Financing Climate Futures
Rethinking Infrastructure

Chapter 2

Plan infrastructure for a low-emission and resilient future

The transition towards low-emission, resilient economies presupposes far-reaching changes to infrastructure, technology and industrial systems that will require prudent planning. This chapter makes the case for improved planning practices as a prerequisite for successfully delivering on both climate and development objectives. It identifies barriers for implementing changes and emerging good practices in reconciling long-term climate and development objectives with near-term demand for infrastructure services. The chapter outlines three priority actions: develop new institutional configurations to align today's decisions with long-term objectives, ensure that resilience to the impacts of climate change is a central component of planning, and harness the benefits of foresight to complement climate models in strategic planning.

Key messages

Long-term strategies can be formidable tools for governments and non-state actors to create consensus on their economic trajectories, provide long-term signals to markets and inform near-term policy and investment decisions. Infrastructure planning must be improved at all levels of government to create pipelines of sustainable infrastructure projects aligned with long-term climate and development objectives. Priority actions include:

- Develop new institutional configurations to align infrastructure plans with a long-term low-emission, resilient development vision.
- Make resilience the norm to limit vulnerability to climate damages, mainstream nature-based solutions and demand-management tools into planning to ensure a resilient future.
- Future-proof infrastructure investment decisions through approaches such as strategic foresight to monitor emerging socioeconomic and technological changes and regularly adjust long-term strategies.

Why is improved planning transformative?

Success in limiting global temperature rise to well-below 2°C and towards 1.5°C hinges on rapid and unprecedented transformations of infrastructure stocks in energy, land-use and industrial systems worldwide (IPCC, 2018[1]). While the emission reductions pledged in countries' 2030 Nationally Determined Contributions (NDCs) can be achieved with current infrastructure systems, post-2030 decarbonisation pathways that meet the Paris Agreement temperature goals will require far-reaching changes to infrastructure, technology and industrial systems. Such radical shifts require better planning practices that align short-term infrastructure investment plans and strategies with long-term climate and development goals.

The Paris Agreement recognises the importance of long-term planning in Article 4.19, which calls on countries to "formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2". Such long-term strategies can help countries scale up the ambition of their NDCs, which has been inadequate to date, and reconcile decisions in the present with long-term climate goals.

Given the long lifespan of infrastructure assets, the alignment of today's infrastructure choices with long-term targets is essential, since what countries build today will determine their emissions and vulnerability to a changing climate for decades to come. If they plan prudently, countries can wean their economies off dependence on fossil fuels and ensure that financing flows towards low-emission, resilient infrastructure projects. Such planning can identify and exploit synergies between climate and economic development goals to foster public support for the transition.

Otherwise, countries risk building infrastructure assets that would inevitably face stranding – i.e. retirement before the end of their economic lifecycle – and lock their economies into elevated future emissions and costly path dependencies. Not only are investments in emissions-intensive infrastructure risky and possibly unprofitable, they also attract capital that could otherwise support and scale up infrastructure compatible with climate objectives.

What is the state of play?

Governments face the dual challenge of planning infrastructure that satisfies the immediate demand of their citizens for services like energy and mobility while simultaneously meeting long-term climate goals. On both counts, business-as-usual planning practices have underperformed, leading to severe underinvestment in infrastructure systems globally and sluggish action to mainstream resilience and curb emissions.

Some countries are beginning to develop long-term low-emission development strategies and systematically integrate climate considerations in infrastructure planning, but they remain the exception rather than the rule. To date, only ten of the UNFCCC's 197 parties have submitted long-term low-emission development strategies: Benin, Canada, the Czech Republic, France, Germany, the Marshall Islands, Mexico, Ukraine, the United Kingdom and the United States (UNFCCC[2]). A 2015 survey led by the G20 Investment and Infrastructure Working Group revealed an uneven mainstreaming of climate change in infrastructure planning across sectors: nine G20 countries include both climate mitigation and adaptation considerations, while a further four only take account of mitigation concerns. Five countries did not take into account neither climate mitigation nor adaptation (OECD, 2017[3]).

The incompatibility of current infrastructure planning with the Paris Agreement's goals and other development goals is evident in many ways:

- **Energy:** The majority of global electricity continues to derive from fossil fuels, and investment flows still overwhelmingly favour fossil fuel supply over renewable electricity generation (IEA, 2018[4]). Looking at coal power plants alone, total lifecycle emissions from all plants currently operating or under development would be high enough to put both the 2°C and 1.5°C temperature goals out of reach. This means many projects will need to be cancelled and existing plants will face early retirement (Shearer et al., 2018[5]).
- **Agriculture, forestry and other land-use (AFOLU):** Countries must strike a balance between food production, biodiversity conservation and other needs while managing the sector's sizeable impact on emissions. Innovation and investment have been insufficient in more efficient production techniques and supply chains, which could relieve pressure to convert forests and other land for crops and reduce food waste and loss. As various elements — such as population growth, greater per capita caloric intake, greater demand for resource — and land-intensive meat and dairy products strain existing systems, current practices could lead to suboptimal crop yield improvements and sustained food price increases in the long term (FAO, 2018[6]).
- **Cities:** Urban sprawl has increased since 1990 in most OECD countries. This promotes dependency on cars for mobility, which worsens air pollution, and contributes to environmental challenges through increased emissions as well as biodiversity and ecosystem loss (see Chapter 7) (OECD, 2018[7]).

What are the opportunities and barriers for change?

Long-term strategies can be formidable tools for governments and non-state actors to create consensus on the direction of travel of their economies, provide long-term signals to markets and to inform near-term policy and investment decisions. However, political pressure to deliver services for development goals in the short and medium terms can predispose governments to pursue development pathways based on well-established infrastructure assets. This, therefore, impedes the required shifts in infrastructure stocks towards low-emission, resilient alternatives and delays climate action.

