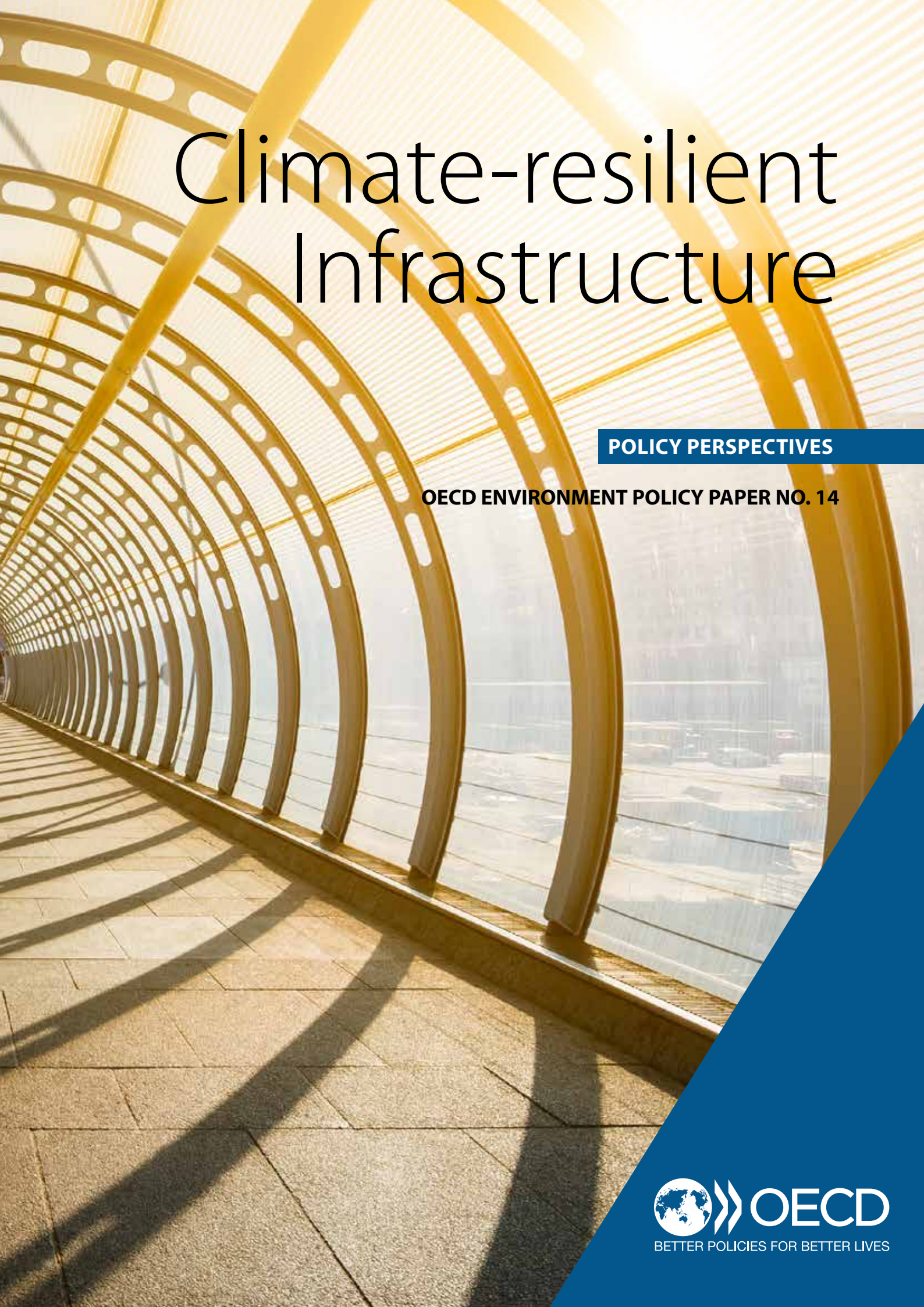
Climate-resilient Infrastructure

POLICY PERSPECTIVES

OECD ENVIRONMENT POLICY PAPER NO. 14



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BETTER POLICIES FOR BETTER LIVES

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ISSN 2309-7841
Authorised for publication by Rodolfo LACY, Director, OECD Environment Directorate



This Policy Paper was drafted by Michael Mullan, with substantive contributions from Lisa Danielson, Berenice Lasfargues, Naeeda Crishna Morgado and Edward Perry. The work was overseen by Simon Buckle (Head of Climate, Biodiversity and Water division) and Anthony Cox (Deputy Director, Environment). It is based on the OECD Environment Working Paper, "Climate-Resilient Infrastructure: Getting the Policies Right", by Lola Vallejo and Michael Mullan.

The document has benefitted from the feedback of: Liwayway Adkins, Charles Baubion, Rodney Boyd, Teresa Deubelli, Jane Ellis, Julianne Jansen, Xavier Leflaive and Leigh Wolfrom (OECD); Craig Davies (EBRD); Maya Hennerkes (IADB); Stéphane Hallegatte (World Bank).

Valuable guidance, information and advice were provided by the Argentine G20 Presidency: Soledad Aguilar, National Director of Climate Change (Argentina), Lucas Di Pietro Paolo, National Adaptation Coordinator (Argentina), Sofía del Castillo and Mariana Trinidad Corvaro (Argentine G20 CSWG team).

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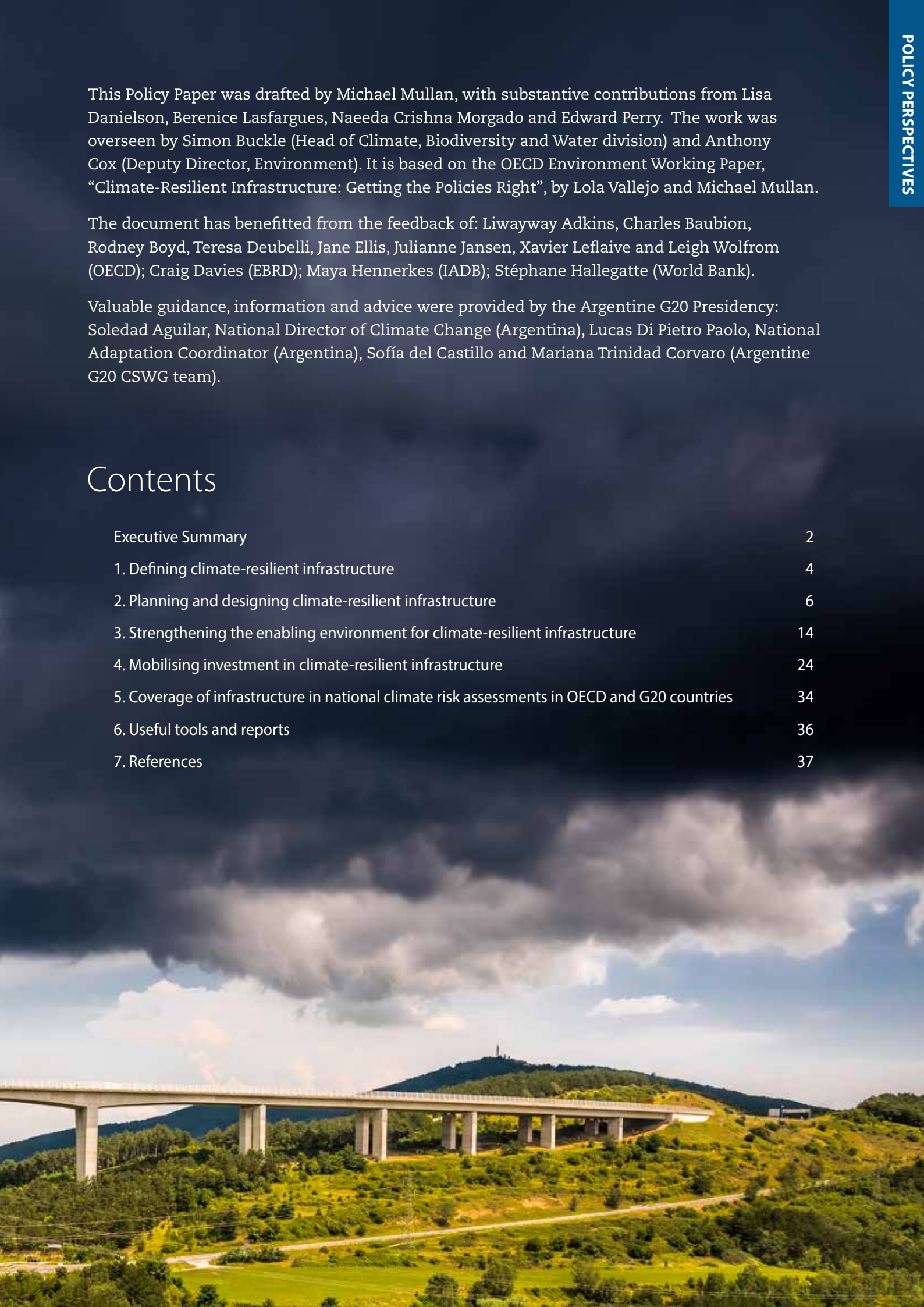
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Executive Summary

Infrastructure networks will be affected by the physical impacts of climate variability and change, but will also play an essential role in building resilience to those impacts. Extreme events illustrate the extent of this potential exposure. For example, OECD modelling of the potential impacts of a major flood in Paris found that 30% to 55% of the direct flood damages would be suffered by the infrastructure sector, while 35% to 85% of business losses were caused by disruption to the transportation and electricity supply and not by the flood itself. Ensuring that infrastructure is climate resilient will help to reduce direct losses and reduce the indirect costs of disruption.

