TEMPORAL SCOPE

Projects are increasingly screened for physical and transitional climate risks earlier in the development process. These approaches have, however, been largely designed to address greenhouse gas emissions and direct physical impacts to proposed assets. They lack the comprehensive analysis of larger landscape-scale impacts on surrounding ecosystems and the potential degradation of their benefits, including those that directly benefit the asset over its lifespan (e.g., the landslide risk reduction

Figure 4. *The current infrastructure development process, from pre-planning to construction, presents limited opportunities to address environmental impacts and risks, at a stage when considerable resources have already been invested in a project. This makes decision makers and other actors already invested in the project far less likely to consider changes that would truly avoid major risks.*



of upstream forests in mountainous regions). Road development, for example, rarely considers the ultimate landscape-scale deforestation that will likely occur over decades resulting from the creation of access to previously remote areas for agriculture or other development.[38] This is due to several complex political, economic, and technical factors, including limited or ineffective strategic planning at the appropriate spatial scale and unique political motivations, vested interests, and other important political economy considerations. One important contributor is the lack of technical analysis defining the costs and benefits of either the maintenance or the loss of natural capital and its benefits to both surrounding communities and the infrastructure itself over the long term. Such are simply not a part of standard planning for infrastructure investments.[25,39]

There is an in increasing awareness of the benefits ecosystems provide in lieu of built infrastructure (also known as “ecological infrastructure”), particularly in certain fields, for example, in ecosystem-based adaptation—but few real examples exist where resilience services provided by intact ecosystems like flood risk reduction or erosion control have been explicitly considered as part of large-scale planning efforts.[39] As Calliari et al. (2019) note, many NBS or EBA solutions fail to deliver cost-effective benefits at such small scales; their promise lies in larger-scale landscape planning to build connectivity to create larger “green networks” that can enhance overall system-

scale resilience. However, even when such interventions have been prioritized as part of regional development plans, they are largely assumed to be static, with analyses assessing current service provisions regardless of the direct impacts of an increasingly erratic climate, and designed without associated activities to similarly help ecosystems adapt to ensure continued services provision in a rapidly warming climate.40 For example, in its review of NDCs, WWF found only eight that explicitly included climate-informed management of protected and other conserved areas to ensure continued delivery of their benefits as the planet continues to warm.[35] Another example is mangrove restoration. It became a global priority following the Asian Tsunami of 2004, due to the highly valuable protection services mangroves provide against increasingly intense coastal cyclones, and the many other benefits, from providing fish nurseries to enabling high-efficiency carbon sequestration. But rarely have such interventions been evaluated for their performance under scenarios of future sea level rise and coastal erosion, even as increasing evidence indicates vast areas of mangrove loss due to rising seas.[41]

Ecological INFRASTRUCTURE

There is an in increasing awareness of the benefits ecosystems provide in lieu of built infrastructure (also known as "ecological infrastructure")

LIMITS OF STRATEGIC ENVIRONMENTAL ASSESSMENT

To address the challenges of limited spatial scales through standard project-specific environmental impact assessments (EIAs), governments and financing institutions have sought solutions through the broader, more comprehensive approach of strategic environmental assessment (SEA). While proven to be useful in many instances around the world, SEA has several inherent limitations that have prevented it from becoming standard practice and solving these challenges. These include high administrative costs and lengthy stakeholder engagement processes that further delay project delivery, without being specifically relevant to key decisions around citing or design of major projects. As a 2012 World Bank review of a history of its SEA applications around the world states: "Some SEA reports resulted in long and tedious descriptions of environmental and social conditions with little relevance for decision making."[42] SEA has also so far rarely considered holistic assessments of climate change and its impacts, which is not surprising given the added complexity such considerations can bring to what is already an exhaustive, complex process. As the review notes, this is especially problematic when the need is for specific, actionable information on cumulative impacts—e.g., integrated ecosystem services, climate change, and community effects of proposed investments:

> "There seem to be limits for the suite of impact assessment methodologies in SEAs, particularly for assessing and forecasting cumulative and induced impacts. The greater the need for assessing the induced and cumulative impacts associated with a development decision, the stronger these limitations are felt…senior staff experienced in EIA perceived policy SEA as a planning tool with little if any relationship to environmental assessment practice"[42]

SEA should nevertheless still be considered an important tool for addressing many of the challenges of integrated climate risk and ecosystem services-based planning. Stakeholder engagement can be messy, lengthy, and costly, but is increasingly essential to addressing the growing complexities of climate change while ensuring equity and participation for communities affected by large-scale projects. As subsequent sections highlight, new tools and ever-advancing modeling science can help reduce complexity to fewer, more manageable decisions needing comprehensive consultation.

PART 2. LEARNING FROM RELEVANT CASE STUDIES

New
APPROACH
Where the forest is plowed through, the river diverted, or the wetland filled in and the concrete poured, it becomes starkly clear just how challenging it is to break the historical mold of least-cost, straightest path (for linear infrastructure) designs and leapfrog to a more holistic, integrated approach.

A review of infrastructure investments in various stages of development from planning to construction around the world demonstrates the reality of the on-the-ground challenges identified in the previous section. Where the forest is plowed through, the river diverted, or the wetland filled in and the concrete poured, it becomes starkly clear just how challenging it is to break the historical mold of least-cost, straightest path (for linear infrastructure) designs and leapfrog to a more holistic, integrated approach. While not comprehensive, an initial case-study analysis shows that while some progress is being made, most examples still only address one element or another: either ecosystem services or climate change. Rarely if ever is planning based on both. And even rarer still are actual in-the-ground built assets explicitly built based on such integrated assessments, with comprehensive understanding of the totality of ecosystem services and the likely changes in their provision in the coming decades of increasing impacts of climate change and larger landscape-scale impacts on ecosystems and their services.[39]

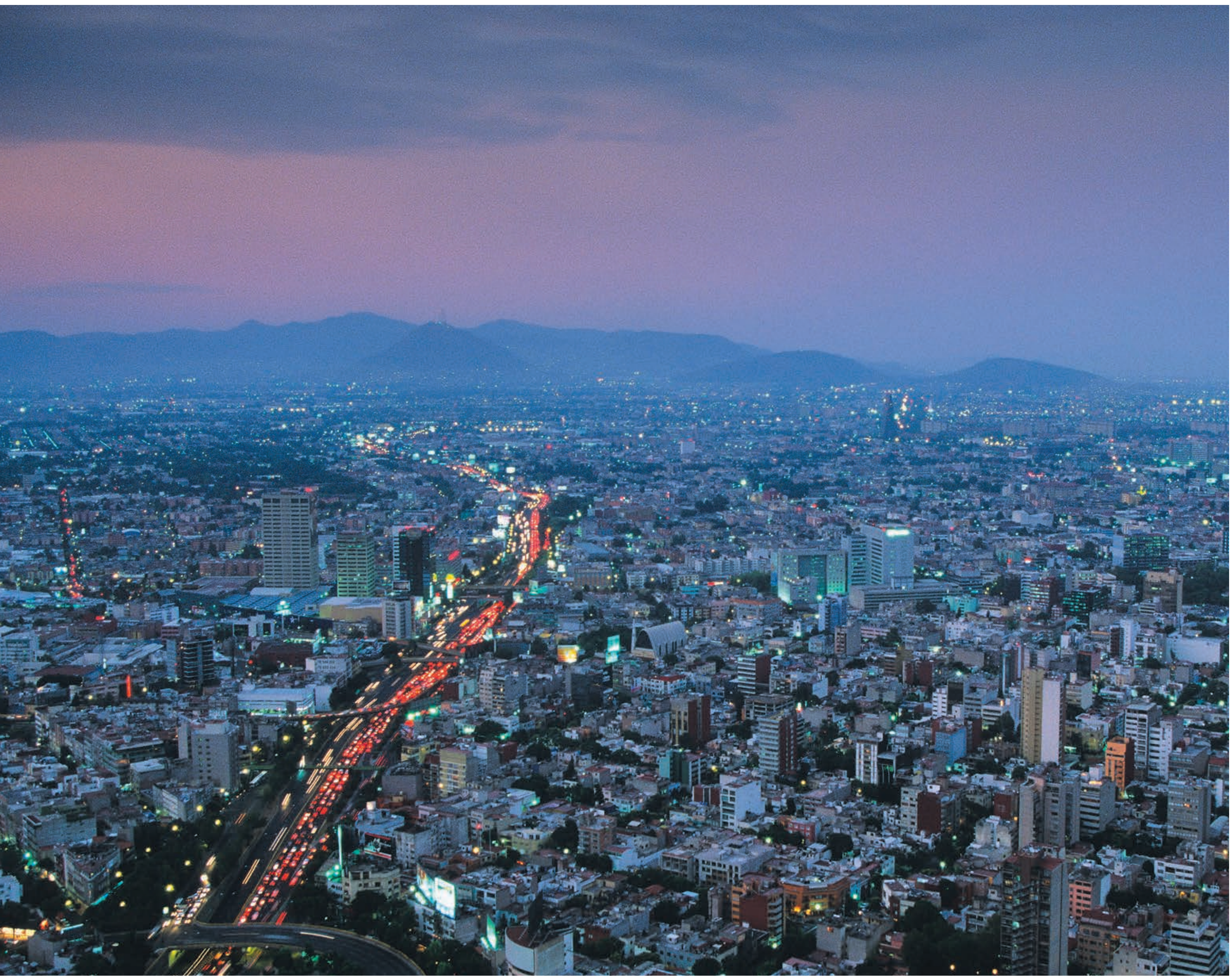
This does not mean that positive progress is not underway: examples of efforts to plan at the appropriate scale around nature and the benefits it provides for people and economies, or around the physical risks to large-scale investments of an increasingly erratic climate, do exist. Thousands of projects have been built following best-in-class social and environmental safeguards, for example. But these were largely developed following a social and environmental safeguards framework designed to *reduce impacts* on people and the natural world, rather than to explicitly maximize integrated, mutually enforcing social and environmental systems in a future of increasing climate change. And the majority were built for a climate that no longer exists; even in the hydropower sector where overbuilding is the norm to mitigate the enormous risks to infrastructure and lives, dams around the world are now fundamentally challenged by new unforeseen climate extremes, requiring costly retrofits and reducing their overall economic performance and service delivery.[43]

Natural Capital and Climate Risk Planning in Practice

In a search for real examples where major infrastructure investments have been planned and designed explicitly based on assessments of surrounding benefits provided by natural capital, and how those services might shift under a changing climate, WWF partnered with Arup to review more than 90 cases of regional planning for infrastructure around the world.[39] To test the hypothesis that examples of such comprehensive assessments have indeed been used to guide infrastructure planning—given that the importance of climate risks and ecosystem services benefits have been understood for decades, especially in the context of investments intended to have lifespans of more than 50 years—WWF and Arup developed seven screening questions focused on climate risk and ecosystem services, geographic scale, and governance impact. The goal was to find innovative examples of such comprehensive planning in developing economies in Asia, Latin America, and Africa, and "best in class" cases in the developed world (on the assumption that regional planning for infrastructure has a longer history and therefore more examples to highlight).

To screen for all potentially relevant examples, the review initially classified projects across five types:

1. A regional and cross-sector strategic or investment plan
2. A master plan, i.e., a long-term plan providing a conceptual layout to guide future development
3. A pipeline of infrastructure projects
4. A single large-scale infrastructure project
5. A mixture of all of the above



One case study in Kennedy et al., 2019 explores current plans to address increasing drought for Mexico City's water supply (see Freeman et al., 2020 for full analysis).