In addition to the lack of long-term infrastructure planning aligned with climate objectives, a prominent barrier to accelerating investment in low-emission, resilient infrastructure is the lack of investor-ready, bankable infrastructure projects that are compatible with a low-emission, resilient future (Nassiry, Nakhooda and Barnard, 2016[8]). Many governments are constrained by a lack of capacities to integrate climate concerns in infrastructure planning and assessment. Institutional structures and incentives currently prevent the adoption of a cross-sectoral, whole-of-government perspective in long-term development strategies as well as infrastructure and climate action plans. Behavioural and data biases encourage choices that are in line with historical practices rather than potential emerging alternatives (Röttgers and Anderson, 2018[9]).

To deliver the transformation needed and help unlock financial flows towards low-emission, resilient infrastructure, countries should develop clear infrastructure investment plans that take mitigation and adaptation objectives into account, as part of their work on long-term low-emission development pathways. Ensuring that infrastructure investments are flexible and robust against a different set of socioeconomic uncertainties is an essential part of building resilience into the system.

2.1. Plan infrastructure in the present with long-term climate goals in mind

Decisions made today, particularly for infrastructure assets with long lifecycles, can either contribute to or hinder efforts to achieve the transition. Long-term planning needs to inform new courses of action in the present and planning in the near and medium terms. This requires aligning different time horizons: short-term plans need to be elaborated with a view to how they will affect long-term climate objectives, while also satisfying current needs.

Create long-term strategies with development and climate at their core

Long-term planning exercises, such as the long-term low-emission development strategies recommended by Article 4.19 of the Paris Agreement, need to become the norm across all countries to prepare adequately for the global transition towards a low-emission, resilient future. Development finance institutions (DFIs) have begun mainstreaming long-term climate concerns into their operations (see Box 2.1), and several multi-stakeholder initiatives have emerged to help countries elaborate and implement their long-term strategies. These include the "2050 Facility", created by the *Agence française de développement* (AFD); the Deep Decarbonisation Pathways Project (DDPP), led by the Institute for Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN); and the 2050 Pathways Platform, launched at COP 22 in Marrakesh. The 2050 Pathways Platform aims to support countries' efforts to develop long-term development pathways in line with the goals of the Paris Agreement, and it has published key principles for developing these strategies (see Box 2.2). These principles stress the importance of reconciling climate action with socioeconomic development objectives and crafting the strategies with input from all stakeholders across sectors, industries and ministerial portfolios (2050 Pathways Platform, 2017[10]). Crucially, the platform not only encourages national governments to undertake this exercise but also cities, subnational governments and companies.[1]

Box 2.1. **2050 Pathways: Integrating long-term climate goals into World Bank operations**

The World Bank is committed to transforming its own operations and aligning its support to countries to help them meet their climate goals. In 2016, the World Bank presented its Climate Change Action Plan and is well on track to meet its targets. In line with countries submitting updated and potentially more ambitious NDCs, the World Bank will present a stock-take of its Climate Change Action Plan and announce new commitments and targets beyond 2020 at COP24 in Poland in 2018.

As an institution, the World Bank recognised that it needs to go even further and undertake more transformative changes to meet the long-term objectives of the Paris Agreement. Therefore, the World Bank engaged in a visioning exercise to explore what long-term low-emission and climate-resilient development pathways might look like (using a 2050 timeframe) in key sectors and countries where the institution is active. The exercise is helping to identify what could be potential implications for the way the World Bank does business, such as introducing new types of services and financial instruments, and integrating long-term dimensions in country engagement strategies and project.

A strategic vision of infrastructure's role in national development that runs across ministerial portfolios allows both the connections between infrastructure for energy, transport, water and other sectors, as well as the co-benefits (such as improved health outcomes) to be exploited. This helps to create synergies, reduce inefficiencies and foster support for the transition. There are more synergies between mitigation efforts that are in line with 1.5°C pathways and the Sustainable Development Goals (SDGs) than there are possible trade-offs. The co-benefits are particularly sizeable for SDGs 3 (health), 7 (clean energy), 11 (cities and communities), 12 (responsible consumption and production) and 14 (oceans). Prudent planning can also help avoid possible trade-offs arising from competition between, for instance, food production and measures supporting afforestation and bioenergy supply (IPCC, 2018[1]).

Existing national pathways offer similar insights into synergies between climate action and broader sustainable development questions. China's Deep Decarbonisation Pathway created by the DDPP, for instance, demonstrates how prudent planning for decarbonisation across industry, transport and energy could dramatically reduce China's emissions while reducing primary air pollutants in major Chinese cities to meet World Health Organisation air quality standards (Liu et al., 2015[11]; Waisman et al., 2015[12]). South Africa's Deep Decarbonisation Pathway, meanwhile, uses scenarios to address political economy concerns resulting from the necessary shift of labour away from the country's coal mining industry towards other sectors. In one scenario, the structure of the economy transforms so that low-emission sectors such as furniture, glass and forestry absorb low-skill workers; in another, an improved educational system provides the necessary educated labour to shift the economy towards high-skill low-emission sectors (Altieri et al., 2015[13]).

Such whole-of-government planning, however, is not yet standard practice. According to an OECD survey, only about half of OECD countries reported having a strategy for infrastructure that covers all sectors (OECD, 2018[14]). In addition to cross-sector synergies, mainstreaming climate change considerations in infrastructure plans is essential to achieve long-term goals. However, the extent to which climate change is considered within countries' infrastructure objectives and long-term plans varies considerably (ITF, 2017[15]).