New infrastructure assets should be prioritised, planned, designed, built and operated to account for the climate changes that may occur over their lifetimes. Existing infrastructure may need to be retrofitted, or managed differently, given climate change. Lastly, additional infrastructure, such as sea walls, will need to be constructed to address the physical impacts of climate change. This additional infrastructure can include traditional infrastructure, such as hard defences and other engineered solutions, as well as natural infrastructure, such as wetlands and other nature-based solutions.

A wide range of actors, both in the public and private sectors, are taking action to strengthen climate-resilience. This report highlights emerging good practices and remaining challenges across OECD and G20 countries. It provides non-prescriptive guidance to countries as they seek to enhance resilience in line with their national circumstances and priorities.

Designing climate-resilient infrastructure

- Climate-resilient infrastructure has the potential to improve the reliability of service provision, increase asset life and protect asset returns. Building climate resilience can involve a package of management measures (such as changing maintenance schedules and including adaptive management to account for uncertainty in the future) and structural measures (e.g. raising the height of bridges to account for sea-level rise or using natural infrastructure such as protecting or enhancing natural drainage systems).
- Flexible, adaptive approaches to infrastructure can be used to reduce the costs of building climate resilience given uncertainty about the future. Climate model projections are a significant source of uncertainty, particularly on a regional or local scale, but other factors (such as socioeconomic changes) are also relevant for climate resilience. Decisions about infrastructure should consider relevant uncertainties to ensure resilience across a range of potential future scenarios.

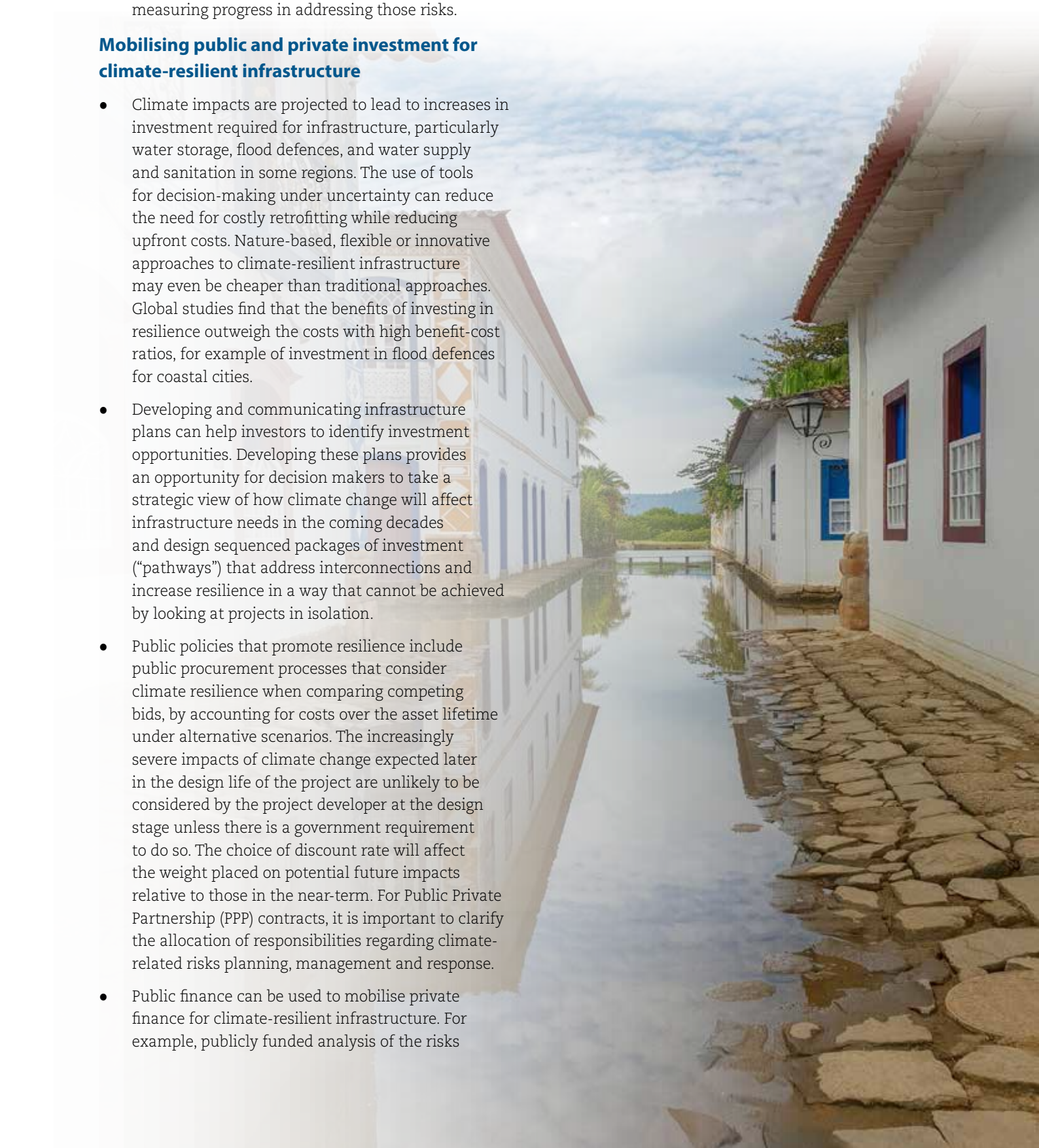
Strengthening the enabling environment for the development of climate-resilient infrastructure

- Decision makers need to have access to high quality information, consistent data and capacity to use this information to inform planning. Uncertainties should be clearly communicated and valued, and there should be access to the tools needed to support decision-making under uncertainty. The use of platforms and online tools can provide accessible, credible and transparent information on past and future climate behaviour. Access to information should be complemented with the development of technical and institutional capacity to manage climate-related risks.
- Tools for mainstreaming adaptation in critical policy areas and encouraging investments in resilient infrastructure include:
  - spatial planning frameworks to redirect development away from high-risk areas;
  - infrastructure project and policy appraisals, including Strategic Environmental Assessment and Environmental Impact Assessment; and
  - regulatory and economic standards (such as building codes).

- Climate risk disclosure can help raise awareness of and encourage efforts to reduce climate-related risks to infrastructure, but needs to be tailored to national circumstances. The risks from climate change are diverse, vary by national circumstances and there are multiple possible metrics for measuring progress in addressing those risks.

Mobilising public and private investment for climate-resilient infrastructure

- Climate impacts are projected to lead to increases in investment required for infrastructure, particularly water storage, flood defences, and water supply and sanitation in some regions. The use of tools for decision-making under uncertainty can reduce the need for costly retrofitting while reducing upfront costs. Nature-based, flexible or innovative approaches to climate-resilient infrastructure may even be cheaper than traditional approaches. Global studies find that the benefits of investing in resilience outweigh the costs with high benefit-cost ratios, for example of investment in flood defences for coastal cities.
- Developing and communicating infrastructure plans can help investors to identify investment opportunities. Developing these plans provides an opportunity for decision makers to take a strategic view of how climate change will affect infrastructure needs in the coming decades and design sequenced packages of investment ("pathways") that address interconnections and increase resilience in a way that cannot be achieved by looking at projects in isolation.
- Public policies that promote resilience include public procurement processes that consider climate resilience when comparing competing bids, by accounting for costs over the asset lifetime under alternative scenarios. The increasingly severe impacts of climate change expected later in the design life of the project are unlikely to be considered by the project developer at the design stage unless there is a government requirement to do so. The choice of discount rate will affect the weight placed on potential future impacts relative to those in the near-term. For Public Private Partnership (PPP) contracts, it is important to clarify the allocation of responsibilities regarding climate-related risks planning, management and response.
- Public finance can be used to mobilise private finance for climate-resilient infrastructure. For example, publicly funded analysis of the risks faced by the port of Cartegena, Colombia motivated investment to manage climate risks. Support for project preparation can help to address capacity constraints relating to climate resilience. Blended finance can be used to improve the risk-return profile of investments where appropriate.





1 Defining climate-resilient infrastructure

The defining characteristic of climate-resilient infrastructure is that it is planned, designed, built and operated in a way that anticipates, prepares for, and adapts to changing climate conditions. It can also withstand, respond to, and recover rapidly from disruptions caused by these climate conditions. Ensuring climate resilience is a continual process throughout the life of the asset. Efforts to achieve climate resilience can be mutually reinforcing with efforts to increase resilience to natural hazards.

Climate-resilient infrastructure reduces, but may not fully eliminate, the risk of climate-related disruptions. The extent to which climate change translates into risks for infrastructure depends upon the interaction of changing climate hazards with exposure (the location of assets) and vulnerability ("the propensity or predisposition to be adversely affected") (Agard & Schipper, 2014). Climate risks to infrastructure can be reduced by locating assets in areas that are less exposed to climate hazards (e.g. avoiding new construction in flood plains), and by making the assets better able to cope with climate impacts when they materialise. The development of infrastructure should also consider the impacts on risk elsewhere: for example, the potential contribution to flood risk resulting from increases in paved surfaces.