The review similarly classified projects across finance sources both public and private, including international development banks, or a mix of public and private. Each project was then given a rating from 1 to 4, depending on the degree to which it met the nine key criteria covering specific aspects of ecosystem services, climate risks, and governance:

Scale	The scale of the project, master-plan, and/or regional plan involves or has the potential to affect a significant scale of ecosystem units, ecological corridors, and watershed regions.
Spatial planning processes	In case of regional plan and/or master plan, this has led to construction and operation of a pipeline of sustainable infrastructure projects.
Ecosystem services baseline assessment	There has been extensive consideration and valuation of the most important of the four types of ecosystem services affecting landscapes: provisioning, regulating, cultural, and supporting.
Climate change risk assessment	There has been consideration of climate change impacts and risks on ecosystems and ecosystem services in an integrated ecosystem and climate analysis.
Non-climatic risk assessment	There has been consideration of non-climatic stressors (e.g., natural hazards, deforestation, infrastructure) on ecosystems and ecosystem services in an integrated sustainability assessment.
Vulnerability to climate change	The receiving ecosystems (and associated ecosystem regulatory, provisioning, supporting, and cultural services) are particularly vulnerable to climate change.
Design solutions	There has been innovative ecosystem-based adaptation, disaster risk reduction, and sustainable infrastructure solutions integrated into the plan/project design to mitigate the impacts on ecosystems and ecosystem services.
Enabling planning, legal and governance environment	There have been strengths or overcoming of challenges in the cross-sector reform of the enabling environment (institutional, legal, regulatory, financial).
Sustainable finance	The finance appraisal process has considered environmental, social, and governance criteria, beyond the minimum required by ESG standards, i.e., climate risks and ecosystem services over future time scales.
Monitoring and reporting	There have been or there are plans for monitoring and reporting on the impact to ecosystems and ecosystem services resulting from the implementation of the plan/project.

An initial screen of the 90-plus cases pared the final list of scored examples down to 40. While this was certainly not a comprehensive assessment of all major infrastructure investments in recent decades, it was immediately apparent in screening the final 40 cases just how few examples ultimately received high scores on these criteria, indicating initially that such holistic planning efforts encompassing climate risks and ecosystem services are still relatively few. To highlight a diversity of cases across continents and facilitate further information gathering through interviews, three cases were chosen in the developing world for deeper information gathering and interviews: planning for large investments in Mexico City's water supply system to address worsening droughts[65]; the planning and citing of the Lamu Port in coastal Kenya as part of the LAPPSET development corridor spanning multiple countries in East Africa using biodiversity and habitat modeling; and the proposed development of the Shenzen sea wall using a mix of ecosystem-based and concrete approaches for multiple benefits. Each case was then analyzed in greater detail to explore unique circumstances and similarities across them to gain greater insights into how to improve future planning for large-scale infrastructure investments, focusing on four key aspects: the spatial and ecological context, the overall approach, resulting outcome, and key lessons for the sector as a whole.

Though such holistic, integrated assessments of climate risks and ecosystem services are an emerging trend for large-scale infrastructure development projects, the relative paucity of concrete examples where such assessments have truly integrated understanding of the economic value of ecosystem services—including in contributing to climate resilience—to guide planning and ultimate development shows a persistent gap. There is a clear need for a more comprehensive analysis to collect and share effective examples across a diverse group of actors involved in infrastructure planning like NGOs, multilateral financial institutions, and country governments, to demonstrate the business case. In this regard, effectively advocating for such approaches requires clear demonstration that ultimately longer, more comprehensive planning upfront is ultimately more economically beneficial in the medium to longer term.

Several institutions have begun to do exactly this through resources highlighting the numerous emerging standards, frameworks, tools, and approaches that are increasingly guiding developers to greater sustainability.[25,44,45] Important gaps remain, however, that present opportunities for standardization, particularly in pre-planning stages: the majority of standards, tools, and frameworks target developers prioritizing single projects. It is not surprising, given the complexity and unique approaches tailored to specific country contexts, geographies, and development planning time lines, that no true standards exist for integrated climate risk and ecosystem services assessments to inform infrastructure citing and design. Such a standard could be beneficial, given the need on a global scale, especially in developing countries often lacking precedent. Procurement processes are one such opportunity ripe for improvement, for example, by requiring holistic analyses as part of tender notes, budgets, and recruitment and management.

Share
EXAMPLES
There is a clear need for a more comprehensive analysis to collect and share effective examples across a diverse group of actors involved in infrastructure planning like NGOs, multilateral financial institutions, and country governments, to demonstrate the business case.

The next section explores many of these challenges in further detail, through the lens of the specific challenges of natural-capital- and ecosystem-service-based planning for climate resilience in Mozambique.

Planning for Resilience and Natural Capital in Northern Mozambique

With a history of cyclones and cycles of drought and flood for hundreds of years, Mozambicans are acutely aware of their exposure to climate risks. Those risks became reality earlier this year when the two strongest cyclones in its history hit back to back in a six-week period. Cyclone Idai slammed into and destroyed 90% of its fourth-largest city, Beira, and then, like the hurricanes of the mid-Atlantic 2017 season, lingered over land and dumped more than 23 inches (600 mm) of rain over the subsequent days, causing extensive flooding in the Zambezi delta that killed more than 1200 people and stranded hundreds of thousands in remote regions beyond roads and modern infrastructure. A little more than six weeks later, cyclone Kenneth landed in the Quirimbas Islands National Park, directly hitting ancient Ibo Island just north of the city of Pemba with 140 mph (220 kph) winds, making it the strongest cyclone and the first time two cyclone-strength storms hit in the same season in the country's recorded history.[46]

Mozambique is also still affected by the fallout of 15 years of a civil war that ended relatively recently in 1992. It significantly limited economic development nationwide, hampered institutional development, and limited basic services provision like clean water and education, all of which continue to make it one of the least-developed countries in the world according to a range of indicators. This is borne out by a global adaptation index ranking of 159 out of 181 countries, behind Bangladesh and Angola, largely due to low and declining scores in readiness, which measures key governance and social indicators like political stability and non-violence, corruption, regulatory quality, rule of law, and social inequality.[47] Perhaps the most indicative statistics of the challenge the country faces are in education: literacy rates are roughly 50% of adults, and only 7% of the country is enrolled in advanced education as of 2017.[48]

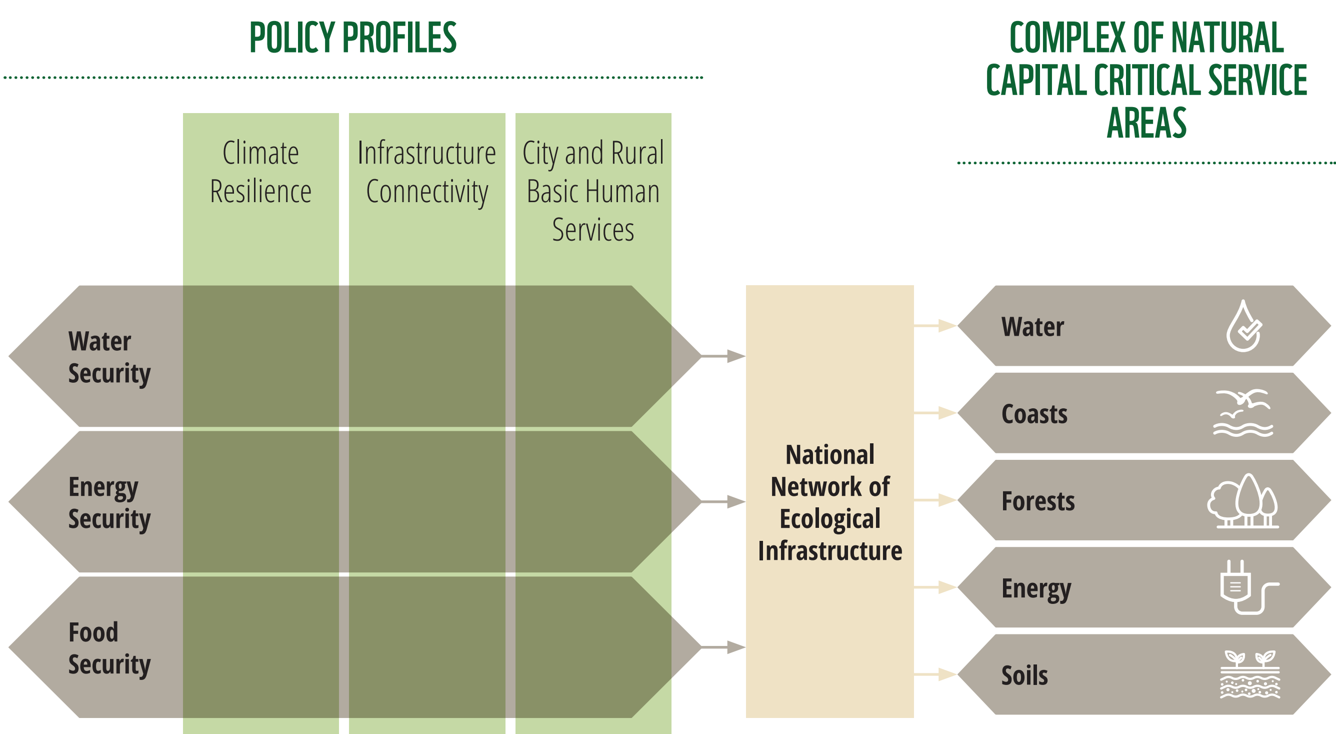
While the conflict and subsequent years of instability and governance challenges resulted in a multitude of negative, long-lasting effects that prevented fundamental poverty alleviation, emergent stability has also created a unique opportunity for Mozambique to embrace a more sustainable development trajectory, harnessing its high natural capital wealth. Looking to seize this opportunity, the government launched a Green Economy Framework at Rio+20 in Brazil in 2012 and a subsequent Action Plan in 2013, establishing the key objective of becoming:

> " ...an inclusive middle income country by 2030, based on protection, restoration and rational use of natural capital and its ecosystem services to guarantee development that is sustainable, inclusive and efficient, within the planetary limits."[49,50]

A key step in this action plan was the development of an interministerial Natural Capital Program in 2017, whose main goals are to develop the baseline information and analysis on five critical natural capitals and their service areas: water, coasts, forests, energy, and soils that would serve as the backbone for the Green Economy Action Plan and the five-year development plan (Figure 5).

While this action plan is ambitious in holistically promoting exactly the kind of integrated planning and sustainable, climate-resilient development with natural capital at its core, implementation has been challenging. Through collaboration with the government of Mozambique and key partners in developing the Natural Capital

Figure 5. *The priority natural capitals, and their support for key green growth and sustainable development policies from the government of Mozambique's Natural Capital Program Implementation Framework. Source: Government of Mozambique, 2018.*



Program and larger Green Economy Framework, including specific application to proposed developments for a key corridor in northern Mozambique, WWF has identified several important lessons relevant to many countries and sustainable infrastructure implementation contexts around the world.

DEVELOPMENT PLANNING IN CABO DELGADO PROVINCE

With the discovery of one of the largest offshore natural gas reserves in the world off the coast of the Mozambican town of Palma, the broader northern coastal region of Cabo Delgado province is at the beginning stages of a boom of foreign investment, driven by gas extraction and onshore liquefied natural gas (LNG) processing. An estimated $40 billion is expected to be invested in processing and associated industrial facilities alone in a remote, relatively undeveloped area outside the small city of Palma, currently home to less than 60,000 people. This investment, alongside regional development plans for the larger corridor in this newly politically powerful, but historically neglected, northern region is expected to create a population boom in Palma to more than 200,000 people by 2030.[51] This raises fundamental questions about how basic food, water, and energy security will be met for a rapid population boom, and how it will affect the region's substantial natural capital wealth.