Box 2.2. **Principles and building blocks of the 2050 Pathways Platform**

Principles: A general approach to 2050 pathways analysis, based on the principles below, is recommended for producing pathways that meet the criteria of clarity, relevance, practicality and credibility.

- Socioeconomic and emissions objectives are incorporated side by side as integral parts of the analysis.
- Backcasting is used starting with the desired long-term goal and working backwards to the present to shed light on key decision points and trade-offs.
- Analysis focuses on the physical transformations required to meet long-term emissions and socioeconomic goals.
- Pathways development engages stakeholders in the analysis and promotes communication of the findings.
- Policy questions, objectives and boundary conditions of the analysis are defined at the outset and the analytical toolkit is selected accordingly.

Building blocks: The principles of 2050 pathways are embodied in three building blocks of the pathways design process.

- Creation of narratives describing possible futures.
- Analysis and modelling of scenarios based on those narratives.
- Use of dashboards for communicating modelling assumptions and results.

Source: 2050 Pathways Platform (2017[10]), *2050 Pathways: A Handbook*.

Build capacity and techniques to link near-term action with long-term climate targets

A key component of success in achieving the Paris Agreement's objectives relates to building climate-related capacities in governments. This includes climate modelling capacities, to understand whether current infrastructure decisions are compatible with carbon budgets and the emissions reduction trajectories of long-term plans. For instance, the United Kingdom has set a 2050 target of reducing emissions by 80% compared to 1990 levels. It has charged the Committee on Climate Change with translating this target into a carbon budget over five-year segments, which are then assigned to individual sectors (OECD, 2018[16]). This creates the necessary link between national long-term targets and the decision-making process in the shorter term.

Models that project current trends into the future are helpful, but decision makers can also employ 'backcasting' to determine which proposed policies or infrastructure projects are compatible with long-term science-based targets. In backcasting, rather than starting from present trends, modellers begin with the desired outcome (e.g. national emissions reduction goals) and work backwards to construct a plausible pathway to achieve it. The approach can be used to identify misalignments between present actions and long-term objectives in policy, infrastructure and investment. It can also shed light on practices that contribute to incremental emissions abatement but that are incompatible with long-term targets (2050 Pathways Platform, 2017[17]).

It is critical that countries' emission reduction pledges in the mid-term are consistent with net-zero emission longer-term goals. While NDCs adopt a 5- or 10-year view with the most recent iterations covering up to 2030, infrastructure assets are often in operation for several decades so their potential impact on emissions and climate go far beyond what NDCs can capture. New coal-fired power plants could, for example, be compatible with energy access objectives and even with 2030 NDCs in certain countries, but over the course of such plants' lifetimes the total emissions would be incompatible with the global goal of achieving net-zero emissions by the second half of the century (ClimateWorks Australia, 2017[18]). Infrastructure investments on a very large scale, like China's Belt and Road Initiative, offer a unique opportunity to ensure that projects align with low-emission pathways (see Box 2.3).

Box 2.3. **Infrastructure built as part of the Belt and Road Initiative will shape recipient countries' future emissions**

China's Belt and Road Initiative (BRI), a large-scale infrastructure development strategy, will involve the world's single largest flow of infrastructure financing and build out ever. It covers more than 68 countries, including 65% of the world's population and 40% of the global GDP. Its investments in infrastructure already amount to USD 690 billion and further commitments will total USD 1.5 trillion by 2025. However, the BRI will only account for a small fraction of total infrastructure investment in recipient countries.

Which infrastructure projects receive financing from the initiative will shape future emissions. Current infrastructure investment patterns in recipient countries are emissions-intensive. Over 50% of planned BRI investments in the power sector are coal-based. Without a major shift in the infrastructure profile, especially in power and transport, aggregate emissions across recipient countries could be several times those of China itself by 2040, effectively putting the Paris Agreement's temperature goals out of reach.

BRI recipient countries could adopt more ambitious growth pathways towards emissions reduction and climate resilience, with major gains possible by embracing existing best-in-class power and transport technologies and infrastructure. The BRI could support this positive deviation from the current trajectory, both through aligning investments with more ambitious climate goals, and related support, such as the greening of domestic financial systems through which an even larger share of the overall investments will flow.

Source: UN Environment (2018[19]), Greening the Belt and Road Initiative (forthcoming).

Create pipelines of bankable infrastructure projects in line with climate objectives

It is essential that investments stop flowing towards projects incompatible with the Paris Agreement's goals. As an alternative to emissions-intensive assets, countries should identify and promote projects that meet development needs and align with their long-term objectives and NDCs. Together, these infrastructure projects should form a 'pipeline' of projects for investment to streamline the process between project conception and financing. To create such pipelines, governments and public institutions must develop detailed infrastructure investment plans and integrate them into the national priority context. This can help create clear signals to investors as to where investments should flow (OECD, 2018[16]).

One emerging good practice is Colombia's Strategic Projects of National Interest (PINES, *Proyectos estratégicos de interés nacional*). These consist of projects proposed by both the public and private sectors, which are assessed by relevant ministries against their sectoral priorities. The most appropriate proposals undergo further scrutiny by the Inter-Sectoral Commission on Infrastructure and Strategic Projects, chaired by the Minister of Transport and composed of Ministers with diverse portfolios: Interior Affairs, Finance and Public Credit, Mines and Energy, and Environment and Sustainable Development. Technical committees assist by evaluating environmental and other aspects of proposals (OECD, 2018[16]).

Another practical way to support pipeline development is to create entities dedicated to this purpose. For example, the EU High-Level Expert Group on Sustainable Finance (HLEG) has proposed to establish Sustainable Infrastructure Europe, which would provide advice, improve capacity and reduce regulatory uncertainty for EU member states (2018[20]). These dedicated entities would convene and link up key actions and host information that could help countries estimate their infrastructure needs and translate them into clear project pipelines.