Risk management requires making trade-offs between risk minimization and cost, where it becomes more expensive and increasingly technically challenging to prepare for events that are very unlikely to occur. Resilience means that the risks have been considered and managed to achieve an acceptable level of performance given the available information, and that capacities to withstand and recover from shocks are in place (OECD, 2014a). The costs of protection need to be weighed against the consequences of damage or disruption. In the case of protective infrastructure (such as flood defences) this will be the assets protected by the defences. For other infrastructure, it will be the costs resulting from damage or disruption to the asset (e.g. business interruption from loss of electricity supply).

The climate resilience of individual infrastructure assets should be viewed in the context of the system as a whole. Considering climate impacts for individual assets, such as a bridge or a railway line, is necessary but not sufficient to ensure that the system functions reliably despite a changing climate. For this reason, efforts to ensure resilience at the project level should be embedded within a strategic approach to infrastructure network planning that accounts for the direct and indirect effects of climate change and climate variability.

This definition of climate resilience focuses on the process used and outcomes achieved to assess whether climate change impacts have been considered and, if necessary, managed. Given the context-specific nature of climate adaptation, the measures used to achieve this will vary widely. In some cases, no structural changes will be needed to achieve this: the climate-resilient fibre optic cable may be identical to the one that would have otherwise been installed. However, where changes are required, they can be grouped into two categories (EUFIWACC, 2016):

- Structural adaptation measures: e.g., changing the composition of road surfaces so that they do not deform in high temperatures, building seawalls or using permeable paving surfaces to reduce run-off during heavy rainfalls. Ecosystem-based approaches using natural infrastructure to design adaptation measures are also key alternatives to be considered alongside structural adaptation measures.
- Management (or non-structural) adaptation measures: e.g., changing the timing of maintenance to account for changing patterns of energy demand and supply, investment in early warning systems or purchasing insurance to address financial consequences of climate variability. These measures can also include enhanced monitoring of existing assets to reduce the risk of failure as climate conditions change. Adaptive management approaches also include provisions to include flexibility from the outset to monitor and adjust to changing circumstances over the assets lifetime.





2 Planning and designing climate-resilient infrastructure

This report examines how core infrastructure sectors can be made resilient to climate change. It focuses on the following sectors: transportation, energy, telecommunications and water. Many of these recommendations are relevant for both rural and urban areas, as well as for other types of infrastructure sectors, such as health or education.

This section outlines the challenges and opportunities from making infrastructure resilient to climate change. Measures to overcome those challenges are discussed in section 3 (strengthening the enabling environment) and section 4 (mobilising investment).

Key messages

- Infrastructure can have an essential role in strategies to manage the risks and minimise the negative impacts of climate change. The physical impacts of climate change – such as increasing temperatures, shifting patterns of precipitation, increased intensity or recurrence of extreme weather events and rising sea levels - will affect all types of infrastructure. Infrastructure should be designed, built and operated in a way that anticipates, prepares for, and adapts to these changing climate conditions. As countries communicate their long-term low greenhouse gas emissions development strategies and implement their emission reduction goals, greater clarity about future emissions trajectories and potential adaptation needs is likely to be achieved.
- Ensuring that infrastructure is resilient to climate change can support the achievement of the Paris Agreement, including through increasing the ability to adapt to climate change and ensuring that financial flows are consistent with low-emissions and climate-resilient development. Climate-resilient infrastructure can also support the efforts to achieve a number of the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction.
- Climate-resilient infrastructure has the potential to improve the reliability of service provision, increase asset life and protect asset returns. Building climate resilience can involve a package of management measures (such as changing maintenance schedules and including adaptive management to account for uncertainty in the future) and structural measures (e.g. raising the height of bridges to account for sea-level rise).
- Ecosystem-based approaches, including natural infrastructure, can provide an effective complement or substitute for traditional built (or "grey") infrastructure. For example, watershed restoration can protect sources of drinking water and reduce the need for subsequent treatment. These approaches can be cheaper than relying solely upon "grey" infrastructure, as well as yielding co-benefits.
- Flexible, adaptive approaches to infrastructure can be used to reduce the costs of building climate resilience given uncertainty about the future. Climate model projections may be a significant source of uncertainty, but other factors (such as socioeconomic changes) are also salient achieving climate resilience. Decisions about infrastructure should consider relevant uncertainties to ensure resilience across a range of potential future scenarios.

The role of resilient infrastructure in a changing climate

The Paris Agreement has the goal of holding temperature increases "well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels". Analysis of existing NDCs suggest that collective ambition needs to be increased if that goal is to be met (Vandyck, Keramidas,

Saveyn, Kitous, & Vrontisi, 2016). Limiting temperature increases to well below 2°C would reduce the risk of encountering "severe, pervasive and irreversible" changes, but people and ecosystems would still have to adapt to potentially serious negative impacts (IPCC, 2014).

Infrastructure should be consistent with low-GHG transitions, but also resilient to the impacts of changing climate. The long-lived nature of infrastructure assets means that decisions made now will lock-in vulnerability if they fail to consider these impacts. The scale of investment decisions being made is significant: (OECD, 2017b) estimated that USD 6.3 trillion per year will need to be invested in infrastructure globally between 2016 and 2030 to keep pace with development. This estimate does not include expenditure driven by adaptation or mitigation. The majority of investment needs will arise from the expansion of urban areas within low- and middle-income countries. The location, design and management of those assets all need to be considered to ensure they are adapted to climate variability and change.

The challenges of building climate-resilient infrastructure vary by country. The primary challenge in developing countries and emerging economies is to build new infrastructure for the expansion of urban areas and the development of new cities, to provide access to energy and safe drinking water for all, and to connect people through transport links and telecoms. Countries also have the challenge of building infrastructure to manage the risk of natural disasters. Industrialised countries predominantly face the challenge of replacing and upgrading existing infrastructure and networks, particularly as technological advances and policy decisions provide opportunities to increase efficiency and reduce emissions.

Extreme weather events vividly illustrate how the provision of infrastructure services could be vulnerable to the effects of climate change. For example, the 2011 flooding in eastern China caused major damage to 28 rail links, 21,961 roads, and 49 airports, as well as cutting power to millions of households (Xi, 2016). In 2015, the water level in São Paulo's main reservoir fell to 4% of capacity, leading to rationing of drinking water and social unrest (Vigna, 2015). In Europe, climate change is projected to increase damage to infrastructure from extreme weather events ten-fold by the end of the century, in the absence of adaptation (Forzieri, et al., 2018). In addition to extremes, trend changes will also have significant impacts for infrastructure. Under a dry climate scenario, the value of hydropower generation in Africa could be reduced by USD 83 billion leading to higher costs for consumers (Cervigni R. , Liden, Neumann, & Strzepek, 2016).

Ensuring that infrastructure is resilient to climate change can support the achievement of the goals of the Paris Agreement, including through increasing the ability to adapt to climate change. Climate-resilient infrastructure can also support efforts to achieve a number of the *Sustainable Development Goals* and the implementation of the *Sendai Framework for Disaster Risk Reduction*. The importance of resilience is also emphasised by relevant OECD guidance in this area, including the *OECD Recommendation on the Governance of Critical Risks* (OECD, 2014b), and the OECD *Framework on the Governance of Infrastructure* (OECD, 2017a).

BOX 1 GENDER AND CLIMATE-RESILIENT INFRASTRUCTURE

There is an important gender dimension to climate-resilient infrastructure. Vulnerability to climate change is influenced by a range of socio-economic factors including gender, poverty and social status. Men and women may have differing needs for infrastructure services: for example, access to piped water can support female empowerment in societies where women are typically responsible for collecting water. Women and men will also be affected differently by the impacts of climate change, including disruption to infrastructure.

Ensuring that infrastructure is resilient to climate change is a means to achieving more resilient societies, rather than an end in itself. As such, the process of ensuring that infrastructure is resilient to climate change should account for gender issues. To achieve this, it will be important to ensure women's meaningful participation in decision-making, and that their needs and perspectives are systematically taken into account.

Source: (OECD, 2016; World Bank, 2010b).

Impacts of climate change on infrastructure

Climate change will affect infrastructure provision and operation, with the severity of these effects depending on the overall emissions pathway and decisions resulting in increased exposure of assets and mal-adaptation. Projections from the IPCC find that the following impacts are likely to occur by year 2100 under the low emissions (RCP2.6) and high emissions (RCP8.5) pathways (Pachauri, et al., 2014). The figures in Table 1 are relative to the averages between 1986 and 2005. Overall, there is more confidence in temperature projections than those for precipitation or sea-level rise (Shepherd, 2014). Modelling of future socio-economic scenarios suggests future emissions are unlikely to reach the levels implied by RCP8.5 (Riahi, et al., 2017).

These global averages are illustrative of the scale and types of climate change that could be expected, but the impacts on a particular asset, such as a road or reservoir, will be uncertain and context specific. There will be varied and sometimes severe impacts at the local scale, as global trends interact with diverse local weather conditions. In addition, risks can arise from the interactions between different climate variables, or cascade through infrastructure networks. Since the publication of the IPCC's Fifth Assessment Report, for example, further research has suggested that sea-level rise could exceed 2 metres on average by the end of the century (Oppenheimer and Alley, 2016).