Cabo Delgado and Niassa provinces are home to a wealth of biodiversity and ecosystems that support local livelihoods and wildlife, from inland areas home to large elephant populations in the Niassa Reserve to globally renowned coastal areas with dense mangroves, seagrasses, and coral reefs that provide habitats and nurseries for fisheries that are important protein and livelihood sources for local communities. These include the unique, high-biodiversity coral reefs of the Quirimbas Islands chain shown to have a mix of characteristics important to climate resilience, including temperature gradients that create natural refugium against rising sea surface temperature.[52] Natural capital in the region has been shown to be highly important for the region's climate resilience, with dense mangroves and other intact coastal ecosystems providing important coastal protection services for inland communities, and upstream woodlands recharging aquifers and supporting water supplies for coastal populations.[53,54]

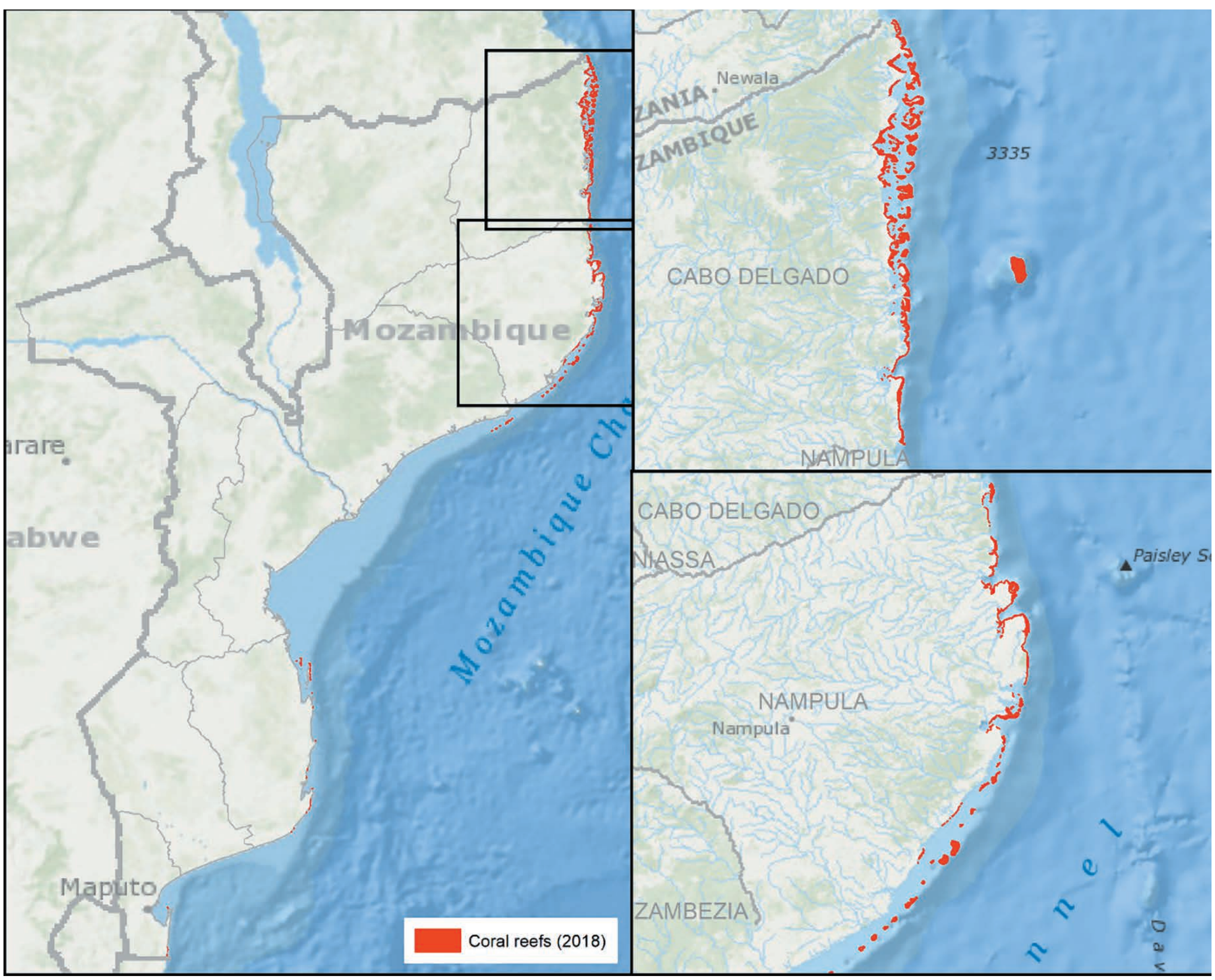
A draft economic valuation assessment of these values demonstrates just how important they are, with the coastal protection of mangroves, reefs, and sea grasses worth at least $1.5 million per year for the province of Cabo Delgado (Table 1). Their value is even greater as fisheries habitat, providing approximately $75 million per year to the local economy. Demonstrating a third important value, nature-based tourism in Quirimbas National Park was found to be worth $7 million per year. These values alone provide nearly $90 million in annual value to an economy in Cabo Delgado where communities and livelihoods directly depend on healthy, thriving natural capital.[53,54]

Table 1. *Estimated values of coastal protection provided by ecosystems for provinces of Mozambique.*

Province	Mangrove extent (ha)	Coral reef extent (ha)	Combined extent (ha)	Value of storm protection services (USD 2017/ ha/yr)	Total value of storm protection services (USD 2017/ yr)
Cabo-Delgado	37117.4	147880	184997	8.5	1,569,400
Zambezia	79347.3	6530.83	85878.1	4.2	360,986
Inhambane	19967.9	3382.38	23350.3	8.1	189,166
Sofala	40928.7	0	40928.7	4.6	187,683
Nampula	52751.4	49012	101763	0.6	62,220
Maputo	7990.04	440.91	8430.95	5.4	45,749
Gaza	360.905	0	360.905	8	2,896
Total	**238464.65**	**207,246.12**	**445,708.96**	**N/A**	**2,418,100**

Source: Van Soesbergen et al., 2019.

Figure 6. *Extent of coral reefs along the Mozambican coast and zoomed in for Cabo Delgado and Nampula provinces (data from UNEP-WCMC, 2019).*



As the region grows rapidly in the coming decades driven by rapid industrial development and associated population growth, this natural capital wealth is fundamentally at risk for over-exploitation. Current trends already demonstrate some of the highest deforestation rates in the country, driven by coastal development and shifting agriculture; poor farming practices causing soil degradation and sedimentation of rivers and streams; destructive fishing practices and over-fishing; agricultural, industrial, and urban water pollution; and reef destruction and dredging from oil and gas operations, to list just some of these challenges.[54] The surging impacts of a warming climate—from coastal cyclones like Idai and Kenneth that can have long-term impacts on food security in communities already struggling with poor soils and low yields, to drought and extreme heat as temperatures warm, alongside other extreme and more gradual changes—are already multiplying the negative effects of overexploitation on the region's natural capital. These will likely worsen as temperatures continue to rise and more extreme storms arrive on rising seas, further throwing off balance a system already facing multiple negative trends.[54–56] It is not too late, however, to stem these trends and set a more sustainable, resilient path in line with the country's green, natural-capital-based growth strategy explicitly designed to do exactly that: compared with similar coastal areas of east Africa, the region's natural wealth is still relatively intact.

RESILIENT PALMA

In this context, WWF and partners in the Natural Capital Program convened a series of workshops in 2018 to 2019 with key government ministries and departments, the private sector, academics, and local NGOs to discuss implementation of the program, including the critical initial step of establishing an information baseline on the country's essential natural capital, applied to future development plans in Palma and the larger surrounding region of Cabo Delgado. Participants included partner ministries of the official Natural Capital Program, multilateral development banks, local government representatives responsible for development plans in and around Palma, private sector oil and gas and other relevant local industry, local and international graduate urban and landscape planning and design students, and local NGOs. The goal was to discuss how to harness the region's natural capital to support more sustainable, climate-resilient development, balancing crucial infrastructure and service needs and industrial development with the need to maintain essential ecosystem services that the province's more than 2 million people currently rely on.

These discussions highlighted several challenges in balancing these tradeoffs to both improve access to key services and provide greater economic opportunities for the region while maintaining natural capital and critical ecosystem services, driven by difficulties unique to Mozambique and other difficulties more universal to developing economies:

1) **Limited local data availability:** To most effectively model natural capital and the ecosystem services benefits it provides to surrounding communities, access to local, regional, and national data sets is essential to correct and ground-truth publicly available global satellite and remote-sensing data. Due in part to the civil war and subsequent years of instability, there are large chronological gaps in data on water flows, weather, fisheries catches, land use and land cover, and other necessary inputs to accurately measure ecosystem services. And as is the case in many countries, there is no one centralized data access point; this means unique relationships must be established with relevant ministries that can be guarded in publicizing data and/or simply do not have an organized process for maintaining relatively easy public access. As a result of these data access challenges, both regional natural capital and ecosystem services assessments in Cabo Delgado and nationwide were forced to rely heavily on publicly available data sets that have more limited resolution. While not as problematic for a rougher nationwide assessment, lower resolution results in less-useful analyses to inform the very site-specific decision-making of infrastructure development planning.
2) **The challenges of inter-ministerial coordination.** Strategic spatial planning based on assessments of climate risks, resilience, ecosystem services, and the services provision needs of local populations fundamentally requires strong coordination across ministries and sectors. As with almost any government on the planet, the incentives for ministries and their respective departments in Mozambique to collaborate are limited. WWF worked with AfDB and other partners to establish a coordinated Natural Capital Program co-led by the Ministry of Economy and Finance (MEF) and Environment and Territorial Development (MITADER) for precisely this reason, but regular coordination,