Existing public financial institutions and entities could also be used to support better pipeline development. In developing countries that may lack in-house capacities, initiatives such as the NDC Partnership[2] can enhance co-operation and provide technical and financial support to enable countries to set climate targets as soon as possible. Initiatives led by development finance institutions, such as the *Agence française de développement* (AFD) and the Inter-American Development Bank (IDB), now help countries screen projects for climate risks. Governments can also use their export credit facilities and official development assistance providers to encourage better infrastructure pipelines that are aligned with the objectives of the Paris Agreement (OECD, 2017[3]). Domestically, green investment banks, which are public financial institutions dedicated to green investment, could be developed or expanded to support the development of pipelines as part of their mandate (OECD, 2016[21]).

2.2. Make resilient infrastructure the norm, not the exception

There is an urgent need to strengthen existing and build new infrastructure that can respond more adequately to the risks and impacts of a changing climate. Climate change poses a number of threats to economic development, with rising sea levels, increased risk of drought in some areas, shifting rainfall patterns and greater prevalence of temperature extremes, including a change in the intensity and frequency of extreme events. In 2017, Hurricane Irma illustrated the major damage that can be caused by extreme weather events, leaving 6.7 million customers without electricity (EIA, 2017[22]). Choosing inclusive, climate-resilient approaches to infrastructure provision at the outset will help to moderate the extent of those negative impacts. The World Bank estimates that "building back better" after disasters could save up to USD 173 billion per year globally in well-being losses due to natural disasters, compared to business as usual (see Box 2.4).

Countries are making progress towards integrating resilience in infrastructure investment. This is evident through an increased number of measures to strengthen the enabling environment for infrastructure resilience: providing climate information, integrating climate risks into technical standards, and encouraging physical climate risk disclosure (see Chapter 5) (Vallejo and Mullan, 2017[24]). In addition, the volume of development finance targeting adaptation, although small, has been increasing. For example, adaptation financing from the multilateral development banks (MDBs) increased from USD 5.9 billion in 2016 to USD 6.8 billion in 2017.[3]

Despite these promising developments, several barriers continue to prevent the alignment of financial flows with resilience. The impacts from climate change often lie beyond the time horizons considered by investors and other decision makers. Further complications include a lack of information, capacity and tools; policy misalignments and market failures; and insufficient weighting given to climate risks. There remains an urgent need to scale up action in a manner commensurate with the threat posed by climate change.

Box 2.4. **Building more resilient infrastructure in the wake of natural disasters is a good investment**

Disaster losses tend to disproportionately affect poor people. The Caribbean hurricane season of 2017 was a tragic illustration of this. Two category 5 hurricanes wreaked destruction on numerous small islands, causing severe damage on islands like Barbuda, Dominica and Saint Martin. The human cost of these disasters was immense, and the impact of this devastation was felt most strongly by poorer communities in the path of the storms.

Yet, amidst the destruction, it is essential to look forward and to build back better. Countries can strengthen their resilience to natural shocks through a better reconstruction process. Reconstruction needs to be strong, so that assets and livelihoods become less vulnerable to future shocks; fast, so that people can get back to their normal life as early as possible; and inclusive, so that nobody is left behind in the recovery process.

The World Bank report *Building Back Better: Achieving Resilience through Stronger, Faster, and More Inclusive Post-Disaster Reconstruction* estimates that the benefits of building back better could be very large: up to USD 173 billion per year globally. They would be greatest among the communities and countries that are hit by disasters most intensely and frequently and that have limited coverage of social protection and financial inclusion. Small island states – because of their size, exposure, and vulnerability – are among the countries where building back better has the greatest potential. A stronger, faster and more inclusive recovery would lead to an average reduction in disaster-related well-being losses of 59% in the 17 small island states covered in the report.

Source: Hallegatte, S., J. Rentschler, B. Walsh (2018[23]), *Building Back Better: Achieving Resilience through Stronger, Faster, and More Inclusive Post-Disaster Reconstruction.*

Reshape demand for infrastructure services

A key action for greater resilience would be to fill the investment gap and mobilise additional resources for projects that enhance adaptive capacity, strengthen resilience and reduce vulnerability. This can be achieved, in part, through new technologies and better data, as well as by influencing the behaviour and investments of infrastructure users and beneficiaries.

These demand-side measures can help to reduce the likelihood of the failure of service provision or reduce the negative consequences when disruption occurs. An increasing number of examples are showing how they can be implemented:

- *Energy:* New technologies, including smart meters and improvements in battery storage, hold the potential to increase domestic users' contribution to grid reliability. In the Netherlands, the Eneco Crowdnett is aggregating home batteries to provide a "virtual power station". There have been early studies of aggregating the batteries of electric vehicles in a similar manner.
- *Transport:* In Seoul, Korea an intelligent traffic management system (TOPIS) provides real-time monitoring of traffic conditions throughout the city. Information gathered is provided to end users through signs, website and mobile apps. The system is open to third parties, thereby stimulating the development of private markets for resilience.
- *Water:* In England, water companies are pursuing a "carrot-and-stick" approach to reduce water consumption, reducing the risk of drought. South East Water covers a severe water-stressed area, and is implementing compulsory metering combined with the provision of free water-saving technologies (such as low-flow showerheads).