Climate model projections are subject to deep uncertainty, and it is not possible to definitively estimate the probability of different climate outcomes occurring at geographic scales relevant for infrastructure. Climate models provide valuable insights about how the climate will respond to rising concentrations of greenhouse gases in the atmosphere at a global level. However, some key aspects of the climate system that affect regional and local projections are not yet sufficiently well understood and modelled (Bony et al., 2015). The most suitable projections will depend upon the purpose for which they are being used. Developments in observations, understanding and modelling capabilities in coming years will improve the quality of projections at the local level, but will not eliminate these uncertainties.

The scale of climate hazards is just one of the set of relevant uncertainties in understanding the risks posed by climate change. For example, the impacts of changes in precipitation on requirements for water storage will also depend upon trends in consumption, which will be affected by economic development, population changes and technological changes. These other factors alter the levels of risks and thus can have a more significant impact on resilient infrastructure planning, design and economics than climate hazards themselves.

Recognising this complexity, the following categories capture the main ways in which the impacts of climate change can affect the demand and supply of infrastructure services. In some cases, there may also be simultaneous impacts on supply and demand as a result of climate impact. For example, heat waves can increase electricity demand for air conditioning, but also limit generation from thermal power plans:

- Demand for infrastructure services, for example:
  - Changing patterns of demand driven by climate change, such as increased energy

Table 1 **Projections of climate change impacts**

Averages in 2081-2100 relative to 1986-2005

	RCP 2.6	RCP 8.5
Temperature	0.3 - 1.7 C	2.6 - 4.8deg C
Sea levels	0.26 - 0.55 m	0.45 - 0.82 m
Precipitation	Increase in average precipitation in high latitudes, decrease in subtropical and mid-latitude dry regions	
Ice cover	Arctic sea ice cover will be reduced, as will the extent of permafrost in high northern latitudes	
Extreme weather events	Risks associated with some types of extreme weather events, including heatwaves and heavy precipitation, are projected to increase with climate change	

Source: (Pachauri, et al., 2014) (IPCC, 2018).

demand for air-conditioning in summer and reduced demand for heating in winter, or increased water demand for irrigation;

  - increased demand for protective infrastructure, such as the construction of coastal defences to address rising sea levels;
  - migration as a result of extreme weather events or gradual climate change.

- Provision of infrastructure services, for example:
  - increased cost of supply, as climate change may increase the costs of providing the same level of service (e.g. larger reservoirs needed to address more variable precipitation);
  - risk of "stranded assets", when investments are no longer economically viable as a result of the physical impacts of climate change, or the impact of climate change policies;
  - damage to assets and disruption to service provision, including cascading effects in other infrastructure sectors as a result of interdependencies;
  - additional investments required to manage increased risk of environmental damage, injuries and deaths due to failure of infrastructure assets;
  - reputational damage to the government, owner or operator of the asset resulting from the above factors.

These impacts will be particularly important for cities, as they rely upon extensive infrastructure networks for access to water, energy and food.

Some examples of potential direct impacts by sector can be found in Table 2. In addition to these, climate change may also have indirect impacts on infrastructure. These indirect impacts could include those resulting from the loss of ecosystem services as a result of wildfires, increased tree mortality and the spread of some invasive species.

Benefits and opportunities from climate-resilient infrastructure

Climate-resilient infrastructure can yield a range of benefits relative to business-as-usual, depending on the measures that have been implemented. These include:

- Increased reliability of service provision - reliable infrastructure has benefits ex-post, by reducing the frequency and severity of disruption. It also has benefits ex-ante, as it reduces the need for users to invest in backup measures (e.g. generators for businesses).
- Increased asset life, reduced repair and maintenance costs - preparing for climate change at the outset can avoid the need for costly retrofitting and reduce the risk of the asset becoming prematurely obsolete.
- Increased efficiency of service provision - in some cases, considering the impacts of climate change can reduce the unit costs of providing a service relative to business-as-usual approaches, for example through better management of hydropower resources.
- Co-benefits - some approaches to climate-resilient infrastructure, particularly the use of natural infrastructure, can deliver an equivalent service to traditional approaches while also generating co-benefits such as amenity value, biodiversity conservation, and climate change mitigation.

The scale of benefits is context specific, but analysis by Hallegatte et al. (2013), for example, estimated that spending USD 50 billion per year (annualised) on flood defences for coastal cities would reduce expected losses in 2050 from USD 1 trillion to USD 60-63 billion. Projects will not necessarily yield all of these benefits, and there will often be trade-offs to be made between climate resilience and other policy objectives.

Many of the techniques for increasing the reliability of service provision may also increase costs: for example, adding redundancy, or designing assets to account for a wider range of potential climates (ITF, 2016; OECD, forthcoming). As well as the possibility of higher costs, there may be other trade-offs to make. For example, installing hard coastal defences have the potential to disrupt ecosystems, or increase the rate of erosion of other properties. The ADB report, *Economic Analysis of Climate-Proofing Investment Projects*, provides guidance on methodologies that can be used to assess such trade-offs.

Given uncertainty about the future, adaptive management approaches can facilitate climate resilience throughout the life of infrastructure assets. Hydroelectric dams, for example, can have a design life of 70-100 years. Over those time horizons, there is very wide variation in the potential climate outcomes: in some regions, there is uncertainty about whether precipitation will increase or diminish. It could be

prohibitively expensive to prepare for all of these outcomes at the outset. Instead, adaptive management (or iterative risk management) approaches can be used to design in flexibility from the outset, monitor and adjust to changing circumstances over the asset's lifetime. More information on tools for decision-making under uncertainty can be found in section 3.

Table 2 **Illustrative impacts of climate changes in different sectors**

	Temperature changes	Sea-level rise	Changing patterns of precipitation	Changing patterns of storms
Transport	– Melting road surfaces and buckling railway lines – Damage to roads due to melting of seasonal ground frost or permafrost – Changing demand for ports as sea routes open due to melting of arctic ice	– Inundation of coastal infrastructure, such as ports, roads or railways	– Disruption of transport due to flooding – Changing water levels disrupt transport on inland waterways	– Damage to assets, such as bridges – Disruption to ports and airports
Energy	– Reduced efficiency of solar panels – Reduced output from thermal plants due to limits on cooling water temperatures – Increased demand for cooling	– Inundation of coastal infrastructure, such as generation, transmission and distribution	– Reduced output from hydropower generation – Disruption of energy supply due to flooding – Insufficient cooling water	– Damage to assets - e.g. wind farms, distribution networks – Economic losses due to power outages
Telecoms	– Increased cooling required for datacenters	– Inundation of coastal infrastructure, such as telephone exchanges	– Flooding of infrastructure – Damage to infrastructure from subsidence	– Damage to above ground transmission infrastructure, such as radio masts
Urban development	– Increased cooling demand – Reduced heating demand	– Inundation and increased flood risk – Changes in land use due to relocation of people living in exposed areas	– Risk of drought – Flooding	– Damage to buildings – Deaths and injuries
Water	– Increased need for treatment – Increased evaporation from reservoirs	– Inundation of coastal infrastructure – Salinisation of water supplies – Decreased standard of protection offered by coastal defences	– Increased need for water storage capacity – Increased risk of river embankments being overtopped	– Damage to assets – Decreased standard of protection offered by flood defences

Note: This table provides an illustration of the impacts that could occur in some sectors and in some regions. The impacts faced by a given infrastructure asset will depend on a range of factors, including location: for example, storms are projected to increase in some regions and decrease in others. A more comprehensive analysis can be found in the IPCC's Fifth Assessment Report.

Challenges in making infrastructure resilient to climate change

A range of barriers can prevent new and existing infrastructure from being built and operated in a climate-resilient manner:

- Time horizons - some benefits of increased climate resilience will occur beyond the time horizons considered by decision makers, while costs are incurred in the shorter term.
- Uncertainty about the future – there are inherent uncertainties in modelling how the climate, and other factors affecting infrastructure resilience, will evolve in the future. This means that climate-resilient infrastructure needs to be prepared for a range of possible future scenarios.
- Information and capacity - awareness and information on the risks from climate change, such as climate projections, may not be readily available, or in a useable format, to inform investment decisions. Information may not be available with sufficient geographic resolution for infrastructure planning. Climate change is complex and additional capacity may be needed to support decision-making under uncertainty.
- Policy misalignments - regulatory decisions and policy frameworks (such as those governing procurement) can inadvertently distort incentives, and discourage the use of innovative and ecosystem-based solutions.
- Externalities - potential benefits, such as the amenity value of nature-based infrastructure, may not result in revenue for the infrastructure operator.

A coordinated policy response is required to address these barriers, involving collaboration between the public sector, infrastructure owners and operators, professional associations and investors. Measures to do so are discussed in section 3.

Experiences in strengthening and building resilient infrastructure

An overview of possible adaptation measures for the energy sector can be found in Table 3. Examples from other sectors can be found in Box 2 and the following report: Emerging trends in mainstreaming climate resilience in large scale, multi-sector infrastructure PPPs (World Bank, 2016).