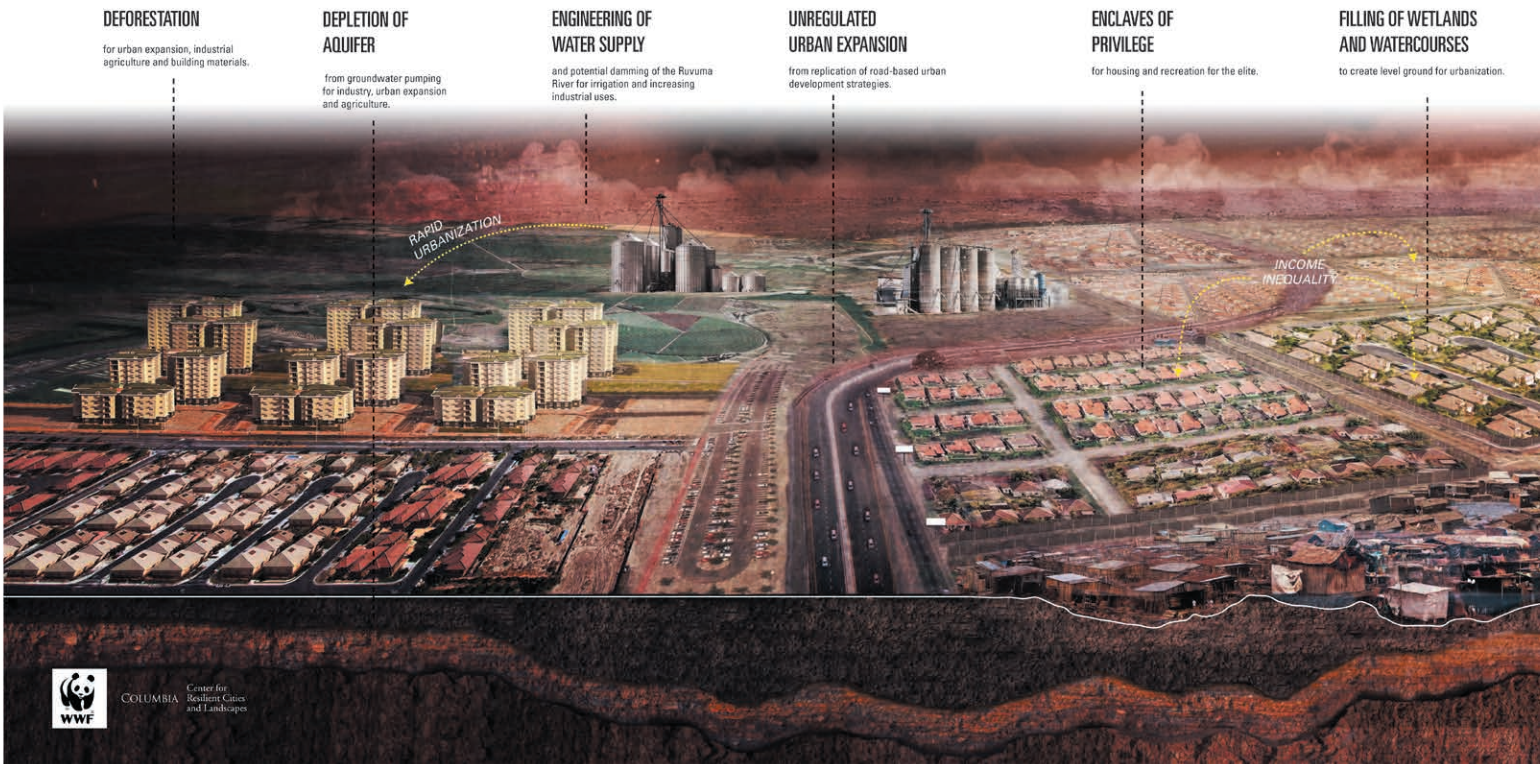
especially to influence specific processes like regional territorial development planning, has been limited by the administrative costs and limited capacity of any one organization to take it on. Recognizing the needs specifically for Cabo Delgado province, the government has recently agreed to establish a stakeholder working group, which will provide important venues for continuing to advocate for a more holistic approach to planning.

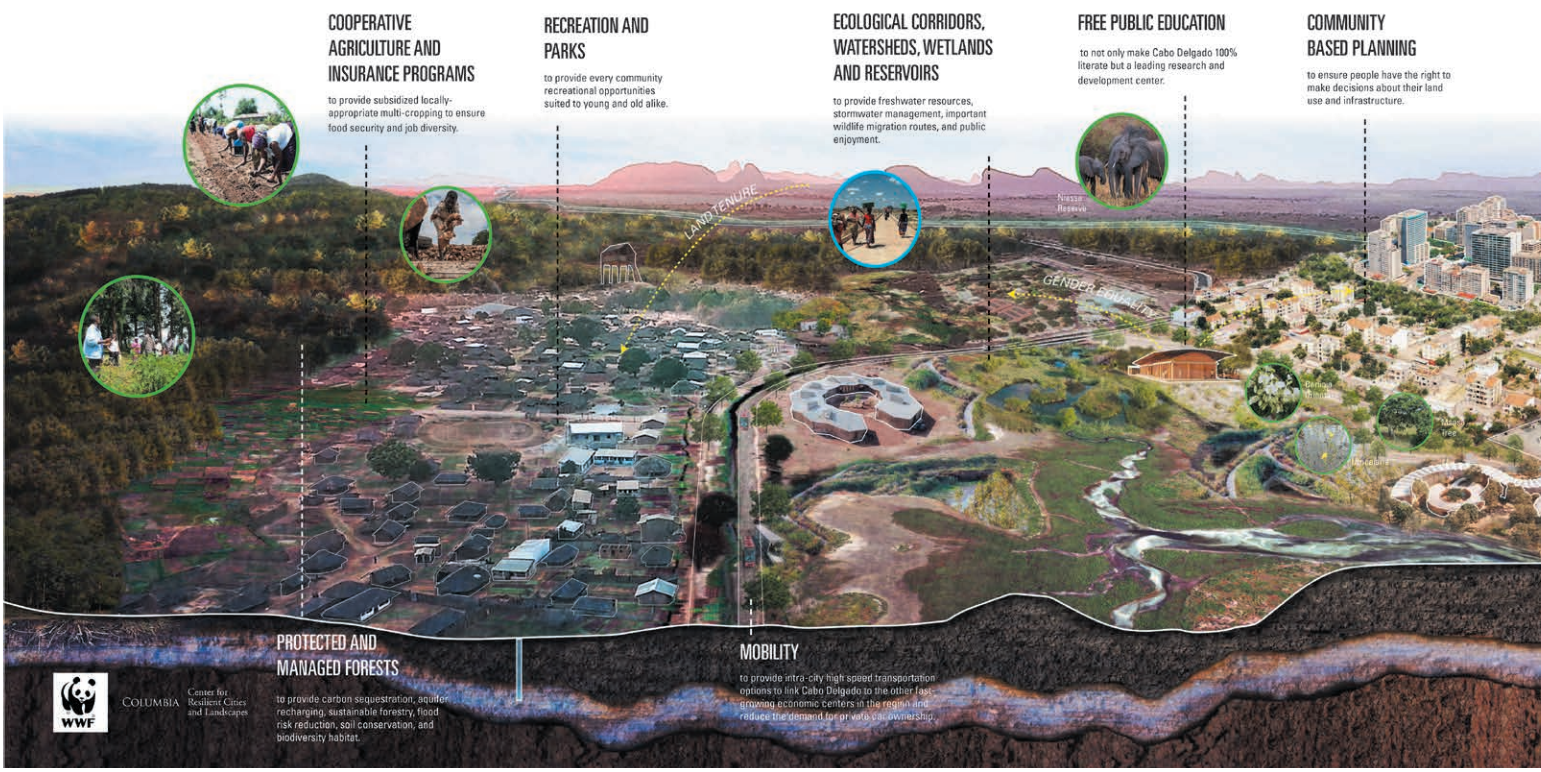
3) **Key gaps and overall limitations in spatial planning.** Capacity is limited in almost every sector in Mozambique, tracing back to the civil war and resulting institutional instability that similarly affected the country's university system. The fact that so few Mozambicans have an advanced degree is emblematic of the limitations in local technical and human resources to support regional and district planning efforts in and around Palma. While the city of Palma does have a zoning plan, and the national government has created one for the Afungi peninsula where the gas processing and associated development will occur, implementing and adhering to either is challenged by informal urbanization in Palma town and limited resources for oversight to ensure adherence to a government plan; the outsize influence of the oil and gas sector on the Afungi also challenges proper oversight. And in both cases, planning for climate change continues to be extremely weak, especially in the Afungi: while the environmental impact assessment (EIA) for the LNG processing facility shows 100-year return period flooding directly affecting the industrial development area, Anadarko representatives could not speak to specific interventions to mitigate flooding and associated risks due to climate change, and city plans show significant development—including priority areas for agriculture—in exactly these flooded areas along river and stream courses.51,57

4) **Limited understanding of the importance of natural capital.** Workshop participants, especially those outside MITADER or the MEF already participating in the Natural Capital Program, repeatedly stated just how little Mozambicans know about the concepts of natural capital and ecosystem services—even when so many communities nationwide are so directly reliant on sectors like fisheries or agriculture to support their livelihoods. This speaks to the challenge of communications with a diverse set of audiences, from the private sector to key stakeholders in national government, and the differences in terminology for each. But without a clear understanding of what exactly nature provides and how valuable it is, including to support resilience to the growing extremes of climate change, changing economic development zoning or planning is extremely difficult.

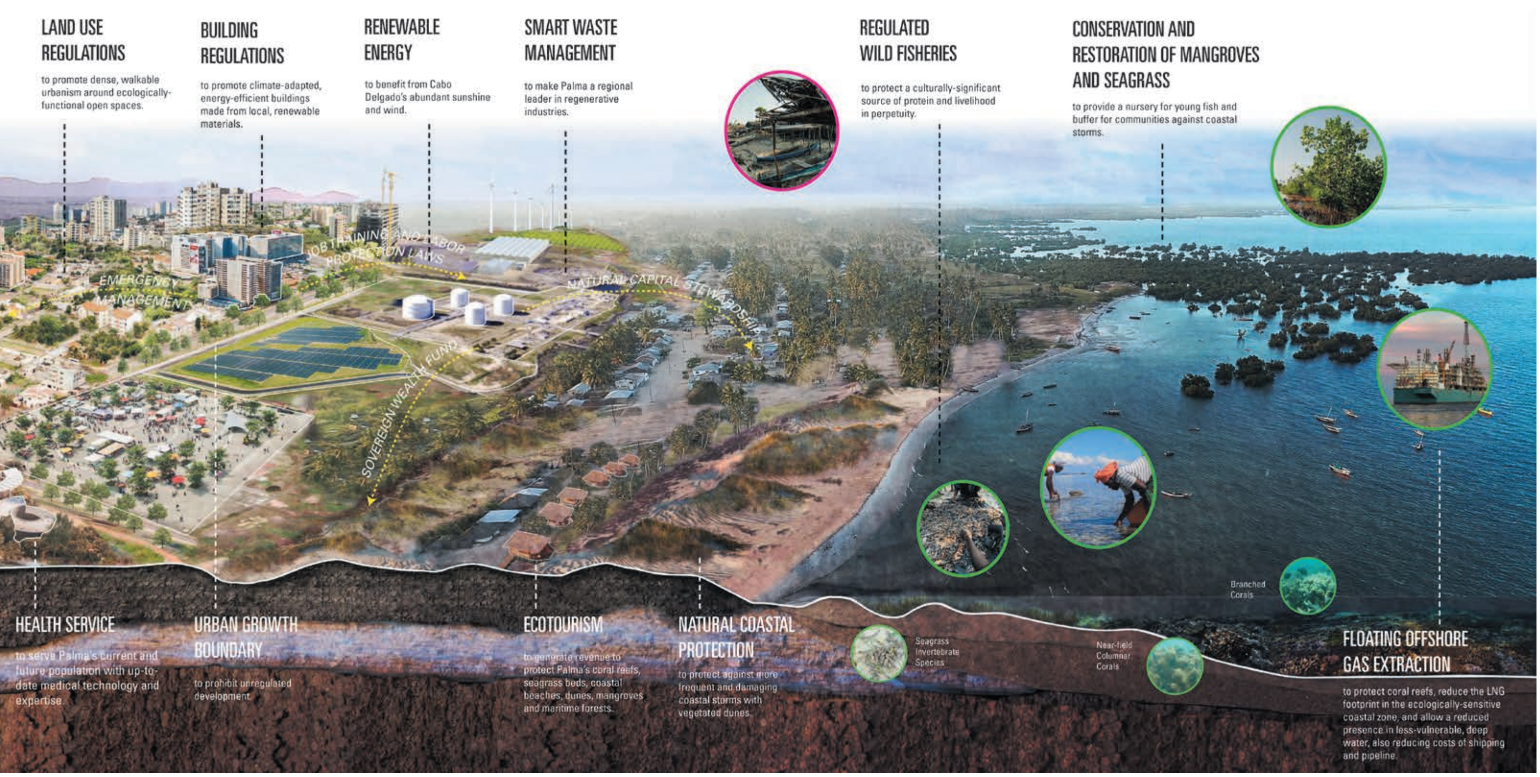
   WWF has worked with multiple academic and research groups both to determine economic values for valuable ecosystem services surrounding Palma and the surrounding region in Cabo Delgado—coastal protection from intact reefs and mangroves, water supplies from forests, coastal fisheries—and to demonstrate just how planning could be done to better account for these values (Figure 7). The next six months present a critical opportunity to communicate these to a wide audience, including the stakeholder working group and those in power to decide the future of Cabo Delgado and Palma, like the provincial governor and the dominant political party in the region.