Increase the use of nature-based solutions

Nature-based solutions are increasingly being used as a complement or replacement for traditional grey infrastructure, particularly in the area of water and coastal management (Jones, Hole and Zavaleta, 2012[25]). These measures have the potential to be significantly cheaper: the City of Copenhagen found that the use of nature-based solutions, such as more green spaces, to cope with heavy downpours would be DKK 7 billion (EUR 940 million) cheaper than reliance upon grey infrastructure alone. Analysis in Portland, Maine found that nature-based approaches to water treatment, such as afforestation and reforestation, would be 51–76% cheaper than a treatment plant (Talberth et al., 2012[26]). As well as being cheaper, these approaches could also yield co-benefits such as amenity value, carbon sequestration and provision of species' habitats.

Nature-based solutions are being used by a range of actors at various scales to improve their resilience to the climate:

- **Shanghai, China "Sponge City"** – Shanghai has been selected as one of 30 "sponge cities", which are to use nature-based solutions to reduce flood risk. A combination of measures including permeable paving, green roofs and rain gardens are being installed to ensure that 70% of storm water runoff is captured, reused or absorbed. The national government is covering 20% of the cost, with the remainder expected to be provided from local governments and private investors.
- **Dow Chemicals "Valuing Nature" initiative** – This company now screens all new capital, R&D and property decisions to identify opportunities for using nature. In 2017, they estimated that the implementation of nature-based solutions under this initiative had led to savings or new cash flow of USD 120 million. Initiatives included the installation of green retaining walls at their site in Aratu, Brazil instead of concrete walls. This approach helps to combat erosion while also reducing surface run-off. This programme is being funded from the company's own resources (Dow, 2017[27]).
- **Quintana Roo, Mexico "Coastal Zone Management Trust"** – Healthy coastal reefs play an essential role in protecting coastal assets against storms. It has been estimated that they can absorb 97% of wave energy from storm surges. This fund combines taxes collected from the local tourist industry and local government funding to maintain the reefs. The fund also purchases insurance against damage to the reef, which then covers restoration activities following particularly severe storms (The Nature Conservancy, 2018[28]).

Nature-based solutions, predominantly in the land-use sector, also have important, cost-effective mitigation applications, through avoided deforestation and restoration of degraded lands, for instance. Policies in agriculture, forestry and other land use (AFOLU) can be used to maximise net emissions abatement by reducing emissions from land-use change and increasing the removal and sequestration of emissions (see Box 2.5).

Nature-based solutions are not a panacea, however, and will be better suited to managing some types of risks than others. Experience has shown that to realise their potential the design of these approaches needs to be tailored to the context of the climate risk. Poorly planned efforts may be worse than useless, failing to deliver the promised benefits of resilience and disrupting ecological systems. A range of guidance is now available for ensuring the effectiveness of these solutions as part of integrated strategies. This includes the World Bank's 2017 publication *Implementing nature-based flood protection: Principles and implementation guidance* (2017[29]).

Box 2.5. **The land-use sector has great potential to remove and store atmospheric CO_2**

How land is used is essential not only for climate resilience, but also for mitigation. In particular, avoiding deforestation and forest degradation, and restoring organic soils and degraded lands could contribute considerably to lower-emission pathways. In fact, all pathways consistent with limiting global temperature rise to below 1.5°C assume CO_2 removal of about 100-1 000 $GtCO_2$ this century.

While there remains a degree of uncertainty around the mitigation potential of the land-use sector, studies indicate that it is significant. The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), for example, estimated the global abatement potential of restoring cultivated organic soils to be 248 $MtCO_2e$/year (at a cost of up to 20 USD/tCO_2e). A more recent analysis estimates that conservation, restoration and improved management of forests, grasslands and wetlands could deliver 23.8 $GtCO_2$ of emission reductions by 2030, even when accounting for food and fibre security and biodiversity conservation. About half of this mitigation potential represents cost-effective climate mitigation, defined as a marginal abatement cost of less than or equal to 100 USD per tonne of CO_2 by 2030. It is estimated that deploying these "natural climate solutions" could deliver up to 37% of the emission reductions needed by 2030 in order to have a greater than 66% likelihood of holding warming below 2°C and 20% of the emissions needed between now and 2050.

Source: IPCC (2018[1]), *Global Warming of 1.5°C*, Intergovernmental Panel on Climate Change, Geneva; Smith, P. et al. (Agriculture, Forestry and Other Land Use (AFOLU), 2014), "Agriculture, Forestry and Other Land Use (AFOLU)", *Climate Change 2014: Mitigation of Climate Change*; Griscom, B. et al. (2017[31]), "Natural Climate Solutions", *Proceedings of the National Academy of Sciences of the United States of America*, 114/44.

2.3. Use strategic foresight to improve decision making under uncertainty

It is impossible to predict precisely what the future will look like in 2050 or beyond, even with the most robust, finely calibrated models. Unexpected shocks – such as geopolitical upheaval or sudden technological breakthroughs – could have unforeseen impacts and disrupt those models' underlying assumptions. Models in the 1970s did not – and, indeed, could not have been expected to – predict the technological changes over the past 50 years; the current models can hardly be expected to capture the changes to come.

Strategic foresight is a useful tool for approaching decision making with such levels of uncertainty and complexity that can complement models by preparing for several plausible scenarios that could emerge from non-linear shocks. It considers points of uncertainty in the present and develops several plausible future scenarios stemming from them. Its insights can inform planning exercises across government agencies for both climate change mitigation and adaptation as a complement to models (see Box 2.6), and the approach has been used in the Financing Climate Futures initiative, notably in the *Shifting the Lens* report (see Box 1.1).

Develop strategic foresight capacity across government agencies

Dedicated strategic foresight teams can analyse possible emerging trends (called "weak signals") to predict how, at a larger scale, they could affect the future. The ability to do so is a key complement to traditional modelling exercises, as it captures the impacts of unexpected disruptions. Building additional capacity dedicated to strategic foresight and the integration of its insights into long-term planning exercises could ensure that the pathways against which current actions are compared adapt to emerging best available knowledge and possible future disruptions.