Table 3 **Examples of adaptation measures for energy infrastructure**

	Climate impacts on infrastructure	Management measure	Structural Measure
Generation	– Inundation of coastal infrastructure, such as generation plants – Reduced efficiency of solar energy – Insufficient cooling water – Temperature of cooling water before and after use – Reduced output from hydropower generation	– Model climate impacts on existing and planned assets in collaboration with meteorological service – Revise maintenance schedules – Update hydropower operating rules	– Fortify coastal, off-shore and flood-prone infrastructure against flooding – Increase cooling system capacity for solar energy – Locate new facilities outside high-risk zones
Transmission and distribution	– Flooding of electricity substations – Damage to transmission lines from climate extremes	– Implement program for pruning and managing trees near transmission and distribution lines – Create disaster mitigation plans – Train emergency response teams for quick repair and restoration actions	– Adjust design criteria for transmission lines, e.g: – Increase transmission tower height – Bury distribution lines – Use stainless steel material to reduce corrosion from water damage
Consumption	– Change in energy demand patterns (e.g. increased demand for cooling and reduced demand for energy for heating)	– Undertake load forecasting using climate information – Promote behavioural change measures to reduce peak consumption	– Improve building and industrial energy efficiency

Source: (IEA, 2015; World Bank, 2016).



BOX 2 SELECTED INFRASTRUCTURE PROJECTS INTEGRATING CLIMATE-RESILIENCE IN OECD AND G20 COUNTRIES

Eyre Peninsula (Australia): a strategy was developed to address climate impacts, including increasingly frequent inundation of coastal infrastructure. A plan was developed using participatory techniques for decision-making under uncertainty to produce sequenced pathways combining management and structural measures to adapt to increasing risks.

Japanese Railways (JR) (Japan): Extreme heat can cause railroad tracks to buckle, as heat causes steel to expand putting stress on ties, ballasts, and rail anchors that keep the tracks fixed to the ground. To achieve "zero accidents" due to track buckling, JR has raised the standard for estimated maximum performance temperature of its railroads from 60°C to 65°C to guide future investments. JR has also developed maintenance vehicles that detect potential joint openings.

Sponge City (Hong Kong, China): Prone to tropical cyclones and with an average annual rainfall of 2400mm, Hong Kong is one of the world's wettest cities. Considering future climate impacts, the Drainage Services Department (DSD) of Hong Kong, China is implementing a nature-based drainage system with the aim of building up flood resilience and improving public spaces, instead of constructing flood resistance infrastructure. A future project is a flood retention lake that will become an open green space for public use on dry days, and operate as a flood retention site during the wet season (Leung, 2017).

Hurricane Sandy Rebuilding Strategy (USA): In August 2013, the Hurricane Sandy Rebuilding Task Force issued the "Hurricane Sandy Rebuilding Strategy" to support the rebuilding of the region affected by the 2012 hurricane. The report contains policy recommendation on ensuring a regionally coordinated and resilient approach to infrastructure investment. It aimed to build back smarter and stronger infrastructure by: aligning federal funding with local rebuilding visions; reducing excessive regulation; coordinating the efforts of the federal, state, and local governments, with a region-wide approach to rebuilding; and ensuring the region's climate change and disaster resilient rebuilding (OECD, 2014a).





3 Strengthening the enabling environment for climate-resilient infrastructure

This section identifies priority areas for ensuring that decision makers have the information, capacity and incentive to integrate climate-resilience into infrastructure development and operation. Efforts to strengthen the enabling environment will facilitate the mobilisation of finance for climate-resilient investments (section 4).

Key messages

- Decision makers need to have access to high quality information, consistent data and capacity to adapt planning to account for climate change. This can be achieved through the development of platforms and online tools to provide accessible, credible and transparent information on past and future climate behaviour. Relevant uncertainties should be clearly communicated, and guidance provided on how to incorporate these into decision-making. Access to information should be complemented with the development of technical and institutional capacity to manage climate-related risks.
- Tools for mainstreaming adaptation and encouraging investments in resilient infrastructure include:
  - spatial planning frameworks, including vulnerability maps, to improve management of climate risks, reduce vulnerability and prevent the construction of new infrastructure in exposed areas;
  - infrastructure projects and policy appraisals, including Strategic Environmental Assessment and Environmental Impact Assessment; and
  - regulatory and economic standards (such as building codes).
- Climate risk disclosure can help raise awareness of and encourage efforts to reduce climate-related risks to infrastructure, but needs to be tailored to national circumstances. The risks from climate change are diverse, vary by national and subnational circumstances and there are multiple possible metrics for measuring progress in addressing those risks.

Improving understanding of climate change-related risks and supporting decision making under uncertainty

Information on climate hazards, exposure and vulnerabilities are required to inform the development of climate-resilient infrastructure. Traditionally, historical data have been used to inform analysis of the potential likelihood and severity of impacts. In addressing climate change, these historical records need to be complemented with projections of how those trends might change in the future.

Historical or observed climate information provides a baseline for understanding how risks may evolve in the future due to climate change. The sophistication of historical datasets is increasing. For example, global climate records between 1901-2016 at a spatial resolution of 0.5° (approximately 55 km) are freely available via the UEA Climatic Research Unit's "CRU TS" dataset (Harris et al., 2014). However, there are major gaps in the recording of how those climate trends have translated into potential hazards, such as floods or droughts. In particular, data on smaller events are not collected or digitised (OECD, 2018a). Efforts to recover such historic data, using data sources such as newspapers and public consultation, can facilitate efforts to ensure that future infrastructure is climate-resilient.

Climate projections are needed to understand how future changes in climate may create risks for infrastructure. Most OECD and G20 countries have produced their own national-level climate projections or downscaled global climate projections to inform decision-making at national and local levels. While fine resolution projections can be more informative for infrastructure planning, they depend upon the quality of the larger-scale model in which they

are embedded. Some relevant uncertainties can be explored by providing different scenarios or providing probabilistic outputs. Even with these approaches, however, long-term, high resolution model results are inherently uncertain (Frigg, Smith and Stainforth, 2015). These uncertainties should be clearly communicated to users of those projections.

Historic climate data and climate change projections can be integrated with other data sources, such as hydrological modelling and information on the location and characteristics of infrastructure assets, to assess climate risk. Authoritative national and sectoral climate risk assessments can inform strategic plans and policies for climate-resilient infrastructure development. They can also provide data and a framework for the more detailed assessments necessary for specific infrastructure assets and development projects. Most OECD and G20 countries have conducted climate risk assessments at national and/or sectoral levels in which infrastructure is covered (see section 5). While these have tended to be qualitative in nature, they could be further developed or complemented by a quantitative analysis of risk and economic costs.

Infrastructure systems are interdependent, which means that climate change impacts on one infrastructure asset can cascade through the system. These interdependencies are particularly high in urban areas due to the dense spatial concentration of assets, and may even extend beyond territorial boundaries. The floods in Bangkok in 2011, for instance, significantly affected the car industry in Japan, as suppliers were located in the flood areas. This illustrates the need to map interdependencies across critical infrastructure and to adopt a multi-sector, multi-hazard approach to climate risk assessments (OECD, 2014a); (Fisher and Gamper, 2017).

Box 3 provides an example of such multisector assessment for the risk of flood from the Seine river in Paris. Effective collaboration and information sharing among key infrastructure organisations is critical for understanding and addressing these shared risks. A number of regional (e.g. EU's Critical Infrastructure Warning Information Network), national (e.g. US Partnership Energy Sector Climate Resilience) and local (e.g. Toronto's WeatherWise Partnership) initiatives have been established to facilitate this (AECOM, 2017).

The scale, complexity, and uncertainties affecting analysis of climate change risks necessitates the engagement of a broad range of stakeholders in climate risk assessments and adaptation planning. These include different levels and parts of government, academics, non-governmental organisations, local and indigenous communities and the private sector. Inclusiveness is important given that vulnerability to climate change varies by factors such as social class and gender.

Well-designed participatory approaches can improve decision-making and build support for implementing climate-resilient approaches. Experience to date highlights the important role of local and indigenous knowledge in identifying vulnerabilities and impacts that may not be well known because of the highly localised and contextual nature of climate risk (Burton et al., 2012). Community-based adaptation can facilitate local-level participation

BOX 3 MODELLING THE MACRO-ECONOMIC IMPACTS OF A MAJOR FLOOD IN PARIS

In France, the OECD calculated the economic impact of a major flood of the Seine river affecting the Paris metropolitan area. For this purpose, a hybrid approach was developed, combining modelling of direct losses, assessment of the impacts connected with the interruption of critical networks and macroeconomic modelling. Three scenarios were built around the historic centennial flood of 1910, and direct damages were estimated between USD 3 and 30 billion, with 10 000 to 400 000 job losses and an impact on the national GDP between 0.1% and 3% cumulated over a 5 year period.

This analysis demonstrated the critical importance of the infrastructure sector:

- 30% to 55% of the direct flood damages were suffered by the infrastructure sector
- 35% to 85% of the business losses were caused by the interruption of transportation and electricity supply and not by the flood itself.

Source: OECD (2014c).

in local and national adaptation planning (Reid and Huq, 2014). Examples of stakeholder engagement in risk assessments and adaptation planning can be found in Box 4.