Figure 7. *Visual scenarios of potential development trajectories for the city of Palma and its surroundings. The top represents business as usual, following similar scenarios for oil and gas extraction landscapes in Africa and around the world; and the bottom demonstrates a more equitable, natural capital-based climate-resilient development approach. Source: Columbia University Center for Resilient Cities and Landscapes, 2019.*






FLOODING
in poorly drained areas of self-built housing.
BOOMTOWN ECONOMY
profit-seeking and speculation dominates all economic activity.
DISPLACEMENT OF CULTURE AND LOSS OF LIVELIHOODS
from constraints on fishing and farming.
HARDENING OF SHORELINE
and loss of coastal habitats, biodiversity, and natural storm protection.
DREDGING AND CONTAMINATION OF COASTAL WATERS
for the deep-water port and industry.
DESTRUCTION OF CORAL REEFS AND SEAGRASS
to accommodate the gas pipeline.
RESOURCE CURSE
DUTCH DISEASE
GAS EXTRACTION
CIVIL UNREST


LAND USE REGULATIONS
to promote dense, walkable urbanism around ecologically-functional open spaces.
BUILDING REGULATIONS
to promote climate-adapted, energy-efficient buildings made from local, renewable materials.
RENEWABLE ENERGY
to benefit from Cabo Delgado's abundant sunshine and wind.
SMART WASTE MANAGEMENT
to make Palma a regional leader in regenerative industries.
REGULATED WILD FISHERIES
to protect a culturally-significant source of protein and livelihood in perpetuity.
CONSERVATION AND RESTORATION OF MANGROVES AND SEAGRASS
to provide a nursery for young fish and buffer for communities against coastal storms.
EMERGENCY MANAGEMENT
SOVEREIGN WEALTH FUND
HEALTH SERVICE
to serve Palma's current and future population with up-to-date medical technology and expertise.
URBAN GROWTH BOUNDARY
to prohibit unregulated development.
ECOTOURISM
to generate revenue to protect Palma's coral reefs, seagrass beds, coastal beaches, dunes, mangroves and maritime forests.
NATURAL COASTAL PROTECTION
to protect against more frequent and damaging coastal storms with vegetated dunes.
Seagrass Invertebrate Species
Near-field Columnar Corals
Branched Corals
FLOATING OFFSHORE GAS EXTRACTION
to protect coral reefs, reduce the LNG footprint in the ecologically-sensitive coastal zone, and allow a reduced presence in less-vulnerable, deep water, also reducing costs of shipping and pipeline.

5) **The technical challenge of integrating climate and ecosystem services.** From a purely technical ecosystem services and climate science modeling perspective, this case demonstrates fundamental limitations in assessing the dynamics of natural capital and ecosystem services in a changing climate. This is partly due to data limitations, but more fundamentally due to the lack of a demonstrable, replicable modeling approach—and the relevant expertise—in the scientific community to properly assess how ecosystem services like water provision, fisheries, or coastal protection will change as the shocks and stressors and longer-term shifts worsen as the planet warms. While identification of important ecosystem service-sheds certainly helps prioritize some areas essential to reducing risks and exposure to climate change impacts—for example, coastal mangroves and coral reefs—key questions remain around how climate will reduce nature's ability to continue to provide such benefits and the resulting stress on surrounding communities and infrastructure, including how to most effectively manage both social and ecological systems to ensure continued services provision into the future.

   In general, progress is being made to better integrate the climate and ecosystem services modeling fields (outlined in more detail in the next section), but data-limited contexts like northern Mozambique, alongside more fundamental climate model resolution limits, will always limit the utility of such modeling, requiring additionally rigorous ground-truthing. Nonetheless, these first maps of ecosystem services provide an essential baseline both to guide planning and to use for continuous improvement as more data analyses are performed in the coming decades.

These challenges are in many ways unique to Mozambique but are also clearly universal to development contexts in developing and developed economies alike. Interministerial endorsement of a natural capital-based, green economy framework is a rare, laudable achievement; these challenges, however, demonstrate just how difficult implementation of such an approach can be. This said, the challenges are not insurmountable: there is a real chance for a different trajectory, one defined by a regional economy and livelihoods built around natural capital, ecosystem services, and climate resilience, especially if key government and non-government stakeholders are all pushing for a similar result. The country's two recent cyclones give a powerful rationale for embracing a more integrated approach: as the Palma administrator stated at the close of an already planned but newly important workshop on planning for resilience and natural capital, they didn't fully appreciate what resilience was or how to go about it, but now realize just how critical it is to embrace moving forward.

Taking the lessons from this Mozambique case and others, the next section outlines an approach for solving some of these challenges through a revised planning framework that explicitly accounts for climate risks and ecosystem services through existing tools and stakeholder engagement best practice, built around future scenario planning.

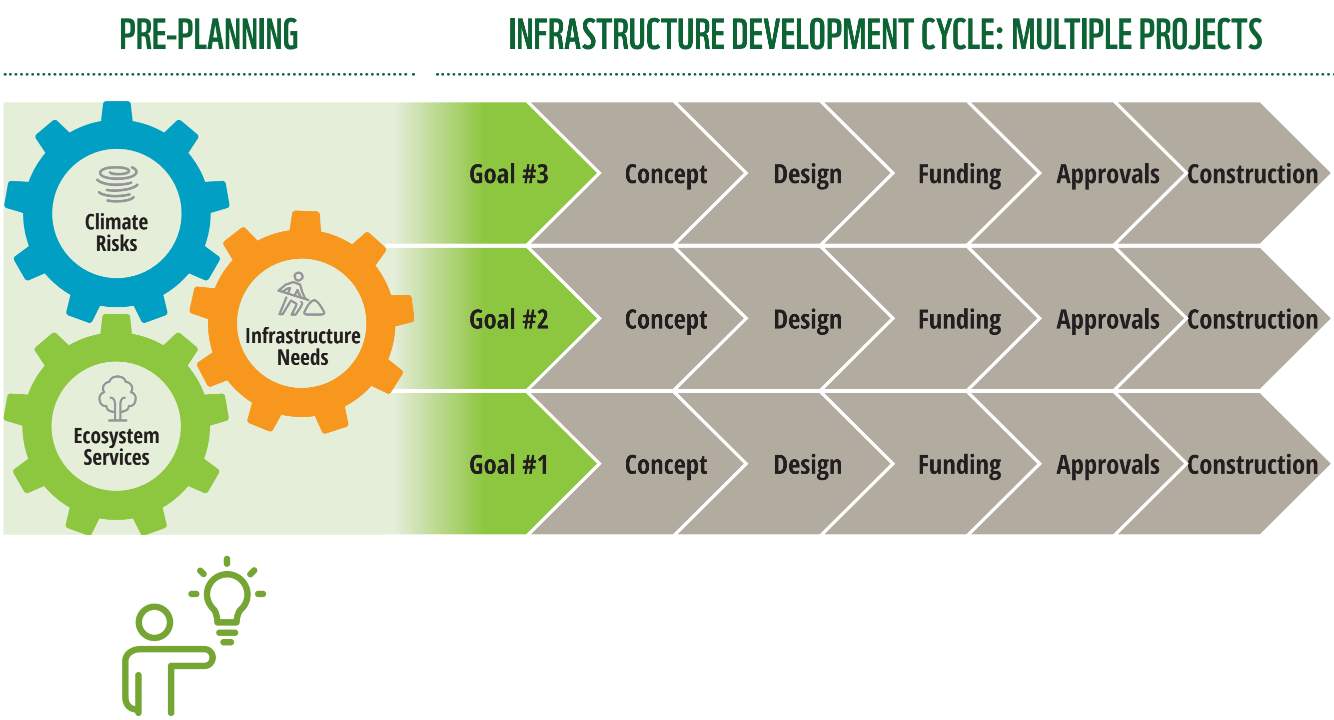

NATHAN KITI

PART 3: AN IMPROVED PLANNING FRAMEWORK

To make progress on the complex, interlinked, and nested challenges identified in the previous section—and for the achievement of multiple national objectives and goals of international agreements in biodiversity, sustainable development, and climate—a new approach to infrastructure planning focused on improved spatial land-use planning with natural capital, ecosystem services, and resilience at its core is needed. It should aim to fill the three previously identified information gaps at the earliest possible strategic planning stages of development:

1) **The totality of services provided by ecosystems** and the reliance upon them by surrounding or downstream populations and economies.
2) **The cumulative, ecosystem-scale impacts potentially posed by planned infrastructure.**
3) **Current and future infrastructure needs based on these dependencies** and other critical trends like population growth, migration, and projected economic development.
4) **Current impacts and likely future risks to 1, 2, and 3 from continued warming** and the necessary pathways and planning steps to facilitate adaptation and resilience-building.

Figure 8. *Pre-planning prior to decision-making around any one infrastructure investment is the ideal opportunity to evaluate of ecosystem services, climate risks, and infrastructure needs in an integrated manner as part of a regional planning process.*



Successfully assessing these factors and using them to guide the entire infrastructure development process, from planning to construction (Figure 8), requires simultaneously addressing a number of other political economy and governance factors important for any global shift in entrenched processes—from improved transparency, participatory governance, and stakeholder engagement to greater investments in technical capacity in key government and planning departments. Purely in terms of technical analysis, however, progress in recent years has made creating and understanding this information increasingly accessible to almost any context around the world, even in more data-limited environments in many developing economies, where remote sensing, ever-increasing publicly available global data, and geospatial mapping tools can overcome barriers.

The most fundamental goal in developing this information is to create the necessary information to support land use decision-making that spatially identifies specific areas for specific sectoral development. In terms of the mitigation hierarchy, the goal is to support more robust decisions in the "Avoid" and "Minimize" stages by identifying:

1) **Essential natural capital or ecological infrastructure** for its provision of multiple services that support economies, people, wildlife, and infrastructure, especially those conveying resilience and reducing climate risks, now and in a future of growing climate risks, that should be protected or conserved to ensure continued ecosystem integrity and services provision.
2) **Ideal or optimized locations for major infrastructure investments and how to design them** to complement continued ecosystem service delivery while also delivering essential services provided by such investments, i.e., in water, energy, or transport.