Box 2.6. **Challenges in energy systems modelling**

Energy systems models, often contained within broader integrated assessment models, are the dominant tool for exploring how energy systems could evolve under a variety of greenhouse gas (GHG) emissions constraints (IPCC, 2001[32]; IPCC, 2007[33]; IPCC, 2014[34]). They are invaluable in providing quantified answers on how to meet current and future energy demand without exceeding prescribed emissions constraints. In particular, they can provide key information, such as future demand for various fuel types, fuel trade between regions, carbon prices and sectoral energy prices consistent with their emissions pathways, and the degree of emissions permit trading between different regions with different emission constraints. These tools are also ideal for undertaking "experiments" with possible low-emission pathways, such as examining the economic costs of delayed mitigation action to achieve given climate targets (Rogelj et al., 2013[35]; Gambhir et al., 2017[36]; Riahi et al., 2015[37]).

While these models are the cornerstone of long-term low-emission development strategies, they would benefit from the insights of other complementary approaches. For example, the current generation of models cannot represent the invention of as-yet unknown technologies, or the emergence of fundamentally new behavioural or social patterns that may affect energy use. For example, the emergence of ultra-high-speed "hyperloops" (Palacin, 2016[38]) could conceivably replace a significant share of domestic aviation. The emergence of circular and shared economy business models could radically shift the demand for infrastructure moving forward.

The models also do not yet represent the costs and implications of investment in, and lock-in to, specific infrastructures, such as electric charging versus hydrogen transport infrastructure, which may reasonably be considered as alternative strategies for achieving low-emission road transport. Further, the sheer range of model outputs (such as carbon prices, rates of decarbonisation and technology mixes) in comparative studies of models – even where certain basic assumptions such as socioeconomic pathways are shared (Rogelj et al., 2018[39])– makes it difficult to know which represent a realistic and achievable set of energy system transformation pathways. Improvements to modelling are likely to make the models better at representing real-world energy system transformation; however, limitations are likely to remain in the degree to which these models can represent the full range of plausible futures.

Complementary approaches are available and, generally, fall into three groups: (1) qualitative methods, which apply subjectivity and creativity to understand future possibilities, using techniques such as brainstorming, workshops, surveys, expert panels and even science fiction analogies; (2) quantitative methods, which use analytical techniques such as trend extrapolations, time series analyses and modelling; and (3) semi-quantitative methods, which apply mathematical methods to quantify the views of experts and commentators (Popper, 2008[40]).

Some of these other foresight methods could be considered as part of a broader portfolio of techniques aimed at better understanding the range of possible low-emission futures, as well as the associated costs, benefits, uncertainties, risks and opportunities. A critical piece of the research and policy-making agenda is how to combine energy systems models and integrated assessment models activities with these other approaches, to produce a more complete – yet still quantifiable – range of future possibilities to inform today's actions.

In some countries, dedicated foresight units or teams within governments already feed their insights into decision making: Policy Horizons Canada (Canada), the National Institution for Transforming India NITI Aayog (India), the National Institute of Science and Technology Policy (Japan) and the Centre for Strategic Futures (Singapore) are good examples. In Finland, a more diffuse model has emerged with several actors across ministries and the private sector contributing to foresight outputs such as the Government Report on the Future, which is published once during each electoral period (Prime Minister's Office of Finland[41]). Governments have not yet employed these units to inform future iterations of long-term low-emission development strategies as the first ones were communicated to the UNFCCC only in 2016, but such capacity presents an opportunity to enhance the planning process.

Incorporate uncertainty into decision making for resilience

Governments can include the management of climate risks in the specifications and procurement policy for publicly funded infrastructure using emerging decision-making strategies for infrastructure that incorporate uncertainty. While most of the global climate change trends are clear, at the local level some uncertainties represent a cost in themselves, as there is the risk of preparing for a future that fails to materialise. Preparing for the "wrong" future can even be more costly than doing nothing: a study of hydropower in the Zambezi basin found that doing nothing could lead to a loss of 18% of baseline revenues, but the wrong adaptation strategy could cost 30% of baseline revenues (Cervigni et al., 2015[42]).

Flexible, adaptive and proportionate approaches to infrastructure resilience can reduce the costs of building climate resilience given uncertainty about the future. Despite promising high-profile cases of innovative approaches in use (see Box 2.7), the use of formal techniques for decision making under uncertainty remains limited. Even within OECD countries, usage appears limited outside large infrastructure projects: for example, an analysis of 44 local adaptation plans in the United States found that three-quarters of those plans identified uncertainty as an issue, but none of them used formal techniques for decision making under uncertainty (Stults and Larsen, 2018[43]).

Box 2.7. **Foresight techniques in infrastructure planning**

- The **Colorado River Basin** provides water for 30 million people and is increasingly under pressure from growing demand and changing hydrology. Robust Decision Making was used to identify the main drivers of vulnerability and develop portfolios of options for managing supply and demand. The approach was dynamic, identifying the actions that needed to be taken in the near term and those that could be implemented depending on circumstances.
- The **Delta Programme** is responsible for protecting the Netherlands against flood risk and ensuring freshwater supplies. Annual investment is EUR 1 billion per year, split between new investments (60%) and operational expenditures (40%). An approach called "Adaptive Delta Management" has been adopted, which provides a long-term and flexible approach to managing water risks. The analytical tool "Dynamic Adaptive Policy Pathways" has been used to analyse the implications of different choices over time.
- The **Thames Estuary 2100** project was undertaken by the Environment Agency to ensure that London was protected against flooding throughout the 21st century. One of the main decisions was if, and when, to upgrade or replace the Thames Barrier, at a cost of GBP 1.6–5.3 billion. The strategy looked at a broad range of potential outcomes in 2100 and then worked backwards to see which sets of measures would be needed over time to manage those risks. This was combined with the identification and monitoring of decision-points to develop flexible approaches over time.