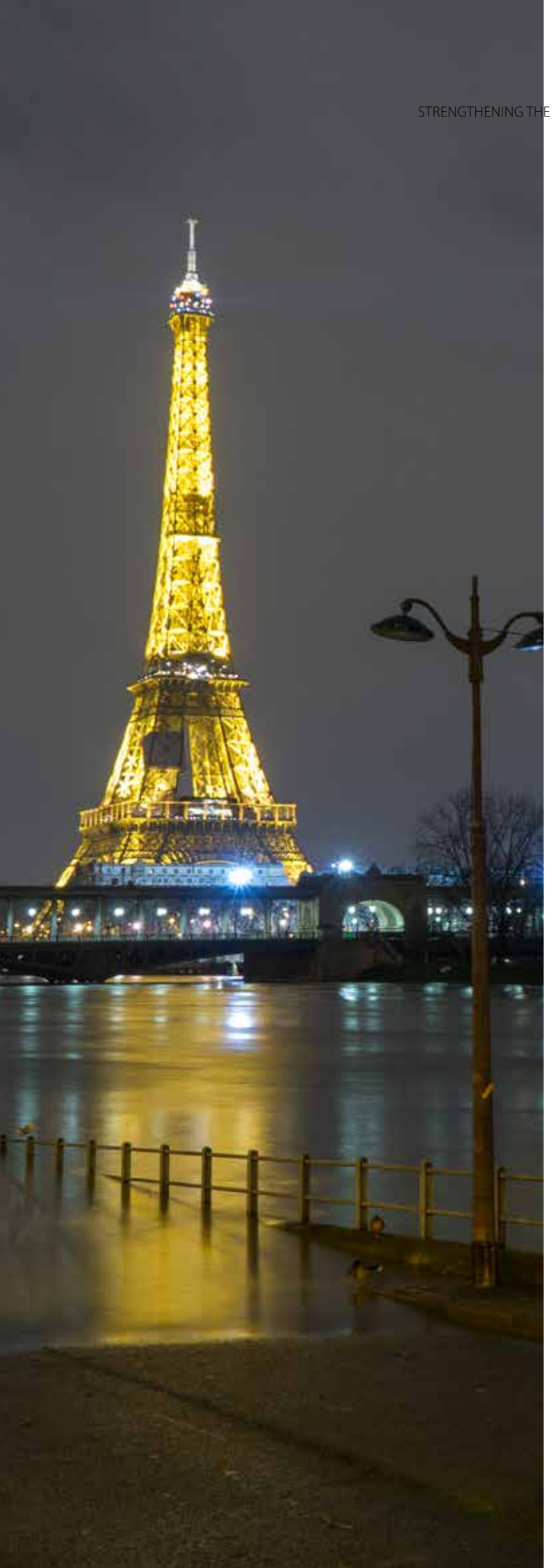
Tools and capacity are needed to make raw climate data useful for decision makers, including national policy-makers, regulators, private sector and local governments. The growing demand for easy-to-use climate information and risk management services has created new business opportunities. Online platforms and data portals are being developed by both public and private sector entities to improve user access to multiple data sets and to deliver customised risk assessments (see Box 5). For these platforms to work effectively, it is important that there is transparency about the underlying data and their limitations.

Technical guidance is being developed to help decision-makers to incorporate climate risk into infrastructure. National standard organisations in Australia, Britain and the US have released risk management guidelines that focus on resilience for buildings and infrastructure. The roads authority in Western Australian has developed Climate Change Risk Assessment guidelines to identify climate change risks relevant to construction of roads and bridges. The United States Federal Highway Agency has developed a tool to support transportation agencies in selecting appropriate materials for road surfaces.

One of the major challenges is to help users make informed decisions given uncertainty about the future climate and socio-economic changes. Given the long lifetimes of infrastructure, it is important to take early action to integrate adaptation into decision making, but also to ensure flexibility or robustness to address future uncertainty. Tools such as Robust Decision Making and Real Options Analysis, portfolio analysis and iterative risk management are being used to support decision-making under uncertainty (OECD, 2015a]). Robust Decision Making, for instance, has been applied to water management in the Colorado River (Groves et al., 2013) and coastal resilience planning in Louisiana (Groves and Sharon, 2013).

Simplified techniques for decision-making under uncertainty can provide valuable insights where the use of more sophisticated approaches would be disproportionate or unfeasible (Shortridge, Guikema and Zaitchik, 2017). Hallegatte (2009) proposes a set of practical strategies to inform adaptation decisions, such as pursuing "no-regrets" options and building in extra safety margins where it is cheap to do so. Stress testing can be used to identify how infrastructure will perform under a wide range of potential future climates.





BOX 4 STAKEHOLDER ENGAGEMENT FOR CLIMATE-RESILIENT INFRASTRUCTURE

Northwest Territories, Canada: Canada's northern infrastructure is heavily affected by permafrost degradation. In the Northwest Territories alone, estimates suggest it could cost as much as CAD 230 million to adapt existing infrastructure to a changing climate. The Standards Council of Canada (SCC) has developed a Northern Advisory Committee, composed of community members and experts across the North, to ensure local knowledge is incorporated into new standards. To date the SCC has released 5 standards that address the unique climate change impacts felt in the north that impact infrastructure design, construction and maintenance (SCC, 2018).

Indore, India: since 2010, the city of Indore undertook a comprehensive process of assessing exposure to climate risks to develop a resilience strategy. This included an extensive process of awareness raising and engagement with communities living in informal settlements, who are particularly vulnerable to climate risks, to identify and manage these risks. This was used to inform the development of the *Indore City Resilience Strategy*. External funders worked with community institutions to support the implementation of adaptation measures, many of which focussed on the supply of safe drinking water (Chu, 2016).

Semarang, Indonesia: In Indonesia, a number of cities are promoting multi-stakeholder approaches to adaptation planning. In the city of Semarang, a body called the Initiative for Urban Climate Change and Environment (IUCCE) was established to bring together civil society and NGOs, academics, and practitioners, as well as local and national government actors to coordinate local adaptation processes and gather evidence. The Best Practice Transfer Program is supporting replication of this multi-stakeholder approach by other Indonesian cities through city-to-city peer-learning opportunities. This is complemented by the Indonesian Climate Alliance, which brings together local and national government, civil society, donors, academics, and private sector representatives to actively support the institutionalization of urban climate-resilience (Archer et al., 2014).

BOX 5 INITIATIVES FOR COMMUNICATING CLIMATE RISKS AND SUPPORTING DECISION-MAKING

Argentina's Climate Risks Map System (SIMARCC): the Argentinian government's National Climate Change Office developed an interactive website (known as SIMARCC) that provides risk maps covering different scenarios of threats and vulnerabilities related to climate change. This platform combines georeferenced data on the potential hazards from climate change with data on social vulnerabilities. This tool was designed to be useful for decision makers in the public and private sectors.

Brazil's AdaptaClima Platform: the AdaptaClima platform was launched in December 2017 to support the dissemination of information and material on climate change to decision makers. It is an interactive and collaborative space for sharing tools, studies and methodologies. The development of the platform was coordinated by the Brazilian Ministry of Environment (AdaptaClima, 2018).

Copernicus Climate Data Store: this platform is intended to support adaptation and mitigation policies by providing free access to climate data based on the best available science and tools for interpreting that data. It provides access to information on historical, current and future climate across the world. This platform is supported by the European Commission.

European Climate-Adapt **Platform**: this platform was developed by the European Commission and European Environment Agency to provide comprehensive, reliable data to inform adaptation decisions. It includes data on projected climate change impacts, adaptation case studies and an extensive set of tools for managing climate change impacts.

Silicon Valley 2.0: The County of Santa Clara's Silicon Valley 2.0 Project created a decision-support tool that maps infrastructure assets and their exposure to climate-related hazards, and quantifies the risk of asset loss. The tool is accompanied by a Climate Adaptation Strategic Guide targeting cities, the County and other key agencies and stakeholders (County of Santa Clara, 2018).

United States Climate Change Adaptation Resource Center **(ARC-X)**: the Cross-Agency Working Group on Adaptation's Climate Change Adaptation Resource Center (ARC-X) helps local and regional government in small to mid-size US cities make decisions about resilience planning. It provides access to data on climate risks, guidance on developing adaptation strategies, case studies and information on potential funding opportunities.



Enabling climate resilience through policy and regulation

Public policy and regulation play a key role in enabling and promoting climate-resilient infrastructure development. Climate change risk assessments and adaptation measures need to be integrated across existing policy processes and decision cycles. This process of mainstreaming requires the identification of suitable entry points at multiple levels of decision-making: national, sectoral, project level and local level. Adaptation choices at these different levels are often linked, so that a decision at the national level may enable or constrain adaptation options at a local level. They also interact with other policy objectives, creating synergies and trade-offs. It is therefore important to adopt a whole-of-government approach to adaptation planning (OECD, 2009).

National policies

National adaptation planning can help identify entry points for mainstreaming, and promote cross-sectoral coordination. Most OECD and G20 countries have, or are developing, national adaptation strategies and plans that address one or more core infrastructure sectors, such as transportation, energy, and water. For example, Brazil's national adaptation plan includes a strategy dedicated to infrastructure (transport, urban-mobility and energy). Local governments are also developing adaptation strategies or plans, particularly in federated countries such as Canada, where most local governments have adaptation strategies or plans (OECD, 2013).