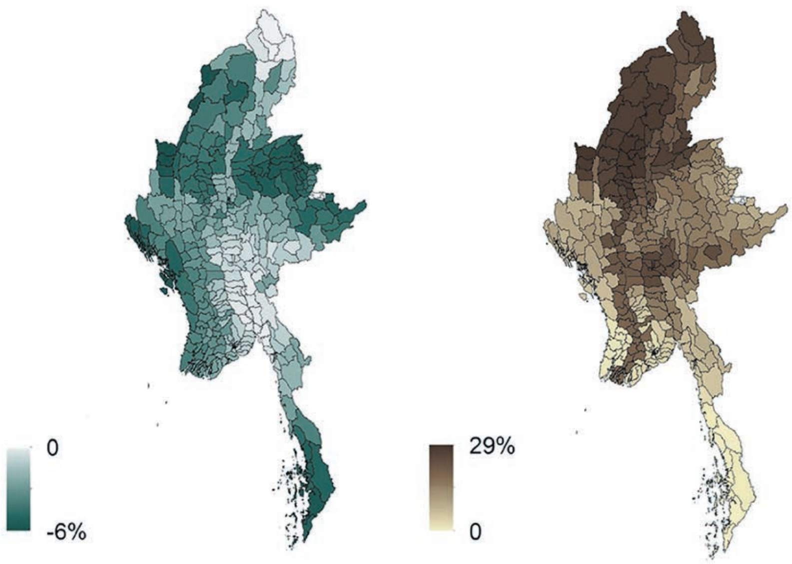
Building a Better Crystal Ball: Visioning Futures Decision Support Tools

Creating an understanding of the above three aspects to inform a more integrated, holistic planning approach requires innovation in modeling and assessment approaches that integrate across fields, including natural capital and ecosystem services assessment and valuation; downscaled general circulation modeling of climate risk; and futures thinking built around scenario planning, back-casting, and sensitivity testing. Leading experts in various fields have begun to converge on exactly such integrated approaches that significantly improve decision-support information, tools, and frameworks previously available to regional planners and large-scale infrastructure developers—as highlighted in the previous section and in greater detail in the case study analysis developed by Kennedy et al.[39] While many of these do still contain important gaps, they demonstrate that the integration of multiple different sources of information on potential risks and dependencies on ecosystem or infrastructure services, along with futures thinking, can guide more effective spatial land use planning and ultimate infrastructure investments, including priority areas that should be left intact as "ecological infrastructure" due to their essential service provision, and areas best suited for large-scale infrastructure investment and resulting impacts. The following are examples of different decision-support tools and assessment processes that helped develop either all three aspects or components of the Visioning Futures process.

NATURAL CAPITAL AND CLIMATE RISK IN MYANMAR

Scientists at Stanford and Columbia University, in partnership with WWF as part of the Natural Capital Project,* developed nationwide maps of natural capital and essential ecosystem services in Myanmar under multiple climate scenarios to inform the country's sustainable development plans (Figure 9).[58] While nationwide and therefore not tailored to one specific infrastructure planning decision, the analysis provided an important national baseline to support adaptation planning at local scales and an important resource for planning for proposed Chinese Belt and Road investments and regional road planning between Myanmar and Thailand.[59] It also provided valuable lessons about the challenges of integrating downscaled climate and ecosystem services modeling approaches, including tradeoffs between complexity and utility for decision-making, driven in part by the limited resolution (climate) and temporal scales (ecosystem services) of the different modeling approaches. In particular, the authors stress the need for advances in incorporating the impacts of extreme events and climate change-driven shifts in vegetation and resulting impacts on ecosystem services provision.

Figure 9. *Changes in sediment retention services provided by upstream forests in Myanmar under low (RCP 4.5) and high (RCP 8.5) climate change scenarios. Source: Mandle et al., 2017.*



PLANNING FOR EBA IN SOUTH AFRICA

Though similarly not driven by a specific infrastructure planning decision, an assessment of social-ecological climate vulnerabilities and needs for ecosystem-based adaptation (EBA) at the regional (sub-national) scale in South Africa demonstrates a particularly innovative approach integrating climate risk assessment and ecosystem services provision. In partnership with local government, scientists developed a multi-criteria analysis modeling approach to guide priorities for investment in ecosystem service provision areas also resilient under future climate change, based on social, ecological, and climate data. Where the Myanmar case does not include projected ecosystem changes in a changing climate, this does, estimating changes in biome distribution under multiple future climate scenarios. Resulting EBA priority maps are composites of maps of water provision areas, important biodiversity habitat, topography and other natural features that support ecosystem adaptation, and concentrated areas of high socioeconomic climate vulnerability and reliance on ecosystem services. While requiring regular stakeholder engagement and multiple data sets to support each individual map, the overall approach is replicable in many contexts where spatial planning is needed to support improved infrastructure decision-making. As the authors state: "The overall approach could usefully be applied at the same sub-national scale for local authorities throughout much of the developing world, where the necessary basic biodiversity and socioeconomic information exist."[28]

* https://naturalcapitalproject.stanford.edu/what-is-natural-capital/#who-we-are.

ECO-ENGINEERING DECISION SCALING

Another concept that can improve upon current infrastructure planning approaches is eco-engineering decision scaling (EEDS).[61, 63-64] As a more recent modeling framework, it has relatively limited examples of application in the developing world, but the case of Mexico City's water supply presents an innovative example of how a Visioning Futures process can work in practice to inform real infrastructure planning based on a robust assessment of climate change and ecosystem services in a changing climate. EEDS is particularly innovative because it flips the typical climate change vulnerability assessment and adaptation planning process on its head: rather than starting with top-down assessment of climate scenarios and determining potential impacts on systems in those scenarios to determine which options are most feasible, it instead begins with preferred outcomes and investments through stakeholder consultation and then does sensitivity testing of those options under a range of possible climate futures to determine which are most "robust" or perform best under expected shifts in rainfall and temperature regimes. As highlighted in Freeman et al. (2020) and Kennedy et al., (2019), this is exactly what a diverse group of stakeholders, including the Mexican water authority CONAGUA, the World Bank, and modeling engineers from the University of Massachusetts-Amherst, determined, ultimately outlining which large-scale water infrastructure investments were likely to perform best in scenarios of growing demand and a shifting, drying climate.

While data intensive and requiring proprietary modeling analysis from multiple engineers, significant funding, and years of regular stakeholder consultation, the Mexico case nonetheless demonstrates that such an approach—explicitly integrating information on climate, ecosystem services (water), infrastructure needs, and economic costs benefits to inform the best planning decision—is indeed possible. A similar approach could be applied to almost any planned infrastructure investment, for example a proposed long-distance road near a protected area, as long as sufficient data is available and partners are willing to invest in the process. The only significant analysis missing in this case is the projected potential change in ecosystem services delivery as a result of shifts in the larger surrounding ecology of the Mexico City watershed; based on the South Africa example, such a projection would not be overly difficult to include in any hypothetical infrastructure planning case.

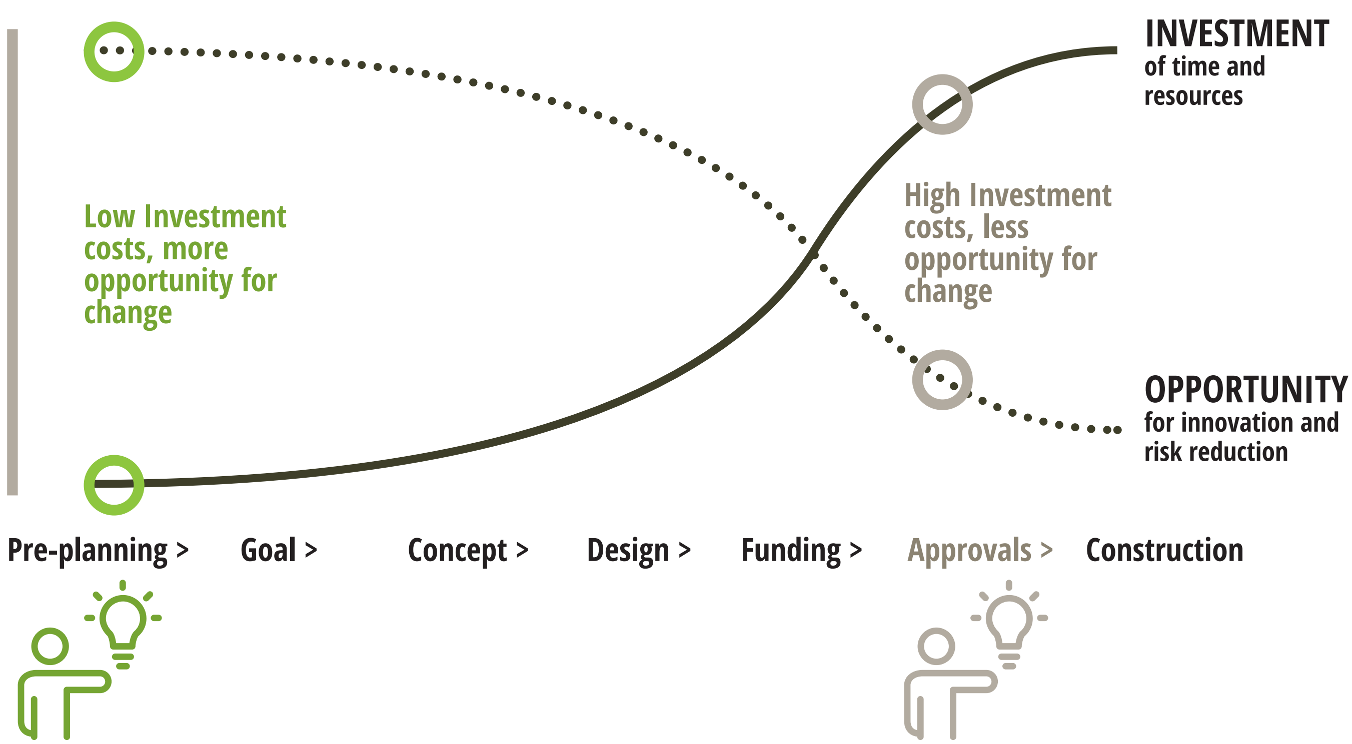
A New Approach

These examples demonstrate that though large-scale infrastructure investments are often complex and data intensive, explicitly planning for them at scale following the three key components of a Visioning Futures approach—1) ecosystem services and dependencies, 2) infrastructure needs, and 3) current and future climate change impacts and risks—is indeed possible. And these are just four out of many other cases where new tools or innovations are driving more effective land use and infrastructure planning around ecosystems. This report does not aim to develop or call for a new set of decision support tools: rather, we aim to present a framework for how existing tools can be used to improve regional planning to better manage tradeoffs among growing infrastructure needs, climate risk and resilience, and maintaining areas providing essential ecosystem services.

Different aspects of these decision support tools and approaches will be necessary as part of longer stakeholder engagement processes, e.g., those driven by strategic environmental assessment. The goal is to provide the most essential information in the pre-planning stages to in turn provide the greatest opportunity to anticipate and avoid environmental, climate, and social impacts and risks (Figure 10).

Based on the above examples, the previous section, and a diverse mix of peer-reviewed literature, the following framework describes the basic steps to integrate climate, ecosystem services, infrastructure needs, demographics, and other critical data through an analytical, participatory co-generation process to achieve the two key goals described

Figure 10. *Addressing environmental risk in the infrastructure planning process. The optimal time in the infrastructure planning and development cycle to address the three key aspects of a Visioning Futures process is during pre-planning, before specific goals have been determined, concepts developed, and designs proposed. This is the only stage that truly allows for effectively following the mitigation hierarchy.*



above: 1) identify essential natural capital and ecosystem services provision areas now and under future climate change, and 2) use this information to guide optimal planning for major infrastructure investments. It is as simple as performing the necessary technical analysis to answer the following key questions:

Natural Capital, Biodiversity, and Ecosystem Services

- Which areas are most important for biodiversity? Where are the most notable/unique/threatened ecosystems?
- Where are crucial wildlife migration corridors? Where will infrastructure cause the most disruption to their connectivity? Which areas are likely to serve as refugia as the climate shifts?
- What areas of the land/seascape, political region, or watershed are currently providing the most ecosystem services benefits, and how valuable are these benefits?
- Who benefits from them and where do they live?
- What are the current economic and population growth trajectories for the region?
- What surrounding natural resources will support that growth, e.g., water, timber, agriculture, fisheries; and to what extent?
- How will the areas providing these ecosystem services be impacted by that growth? How will that change their delivery and value?