Sources: Groves, D. et al. (2013[44]), "Adapting to a Changing Colorado River", RAND Corporation; Haasnoot, M. et al. (2013[45]), "Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world", *Global Environmental Change*, 23/2; Ranger, N., T. Reeder and J. Lowe (2013[46]), "Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project", *EURO Journal on Decision Processes*, 1/3-4.

Notes

1. Its membership currently includes 27 countries (both advanced and developing economies), 15 cities, 17 subnational governments and 192 companies.
2. Launched at COP22 in Marrakesh, the NDC Partnership is a coalition of countries and institutions working to mobilise support and achieve ambitious climate goals while enhancing sustainable development: *https://ndcpartnership.org*
3. According to the 2016 (pg. 12) and 2017 (pg. 13) Joint Reports on MDB Climate Finance. MDBs use a common method for tracking adaptation finance, which identifies adaptation activities within broader development operations carried out in response to perceived or expected climate impacts.

References

2050 Pathways Platform (2017), *2050 Pathways: A Handbook*, *http://www.2050pathways.org/wp-content/uploads/2017/09/2050Pathways-Handbook-1.pdf*. [10]

2050 Pathways Platform (2017), *Why Develop 2050 Pathways?*, 2050 Pathways Platform, *https://www.2050pathways.org/wp-content/uploads/2017/09/Whydevelop2050Pathways.pdf* (accessed on 05 July 2018). [17]

Altieri, K. et al. (2015), *Pathways to Deep Decarbonization in South Africa*, SDSN - IDDRI, *http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_ZAF.pdf* (accessed on 05 July 2018). [13]

Cervigni, R. et al. (2015), *Enhancing the Climate Resilience of Africa's Infrastructure: The Power and Water Sectors*, World Bank, Washington, DC, *http://dx.doi.org/10.1596/978-1-4648-0466-3*. [42]

ClimateWorks Australia (2017), *Taking the long view: Why a long term approach for the developing world is critical to achieving sustainable development goals and climate safety*, ClimateWorks Australia, *https://climateworksaustralia.org/sites/default/files/documents/publications/cwa_long_view_issues_paper_0.pdf* (accessed on 19 July 2018). [18]

Dow (2017), *2017 Sustainability Report*, Dow Chemical Company, Midland, Michigan, *https://www.dow.com/en-us/science-and-sustainability/highlights-and-reporting* (accessed on 17 October 2018). [27]

EIA (2017), *Hurricane Irma cut power to nearly two-thirds of Florida's electricity customers*, US Energy Information Administration (EIA) Web Portal, *https://www.eia.gov/todayinenergy/detail.php?id=32992* (accessed on 25 October 2018). [22]

EU High-Level Expert Group on Sustainable Finance (2018), *Financing a Sustainable European Economy: Final Report*, European Commission, *https://ec.europa.eu/info/sites/info/files/180131-sustainable-finance-final-report_en.pdf* (accessed on 05 July 2018). [20]

FAO (2018), *The Future of Food and Agriculture: Alternative Pathways to 2050*, Food and Agriculture Organisation (FAO), Rome, *http://www.fao.org/3/I8429EN/i8429en.pdf* (accessed on 24 October 2018). [6]

Gambhir, A. et al. (2017), "Assessing the Feasibility of Global Long-Term Mitigation Scenarios", *Energies*, Vol. 10/1, p. 89, *http://dx.doi.org/10.3390/en10010089*. [36]

Griscom, B. et al. (2017), "Natural climate solutions", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 114/44, pp. 11645-11650, *http://dx.doi.org/10.1073/pnas.1710465114*. [31]

Groves, D. et al. (2013), *Adapting to a Changing Colorado River*, *https://www.rand.org/pubs/research_reports/RR242.html*. [44]

Haasnoot, M. et al. (2013), "Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world", *Global Environmental Change*, Vol. 23/2, pp. 485-498, *http://dx.doi.org/10.1016/J.GLOENVCHA.2012.12.006*. [45]

Hallegatte, S., J. Rentschler and B. Walsh (2018), *Building Back Better: Achieving Resilience through Stronger, Faster, and More Inclusive Post-Disaster Reconstruction*, World Bank Group, Washington, DC, *http://hdl.handle.net/10986/29867* (accessed on 27 July 2018). [23]

IEA (2018), *World Energy Investment 2018*, International Energy Agency, *https://www.iea.org/wei2018/*. [4]

IPCC (2018), *Global Warming of 1.5 degrees C*, Intergovernmental Panel on Climate Change, Geneva, *http://www.ipcc.ch/report/sr15/*. [1]

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, *http://www.cambridge.org* (accessed on 22 July 2018). [34]

IPCC (2007), *Climate Change 2007: Mitigation of Climate Change*, Cambridge University Press, *https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4_wg3_full_report.pdf* (accessed on 22 July 2018). [33]

IPCC (2001), *Climate Change 2001: The Scientific Basis*, Intergovernmental Panel on Climate Change, *https://www.ipcc.ch/ipccreports/tar/wg1/pdf/WGI_TAR_full_report.pdf* (accessed on 22 July 2018). [32]

ITF (2017), "Strategic Infrastructure Planning: International Best Practice", *International Transport Forum Policy Papers*, No. 29, OECD Publishing, Paris, *http://dx.doi.org/10.1787/4142787d-en*. [15]