Infrastructure adaptation to climate change can be facilitated by incorporating climate risk into broader infrastructure planning frameworks, as well as the critical infrastructure protection programmes that are in place in over 20 OECD countries (OECD, 2018). In the UK, for instance, major infrastructure project applications are reviewed by the Planning Inspectorate to ensure compliance with a set of National Policy Statements that include an explanation of how to account for climate change adaptation. Developers of major projects are providing evidence to inspectors of how they have considered the latest climate projections, and taken into account climate robustness to extreme changes beyond the range provided by those projections, in their project proposals.

Spatial planning can help reduce infrastructure exposure to climate hazards by determining the possible locations for different types of infrastructure development. Integrating climate risk into decision-making at this early stage of planning can help to minimise downstream costs associated with adaptation measures and maintenance costs, and avoid locking in maladaptation. It can also facilitate ecosystem-based approaches to adaptation, by maintaining restrictions or creating incentives that protect ecosystems (e.g. wetlands and forests) and ensure the ongoing provision of ecosystem services such as flood defence and erosion control. Box 6 provides an example of how South Africa is promoting Ecosystem-based Adaptation.

Spatial planning frameworks tend to be established nationally, but local authorities are involved in their implementation and may issue their own regulatory requirements. For example, the Danish parliament passed a law enabling municipalities to account directly for adaptation in local city planning decisions. The new law allows municipalities to ban construction in certain areas solely due to reasons relating to climate change adaptation (OECD, 2013).

SEA and EIA

A key element of mainstreaming adaptation into infrastructure is the integration of climate risks into the decision-support tools used in standard policy and project appraisals. A Strategic Environmental Assessment (SEA)[1] designed to account for climate risk can serve as a tool for mainstreaming adaptation into infrastructure-related policies, plans and programmes. The Netherlands, for example, used an SEA in the development of a Delta Programme to protect the country against sea level rise and more severe rainfall. The SEA compared the "business as usual' scenario to alternative strategies, and promoted a new risk-based approach that resulted in more cost-effective climate protection, while creating opportunities for other services such as nature conservation and cultural heritage (Jongejans, 2017).

1. Strategic Environmental Assessment refers to a range of "analytical and participatory approaches that aim to integrate environmental considerations into policies, plans and programmes and evaluate the interlinkages with economic and social considerations" (OECD, 2006).

BOX 6 PROMOTING ECOSYSTEM-BASED ADAPTATION IN SOUTH AFRICA

South Africa is promoting the use of Ecosystem-based Adaptation (EbA) which uses biodiversity and ecosystem services to help people adapt and build resilience to the adverse effects of climate change. EbA encourages the use of ecological infrastructure as a complement or substitute for built infrastructure. Ecological infrastructure includes healthy mountain catchments, rivers, wetlands, coastal dunes, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape.

The Department of Environmental Affairs and South African National Biodiversity Institute (SANBI) led the development of a Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (also known as the EbA Strategy, 2016 – 2021). The Strategy identifies four areas of work that will contribute towards achieving this vision. These are structured into the following outcomes (1) Effective coordination, learning and communication mobilises capacity and resources for EbA, (2) Research, monitoring and evaluation provide evidence for EbAs contribution to a climate-resilient economy and society, (3) Integration of EbA into policies, plans and decision-making supports an overall climate change adaptation strategy, (4) Implementation projects demonstrate the ability of EbA to deliver a wide range of co-benefits.

As part of implementing the Strategy, South Africa also developed EbA Guidelines, established a coordinating mechanism to support the implementation of the Strategy and embarked on a pilot project on ecosystem restoration initiative that is supported by the Adaptation Fund in the uMgungundlovu District Municipality namely "uMngeni Resilience Project" and the "Taking adaptation to the ground: a Small Grants Facility for enabling local level responses to climate change in South Africa".

Source: (DEA and SANBI, 2016).

At the project level, Environmental Impact Assessments (EIA) provide a natural entry point for considering whether infrastructure projects are vulnerable to climate change or could exacerbate climate risks elsewhere. In South Africa, a mandatory EIA was conducted for the expansion of the Port of Durban that included a dedicated report on climate change risks. As a result of the EIA, changes were made to the original design, including making the port higher to cope with sea level rise and developing an environmental management plan to address heavier rainfall and winds (Kolhoff and Van den Berg, 2017).

In some cases, governments may need to revise their EIA legal frameworks to promote a more consistent and comprehensive consideration of climate risks in infrastructure development. The EIA process in EU Member States, for example, has been strengthened by an amendment to the EIA Directive (2014/52/EU amending 2011/92/EC), which places a stronger emphasis on climate change adaptation and resilience across the screening, scoping and assessment process (Vallejo and Mullan, 2017).

Technical codes and standards

Regulatory standards, such as technical codes, are being reviewed and strengthened to promote climate resilience. For example, in 2014 the New York state utilities regulator (Public Service Commission) approved a settlement requiring power utility Con Edison to use state-of-the-art measures to plan for and protect its electric, gas and steam systems from the effects of climate change. France's Nuclear Safety Agency updated its water discharge regulation in case of heatwaves, based on new evidence on the impact of discharged water temperature on fish populations (Vicaud and Jouen, 2015).

Modifying economic regulations can also lead to more resilient infrastructure, by removing barriers to investment in adaptation measures. Energy, water and rail regulators in the United Kingdom, for instance, aim to refine their price control review mechanisms to reflect longer asset life spans, and encourage a focus on longer run issues and better management of uncertainty. Similarly, in Germany, the Working Group on Regulation (Future-Oriented Grids Platform) is examining options within the framework of incentive

regulation to allow additional adaptation-relevant investments for power generation transmission and distribution to be accredited or reimbursed (Vallejo and Mullan, 2017).

National governments are revising national technical standards to account for climate resilience. A screening of 6th National Communications to the UNFCCC and national associations' sources show five OECD countries (Australia, Canada, Denmark, Germany and Korea) have made revisions to their standards. The Commission on Process Safety in Germany, for instance, has updated its technical rule on precipitation and flooding for flood safety of plants subject to the German Major Accidents Ordinance, while the Korea Expressway Corporation has strengthened the design requirements for drainage capacity, bridge design and embankment slopes.

Two major international standardisation organisations, the European Committee for Standardisation (CEN, Centre Européen de Normalisation) and International Standards Organisation (ISO), are reviewing existing standards to better address climate risk. The CEN is amending and extending the scope of the European civil engineering technical standards (Eurocodes), with a focus on transport and energy infrastructure, as well as building and construction. They are also amending product standards to account for climate change. The ISO is working through its Adaptation Task Force to develop a set of standards for vulnerability assessment, adaptation planning, and adaptation monitoring and evaluation (ISO, 2015). Both of these reviews cover the assessment, re-use and retrofitting of existing infrastructure, as well as the design of new developments.

The development of new standards or the modification of existing ones to better account for climate change increases the extent to which the relevant climate risks are managed as a matter of course. An underlying challenge in achieving this is the tension between two goals: establishing standards that are straightforward and can be applied consistently, while also taking into account the uncertain and context-specific nature of climate risks. Where risks are context specific, care should be taken to ensure standardised approaches do not lead to systematic over- or under-investment in resilience.

Facilitating climate risk disclosure

Increased public disclosure of climate risks[2] can support infrastructure resilience by informing investment decisions. The process of reporting can also be valuable in raising awareness within organisations about their exposure to climate risks, stimulating action to reduce those risks. This section focuses on the disclosure of physical risks from climate change. More information on the other risks related to climate change - transition risks and liability risks - can be found in the background paper produced for the February 2018 meeting of the Round Table for Sustainable Development, *Integrating Climate Change-related Factors in Institutional Investment*.

Government policies can be used to encourage or require risk disclosure by the private sector, but this is at an earlier stage for climate resilience than mitigation. Fifteen G20 countries had mandatory greenhouse gas reporting in place in 2015, while the situation for climate resilience is more complex. Public companies are required to disclose risks that are deemed "material" in most G20 countries (Task Force on Climate-Related Financial Disclosures, 2017). In principle, this covers the physical risks from climate change, but this does not happen consistently. Some countries have introduced specific initiatives to encourage reporting (Task Force on Climate-Related Financial Disclosures, 2017):

- Article 173, Law on Energy Transition for Green Growth (France) - listed companies are required to report on climate change impacts, or explain why they have not done so. Companies are encouraged to include disclosure of physical climate risks in their reports.
- Adaptation Reporting Power (United Kingdom) - this gives the government the power to require many types of infrastructure providers to report on their exposure to climate risks. The first round of reports were mandatory, but it is now being used on a voluntary basis.
- Securities and Exchange Commission (SEC) guidance (United States) - the SEC issued "interpretative guidance" in 2010 stating that climate risks that are material to the company were covered by existing disclosure requirements.

2. For the purpose of this report, financial climate risks refer to physical risks which can be event driven (acute) or longer-term shifts (chronic) in climate patterns. These are different from transition risks, which are financial risk associated with the transitions to low GHG economies.