Climate Risk

- How are current climate change impacts already affecting services provision and the dependency of local populations?
- How will increasing climate change directly and indirectly impact ecosystems and their ability to provide services in the landscape?

Infrastructure Needs

- What infrastructure investments are needed to provide services and support growth, but not at the cost of long-term ecosystem services provision and ecosystem integrity?
- Where should these investments be optimally located to balance tradeoffs among economic and environmental benefits?

The following key analysis steps of the Visioning Futures process (Figure 11, page 47), performed upstream of any single infrastructure project, describe how to answer these questions.

Step 1. Define the Spatial Scope

The first most essential step in the process is determining the relevant planning scale. Depending on the ultimate driver of the process, whether the potential development of a large-scale single asset—e.g., a road, railway, port, or large-scale hydropower dam—regular planning cycle at the national level, regional development plan, or strategic environmental assessment, the geographic focus will vary. It is essential, however, that the scale is sufficiently large to adequately reflect system-scale social and ecological processes. This is particularly important from an ecological perspective: if too small an area, it will be impossible to evaluate ecosystem services that generally only provide comparable benefits at larger scales and cumulative environmental impacts that may play out at scales far larger than the project footprint. It also dictates which actors and interests are essential to the planning process. Following stakeholder engagement best practice, a wide variety of interested parties across sectors, from local communities to infrastructure developers to government planners, academics, and NGOs, should not only be consulted, but in many cases play an integral role in the process. To maximize the ultimate buy-in of proposed solutions, it is particularly important that relevant government and in-country civil society and academic technical experts work hand in hand with whichever technical team is leading the assessment process.

Step 2. Future Objective and Alternatives

With geographic scope set, a critical next step is to work through participatory stakeholder processes to identify the key development objectives for the coming years and decades and options for achieving them, ideally across a spectrum of ecosystem services maintenance and provision and infrastructure development. This should be far enough in the future to ensure long-term impacts of large physical assets are considered alongside climate scenarios. The simple guiding question is: in 20 or 30 years, what future do people want to see? What level of economic growth and development and where, and what mix of infrastructure and ecological protection and service provision is necessary to get there? Ensuring participation of a broad, diverse group of stakeholders at this stage is essential to create ownership by essential actors in the process, which reduces conflict and increases chances of endorsement and adoption of planning decisions. While the ultimate vision should be the result of stakeholder participation, it is essential that government priorities, including commitments to international agreements like Paris, CBD, and the 2030 Agenda, alongside national and regional development goals, provide the skeletal structure and ultimate objectives of the process.

Step 3. Evaluate Risks and Dependencies

With this vision of the future and specific objectives defined, the next step is to gather the information necessary to evaluate different options for achieving the prioritized future objective and then to sensitivity test alternatives under different risk and impact scenarios, including climate change. These assessments should be organized into three basic categories: climate risk and scenarios; natural capital and ecosystem services provision; and infrastructure plans, trends, and future needs. Each will require different sources of qualitative and quantitative information, including relevant econometric data to support valuation of services and cost-benefit analyses across a range of climate and development scenarios:

Analysis	Data Need	Relevant Tools and Data Sources
Natural Capital and Ecosystem Services Assessment	Biophysical (land cover and land use), topographical (digital elevation), demographic (population concentration), wildlife (population, biodiversity indices, corridor maps), economic (fisheries catch and prices, agricultural input prices, energy prices, tourism spending) [also measures of well-being that may not directly translate to financial returns: e.g., health, cultural services]	InVEST Suite, Co$ting Nature and Water World; ARIES; TESSA; see Neugarten et al., 201862
Current and Future Scenarios of Climate Risk	Observed weather (30 years of local station data), topographical (land subsidence for sea level rise estimation), future projections of seasonal weather patterns, shifts, and extremes (downscaled climate models)	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP); Climate Central Surging Seas Risk Zone Map; WorldClim (historical and future projections)
Infrastructure Plans, Trends, and Future Needs	Current infrastructure (transport, energy, water spatial maps), proposed infrastructure investments (spatial data if they exist for transport, energy, water), official plans (regional and national, qualitative or spatial), demographic and census data (projected population growth), global data sets of existing and proposed infrastructure (dams, ports, roads)	Global Dam Watch; peer-reviewed global analyses: Meijer et al., 2018 and other global infrastructure spatial data [also national and sub-national data sets; much of this data will likely sit in government databases]

The goal here is not perfection, but to create a reasonable understanding based on best available data of key components and trends within the larger system and their values so impacts and risks under alternative development and climate scenarios can be assessed. While purely economic, dollar-value (or whatever relevant local currency) assessments are in many ways essential to compare like and kind with proposed engineered investments, it is also important to not solely produce and rely on economic analyses of "value."

Many ecosystem services are also inherently difficult to evaluate in purely economic terms, especially in developing economies where subsistence and household utility are often not defined in purely economic terms. In sum, economic valuation is important where the data can support it, but local context is essential, and additional non-economic assessments of value are likely just as important. The number of beneficiaries or populations reliant on services, for example, can be powerful results without explicit evaluation of direct economic benefits. The coastal protection benefits of mangroves and coral reefs are a perfect example: in purely economic terms, they are much more valuable in coastal Texas or Florida due to higher dollar value of the homes, infrastructure, and other assets than they are in coastal Mozambique, where their values are low in purely economic terms due to the similarly low dollar value of homes in poorer coastal communities. In Mozambique, however, these ecosystems are much more essential to supporting subsistence-based livelihoods like fishing, and thus likely more "valuable" in non-economic terms.

Step 4. Integrated Assessment and Sensitivity Testing for Trade-Off Analysis

The challenge in this step is to integrate the above separate analyses to sensitivity test impacts on ecosystems and the services they provide across a range of combinations of development and climate scenarios (e.g., following the Mexico City case outlined in Freeman et al., 2020 and Kennedy et al., 2019). The goal is to identify how service provision will change under both alternative development and climate scenarios (which will change calculations around infrastructure services development costs and benefits), where certain natural capital may become even more important as warming increases (e.g., in the Myanmar and South Africa examples, through integrated climate, land use, and ecosystem services modeling). As noted previously, there are still important technical limitations to integrating climate and ES modeling results, but it is increasingly feasible to do this (e.g., Mandle et al., 2017; Bourne et al., 2016; Freeman et al., 2020; Kennedy et al., 2019). The key step is to overlay and integrate proposed development pathways—including specific asset options—into the analyses of ecosystem services under climate scenarios. This allows for sensitivity testing under alternative climate scenarios that determine which alternatives—e.g., mix of infrastructure and ecosystem services investments—perform best across a range of possible climate futures.

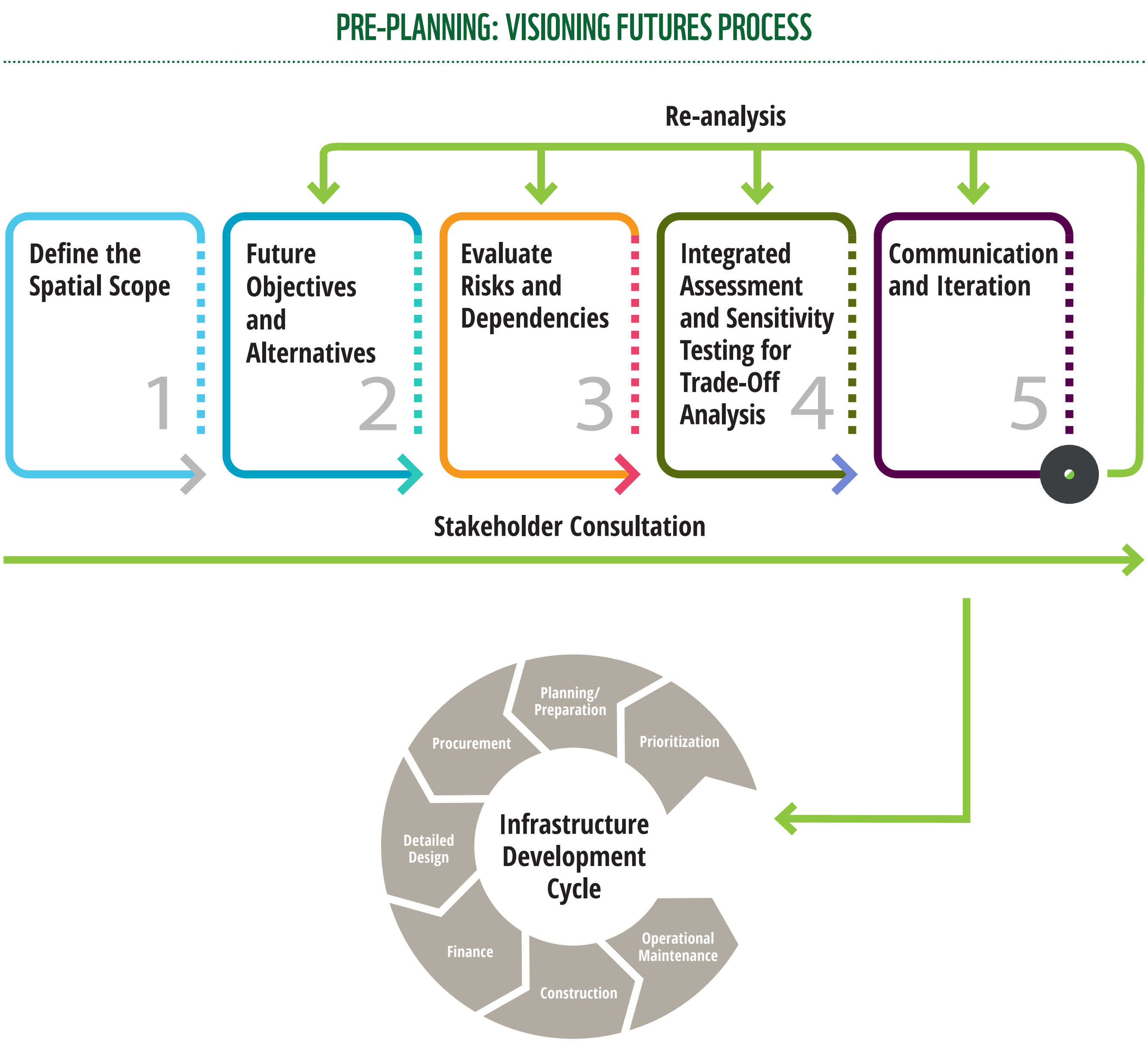
Step 5. Communication and Iteration

Key stakeholders should be consulted throughout the process, but this step is critical to present the results of technical analyses to a wider group of stakeholders to solicit feedback identifying potential incorrect data or results. This is especially important in a spatial mapping context, where ground-truthing based on local expert knowledge—including affected local communities—is essential to improve and fill in gaps in global data that would otherwise incorrectly identify land use types, ultimately leading to incorrect assessments of ecosystem services. Analyses should then be re-run to incorporate feedback and additional data sources that often become available. Some or all of the following maps and analyses should be produced targeting key technical staff in relevant national and regional government planning departments:

1. Priority areas for natural capital, corridors essential for ecological connectivity, and methodologically robust benefits assessments, including economic valuation of ecosystem services where appropriate and other non-economic valuation approaches, especially in more subsistence-based communities.
2. Changes in services provision (compared with a current baseline) under multiple climate scenarios and the values/costs of those changes.
3. Changes in services provision under future alternative development scenarios and resulting changes in values or costs of changes.
4. Infrastructure services delivery under alternative development and climate scenarios (including impacts to ecosystem services provision) and associated costs and benefits.
5. Analysis of 1-4, including economic performance (and progress toward SDG targets) across scenarios; and guidance recommendations for the relevant cross-section of government departments overseeing land-use, infrastructure, and environmental planning decision-making.