Jones, H., D. Hole and E. Zavaleta (2012), "Harnessing nature to help people adapt to climate change", *Nature Climate Change*, Vol. 2/7, pp. 504-509, *http://dx.doi.org/10.1038/nclimate1463*. [25]

Liu, Q. et al. (2015), *Deep Decarbonization Pathways to in China*, *http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_CHN.pdf* (accessed on 11 October 2018). [11]

Nassiry, D., S. Nakhooda and S. Barnard (2016), *Finding the Pipeline: Project Preparation for Sustainable Infrastructure*, Overseas Development Institute (ODI) & New Climate Economy, *http://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/11/Finding-the-Pipeline.pdf*. [8]

OECD (2018), *Capital Budgeting and Infrastructure Survey 2018 (forthcoming)*, OECD Publishing, Paris. [14]

OECD (2018), *Developing Robust Project Pipelines for Low-Carbon Infrastructure (forthcoming)*, OECD Publishing, Paris. [16]

OECD (2018), *Rethinking Urban Sprawl: Moving Towards Sustainable Cities*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264189881-en*. [7]

OECD (2017), *Investing in Climate, Investing in Growth*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264273528-en*. [3]

OECD (2016), *Green Investment Banks: Scaling up Private Investment in Low-carbon, Climate-resilient Infrastructure*, Green Finance and Investment, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264245129-en*. [21]

Palacin, R. (2016), "Hyperloop, the Electrification of Mobility, and the Future of Rail Travel", *IEEE Electrification Magazine*, September 2016, Institute of Electrical and Electronics Engineers (IEEE), *https://doi.org/10.1109/MELE.2016.2584918*. [38]

Popper, R. (2008), "Foresight methodology", in Georghiou, L. (ed.), *The Handbook of Technology Foresight: Concepts and Practice*, Edward Elgar Publishing. [40]

Prime Minister's Office of Finland (n.d.), *Government report on the future*, *https://vnk.fi/en/government-report-on-the-future* (accessed on 04 September 2018). [41]

Ranger, N., T. Reeder and J. Lowe (2013), "Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project", *EURO Journal on Decision Processes*, Vol. 1/3-4, pp. 233-262, *http://dx.doi.org/10.1007/s40070-013-0014-5*. [46]

Riahi, K. et al. (2015), "Locked into Copenhagen pledges — Implications of short-term emission targets for the cost and feasibility of long-term climate goals", *Technological Forecasting and Social Change*, Vol. 90, pp. 8-23, *http://dx.doi.org/10.1016/J.TECHFORE.2013.09.016*. [37]

Rogelj, J. et al. (2013), "Probabilistic cost estimates for climate change mitigation", *Nature*, Vol. 493/7430, pp. 79-83, *http://dx.doi.org/10.1038/nature11787*. [35]

Rogelj, J. et al. (2018), "Scenarios towards limiting global mean temperature increase below 1.5 °C", *Nature Climate Change*, Vol. 8/4, pp. 325-332, *http://dx.doi.org/10.1038/s41558-018-0091-3*. [39]

Röttgers, D. and B. Anderson (2018), "Drivers and barriers to the decarbonisation of the electricity sector (forthcoming)", *OECD Environment Working Papers*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/19970900*. [9]

Shearer, C. et al. (2018), *Boom and Bust 2018: Tracking the Global Coal Plant Pipeline*, CoalSwarm, Sierra Club & Greenpeace, *https://endcoal.org/wp-content/uploads/2018/03/BoomAndBust_2018_r4.pdf* (accessed on 11 September 2018). [5]

Smith, P. et al. (2014), "Agriculture, Forestry and Other Land Use (AFOLU)", in Edenhofer, O. et al. (eds.), *Climate Change 2014: Mitigation of Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, *http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter11.pdf* (accessed on 27 July 2018). [30]

Stults, M. and L. Larsen (2018), "Tackling Uncertainty in US Local Climate Adaptation Planning", *Journal of Planning Education and Research*, pp. 1-16, *http://dx.doi.org/10.1177/0739456X18769134*. [43]

Talberth, J. et al. (2012), "Insights from the Field: Forests for Water", *Southern Forests for the Future Incentives Series*, No. 9, World Resources Institute, Washington, DC, *https://www.wri.org/publication/insights-field-forests-water*. [26]

The Nature Conservancy (2018), *Launch of the Coastal Zone Management Trust*, The Nature Conservancy, Quintana Roo, *https://thought-leadership-production.s3.amazonaws.com/2018/03/08/14/23/46/1ac3a4be-11d2-4651-9d98-50326d81e1b8/TNC_Mexico_CoastalManagementTrust_Factsheet.pdf* (accessed on 17 October 2018). [28]

UN Environment (2018), *Greening the Belt and Road Initiative (forthcoming)*, UN Environment. [19]

UNFCCC (n.d.), *Communication of long-term strategies*, *https://unfccc.int/process/the-paris-agreement/long-term-strategies* (accessed on 17 October 2018). [2]

Vallejo, L. and M. Mullan (2017), "Climate-resilient infrastructure: Getting the policies right", *OECD Environment Working Papers*, No. 121, OECD Publishing, Paris, *https://doi.org/10.1787/19970900*. [24]

Waisman, H. et al. (2015), *Pathways to Deep Decarbonization*, IDDRI, *https://www.iddri.org/sites/default/files/import/publications/ddpp_2015synthetisreport.pdf* (accessed on 03 July 2018). [12]

World Bank (2017), *Implementing nature-based flood protection Principles and implementation guidance*, World Bank, *https://openknowledge.worldbank.org/handle/10986/28837*. [29]