It is critical these results are communicated via multiple information pathways, including public interactive mapping platforms and stakeholder forums, to ensure maximum ownership by necessary actors and transparency to government and other managers of the process. Once results are relatively final, they are then used to support a government-led, cross-sectoral land-use planning process involving many of the previous stakeholders, but adding in new actors responsible for finance, construction, and design of specific infrastructure assets to achieve the prioritized development trajectory outlined previously, e.g., the project development cycle (Figure 11).

Figure 11. *The Visioning Futures process described in more detail above. While stakeholder consultation should be constant throughout, the final stage of communication and iteration provides an important opportunity to solicit additional feedback and gather new data to then integrate into re-analysis and in some cases prompt revisions to objectives and alternatives if no alternatives are sufficiently robust under multiple climate futures.*



PART 4. CONCLUSIONS AND RECOMMENDATIONS

Work
UPSTREAM
The greatest opportunity for achieving impactful change is at the earliest stages of planning, where more comprehensive information on the benefits nature provides, especially in supporting climate resilience in social and ecological systems, is essential to support decision-making for infrastructure citing and design.

With new daily reminders of the impacts of climate change and a constant flow of new science showing the impacts of development on nearly every biome and ecosystem on earth, the need for a change in course is clear. As we face trillions of dollars in expected infrastructure investment in the coming decades in some of the last remaining intact habitats, it is starkly obvious that the development model of the 21st century cannot be the same as that of the 20th. While there is growing consensus around principles to drive change and increasingly accessible data and decision support tools to support implementation, this report demonstrates that there are several important gaps and barriers preventing true progress in countries where it is most needed.

The greatest opportunity for achieving impactful change is at the earliest stages of planning, where more comprehensive information on the benefits nature provides, especially in supporting climate resilience in social and ecological systems, is essential to support decision-making for infrastructure citing and design. This report has outlined how various tools and approaches can be used in a more holistic manner to support more integrated, holistic upstream planning, but it is also clear that the barriers to its greater diffusion are not solely technical. Truly supporting such efforts in developing economies with enormous needs for basic services provision—water, energy, food—while simultaneously increasing ambition toward global goals in biodiversity conservation, sustainable development, and climate change adaptation and mitigation, and most importantly the necessary integration across all of them that can only happen at the national level, will require greater action in international fora and in-country from a number of institutions with outsized influence in economic development planning, conservation, and infrastructure finance, development, and design. The actions below represent real opportunities to make critical incremental progress.

International Finance, Policy, and Technical Support

Institutions operating internationally with influence over infrastructure, economic development, and conservation finance—environmental NGOs, bilateral aid agencies, major funders including MDBs, and country working groups like the G7, G20—should do the following to create the enabling conditions for improved planning that can help countries manage the inherent tradeoffs among, and achieve, the goals of the simultaneously essential global agreements in climate, biodiversity, and sustainable development (among others):

1) **Develop explicit funding programs designed to support holistic, cross-sectoral landscape- or regional-scale planning** efforts in collaboration with existing international funding mechanisms like the GCF and GEF, and other major funders like the MDBs, to support technical assessments and simultaneous capacity-building around a Visioning Futures or similar approach in-country, to help de-risk potential investments to attract the private sector and explicitly meet country commitments under NDCs, CBD, and SDGs.

2) **Develop integrated regional- or landscape-scale planning standards** through cross-sector collaboration with landscape, city, and infrastructure planners, design firms, and major funders for a Visioning Futures approach or similar that explicitly considers ecosystem services and climate risks, connects to project level sustainability and resilience standards, and meets national NDC objectives, the CBD post-2020 Framework, and SDGs.

3) **Expand existing and develop new open data access platforms to improve transparency and accessibility**, to increase stakeholder knowledge and ownership in regional planning and infrastructure development processes and facilitate necessary technical assessments that inform planning.

4) **Update existing project screening and other "checklist" tools** commonly used by multilateral development banks and other funders when reviewing infrastructure projects (e.g., the Sustainable Infrastructure Foundation's SOURCE planning tool adopted by the major MDBs44) to explicitly include or require integrated, forward-looking assessments of ecosystem services, climate risks, and infrastructure needs.

5) **Create new procurement criteria for large-scale infrastructure funding** through collaboration with major funders—e.g., MDBs—and private sector developers that require direct integration with existing regional, landscape, or watershed plans that have been developed based on integrated assessments that explicitly account for ecosystem services and climate risks

6) **Increase investment in ecosystem service modeling science** to improve existing geospatial tools to allow greater flexibility, ease of use, and standardization, through collaboration with developers, funders, and academia, to improve accounting of climate change dynamics and risks explicitly tailored to regional development planning and infrastructure pre-planning contexts.

7) Use existing climate and development policy support and coordination initiatives (such as the NDC Partnership, among others) to incentivize improved, holistic upstream infrastructure planning approaches and investments in natural capital and ecosystem services in developing economies through technical support for more ambitious and integrated (adaptation, mitigation, biodiversity, SDGs) nationally determined contributions (NDCs) and other national commitments under global agreements.

In-Country

These same relevant institutions operating in international fora should similarly seize directly related opportunities in-country to ground the shifts in policy and finance in affecting actual landscapes, watersheds, regional plans, and ultimate infrastructure investments:

1. **Collaborate with relevant ministries and departments (planning, finance, public works, environment) to access global funds to support integrated planning approaches** in landscapes with urgent infrastructure needs to create the de-risking conditions to crowd in private sector developer investment; and develop model case studies to replicate and scale nationwide and contribute additional "business cases" that demonstrate the benefits of a Visioning Futures-like approach.

2. **Expand and develop national regulatory frameworks** enshrining holistic consideration of natural capital, ecosystem services, and climate risks in national policies, laws, and regulations governing spatial or strategic planning processes, including procurement requirements, whether driven by large-scale infrastructure investments or otherwise.
3. **Create and expand existing financial, technological, and human resource investments** in cross-sectoral, inter-ministry, and academic natural capital programs that support modeling teams to provide regular technical support for regional planning efforts, including explicit partnership with relevant climate risk assessment departments and agencies; and train the next generation of political leaders to improve national planning and decision-making using such information.
4. **Institutionalize cross-sectoral collaboration and integration in planning processes** via designated official bodies like an inter-agency/ministerial working group or commission with direct oversight and decision-making power in regional and sub-national planning efforts for large-scale infrastructure. Participation should include leaders and support staff in planning, finance, economic development, environment, public works, and other essential ministries.
5. **Expand existing programs and establish accredited integrated regional planning degrees in national universities** integrating curricula across schools of engineering, ecology, earth science, and economics around ecosystem services, natural capital, climate risk assessment and scenario planning, back-casting, decision-scaling, and other scenario planning approaches to train the technical experts necessary to manage and implement cross-sectoral planning processes.
6. **Increase ambition in NDCs through holistic mitigation and adaptation goals and programs**, achieved through the use of Visioning Futures or similar planning frameworks that can improve planning for both nature-based solutions and decarbonization in major infrastructure sectors like transportation, energy, and water supply, among others.

These are not the sole actions necessary to create such a substantial shift in practice away from standard least-cost spatially and temporally myopic approaches that currently dominate infrastructure planning. The same political economy reforms necessary to drive any change toward improved natural resource governance and sustainable, resilient development in general—greater transparency, capacity building, cross-sectoral integration, and collaboration—are just as essential here to create the chances for success of any of the above. However, their achievement would make substantial progress in filling the key planning gaps outlined at the outset of this report, at a minimum improving understanding and decision-making to harness the important and essential benefits nature provides for millions of people, infrastructure, and economies in building resilience to a rapidly warming world. It also provides a valuable framework for countries to manage at a national and subnational scale the sometimes conflicting goals of multiple global agreements in climate, biodiversity, and sustainable development.

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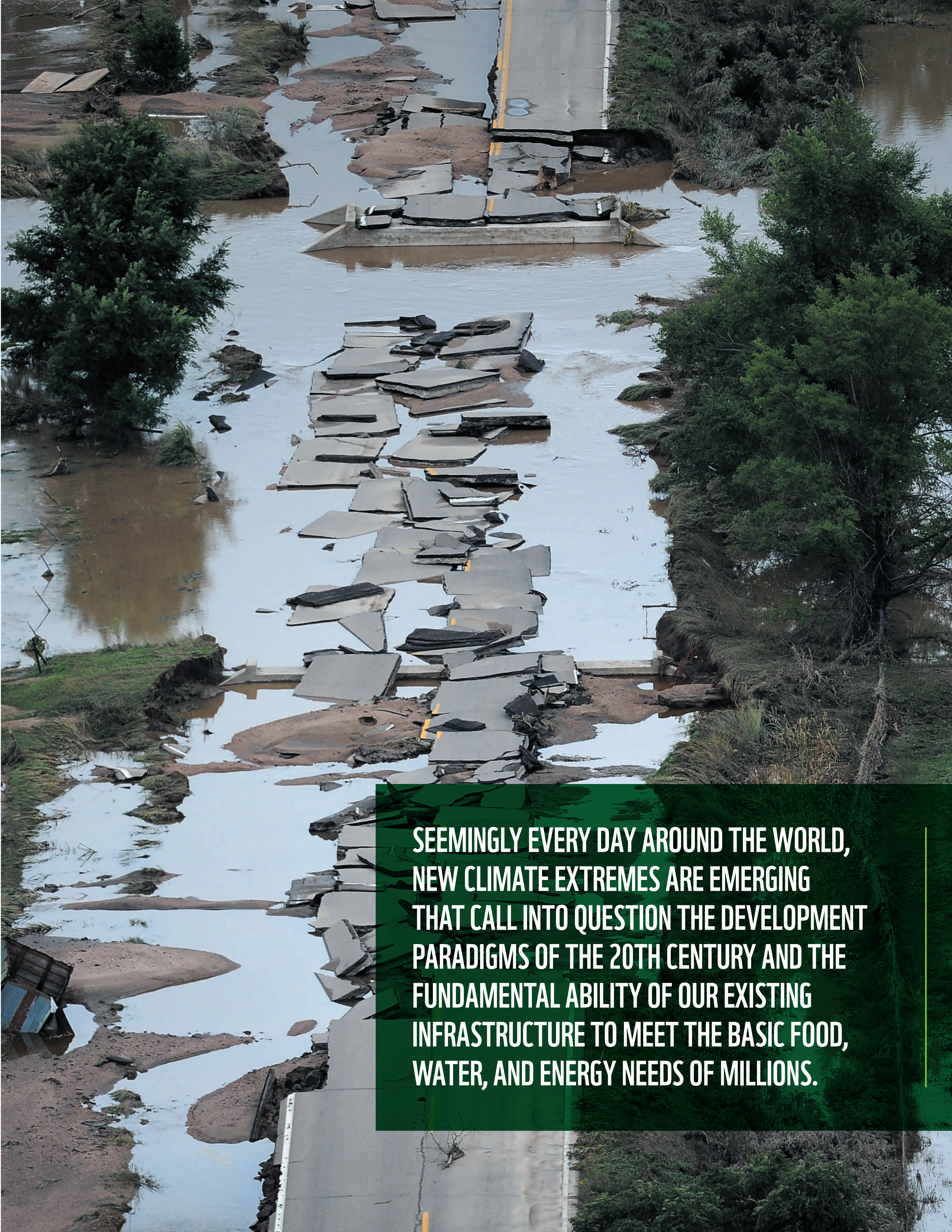

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