These initiatives provide considerable flexibility in how companies choose to report climate impacts. The G20 encouraged greater consistency and action on this topic by mandating the Task Force on Climate-related Financial Disclosure (TCFD) to create a voluntary framework for climate-related risks and opportunities (Task Force on Climate-Related Financial Disclosures, 2017) . This framework calls for the reporting of, inter alia, physical risks relating to the impacts of climate change, with a focus on the following areas (Task Force on Climate-Related Financial Disclosures, 2017): governance, risk management, strategy and metrics.

Climate risks do not have a single metric, equivalent to the tonnes of CO_2eq that is commonly used for mitigation[3]. Yet investors and lenders need to have reasonably comparable and usable data with which to compare the characteristics of their investments. The TCFD guidelines suggest indicative metrics to consider using to inform investment decisions, but identifies the development of methodologies, datasets and tools as an area where further work is required.

Frameworks for risk disclosure should be tailored to national circumstances. Developing countries will be particularly adversely affected by climate change, but also rely upon investment for economic development. Approaches to climate risk disclosure, and incorporation of these risks into decision-making, should be designed to avoid deterring investment in developing countries. Approaches to disclosure should also account for differences in capacity and the sophistication of financial markets to avoid generating undue administrative burdens.

Voluntary guides, toolkits and standards for disclosing climate risks

Tools for disclosure should encompass both the physical vulnerability of specific assets, and examine whether management responses are sufficient to ensure continual management of climate-related risks. Relevant initiatives are being developed to support this ambition. For example, EBRD and the Global Centre of Excellence on Climate Adaptation (CGECA) are currently developing metrics for climate risks and opportunities, and identifying how climate risk information can be incorporated within financial reporting systems.

There is a growing number of private sector and voluntary initiatives to support risk disclosure, aimed at different audiences.

Infrastructure developers and engineers

Climate resilience is now being integrated into frameworks of voluntary sustainability rating programmes. Potential benefits of these ratings include increased performance, reduced costs and marketing advantages. They provide a consistent form for tenderers to require, and bidders to demonstrate, compliance with sustainability objectives. Sustainability rating tools include:

- Infrastructure Sustainability Rating Tool (Australia)
- CEEQUAL (UK)
- ENVISION (USA)
- SURE Infrastructure Resilience Standard

There are no comprehensive statistics available on the extent to which infrastructure is being covered by these rating programmes, but the value of rated assets remains a small proportion of total investment. For example, the global capital value of certified projects under the Infrastructure Sustainability Rating Tool is AUD 8 billion. However, there are initiatives underway to increase use of these tools. For example, since 2016 all public works in Los Angeles are required to demonstrate compliance with the ENVISION standard (Meister Consultants Group, 2017).

Investor initiatives

Investors are taking an increasing active role in requesting information on the exposure of their assets to the risks of climate change. These risks include physical risks from climate change, and those arising from the move to a low-GHG economy. Voluntary disclosure initiatives have been developed to meet this need. They include analysis of the risks from climate change within broader frameworks of sustainability. If designed well, they have the potential to encourage infrastructure owners and operators to improve their management of climate risks.

Some of the main initiatives that address climate risks include:

- CDP - this global reporting framework covers a range of sustainability issues, including climate resilience. They report that 650 investors, representing USD 87 trillion of assets under management request information under this

3. There are, nonetheless, differences in the climate and other effects of long-lived and short-lived greenhouse gases and other climate pollutants that are captured by the CO_2eq metric.

framework. Over 6 300 companies currently report through this framework.

- Global Reporting Initiative (GRI) - this modular reporting framework is widely used, with 93% of the world's 250 largest corporations having adopted it. The modules include some metrics relevant to climate risks.
- Sustainability Accounting Standards Board (SASB) - this initiative, based in the United States, provides guidance for corporations on how to disclose material sustainability information through their financial reporting. The framework includes 79 industry standards identifying financially material risks, including physical risks from climate change.

Further refinements of these initiatives will help to ensure that they are effective in encouraging companies to consider climate resilience in their operations. In particular, the metrics relevant to resilience are generally expressed in non-financial terms (e.g. water consumption), which do not readily fit within the financial models used by investors. The TFCD recommendations are encouraging further work in this area to refine metrics and encourage harmonisation between systems.





4 Mobilising investment in climate-resilient infrastructure

This section explores how climate resilience can be mainstreamed into the identification, design and financing of infrastructure projects. It identifies mechanisms through which public support can help to mobilise private finance for climate resilience. These mechanisms will be most effective when combined with the measures to strengthen the enabling environment (section 3).

Key messages

- Climate impacts will have implications for existing global infrastructure investment needs, including increasing, decreasing, or re-directing particular investment needs in relevant sectors, particularly flood defences, and water supply and sanitation. The use of tools for decision-making under uncertainty can reduce the need for costly retrofitting while reducing upfront costs. Natural infrastructure and other flexible or innovative approaches to climate-resilient infrastructure may even be cheaper than traditional approaches in some circumstances. Global studies find that the benefits of investing in resilience outweigh the costs with high benefit-cost ratios, for example of investment in flood defences for coastal cities.
- Developing and communicating infrastructure plans can help investors to identify investment opportunities. Developing these plans provides an opportunity for decision makers to take a strategic view of how considerations such as climate change will affect infrastructure needs in the coming decades, and design sequenced packages of investment ("pathways") that address interconnections and increase resilience in a way that cannot be achieved by looking at projects in isolation.
- Public procurement processes can support climate resilience by comparing bids' costs over the asset lifetime. This includes considering both operating expenses (OPEX) as well as capital expenses (CAPEX). The increasingly severe impacts of climate change later in the design life of the project are likely not to be considered by the project developer at the design stage unless there is a government requirement to do so. For Public Private Partnership (PPP) contracts, it is important to clarify the allocation of responsibilities regarding climate-related risks planning, management and response.
- Lenders and public funders are increasingly using risk screening to identify infrastructure that may be vulnerable to climate change. One of the emerging lessons is that screening should be combined with support to generate solutions to the risks that have been identified in the screening process.
- Public finance and policies can be used to mobilise private finance for climate-resilient infrastructure. Support for project preparation can help to address capacity constraints relating to climate resilience. Blended finance can be used to improve the risk-return profile of investments where appropriate, in combination with efforts to improve the enabling environment for private investment.

Scaling-up finance for climate-resilient infrastructure

There is already a significant gap between total projected infrastructure needs and trends in infrastructure investment. OECD estimates USD 6.3 trillion per year is required under business-as-usual just to meet the infrastructure needs for continued economic development, while global investment was estimated to be USD 3.4 trillion in 2014 (Bhattacharya et al., 2016). Thus, rather than being looked at in isolation, there is significant scope for mainstreaming climate resilience considerations as part of broader efforts to address this existing infrastructure investment gap. More information on this broader challenge can be found in *Investing in Climate, Investing in Growth* (OECD, 2017b) and *Crossing the Bridge to Sustainable Infrastructure* (Mercer & IDB, 2017).

Climate impacts will have implications for existing global infrastructure investment needs. There are no comprehensive estimates of these needs for G20 countries, but sectoral estimates provide some indications of the potential scale of investment needs and allow for more detailed analysis than is possible at the global level. The estimates that exist are not directly comparable due to differences in assumptions and methodologies (OECD, 2015a). A study of 136 major coastal cities found that an additional USD 50bn per year would need to be invested in flood defences to offset the impacts of climate change (Hallegatte et al., 2013). Hinkel et al. (2014) estimate that an additional USD 12-71 billion would need to be spent on flood defences by 2100 to address sea-level rise. National-level estimates tend to be higher than the global results would suggest.

These estimates help clarify the scale of funding needs for climate-resilient infrastructure, but the costs for a given project will vary widely depending on context. One estimate suggests that, on average, integrating climate resilience would add 1-2% to the total cost of infrastructure projects (World Bank, 2010a). More resources will be required at the project development and design phases to consider climate risks. A 2011 study by IDB found that the additional analysis required to identify and evaluate climate change risks can add 25% to the average costs of an environmental and impact assessment (Iqbal and Suding, 2011). Depending on the climate resilience measures required, implementation costs could be negligible, negative or they could require significant changes in project design. The use of tools for decision-making under uncertainty can reduce the need for costly retrofitting while reducing upfront costs.

There can be a strong business case for making these investments in climate-resilient infrastructure. The global studies cited above all find that the benefits of investing in resilience outweigh the costs. In a different context, analysis of Alaskan infrastructure resilience finds high ratios of benefits to costs (Melvin et al., 2017). Natural infrastructure and other flexible or innovative approaches to climate-resilient infrastructure may even be cheaper than traditional approaches (see Box 7).

Financing for climate-resilient infrastructure will require a mixture of public and private resources. The split between these sources of finance for infrastructure varies, with the share of public finance estimated at 60-65% in developing countries compared to 40% in developed countries (Ahmad, 2016; Bhattacharya et al., 2016). There are no comprehensive data on the finance flows for climate-resilient infrastructure, thus it is not possible to assess the relative roles the public or private sector is currently playing in financing climate-resilient infrastructure. However, finance flows for adaptation from public sources, including governments, bilateral development finance providers, multilateral climate funds and development banks and development finance institutions continued an upwards trend in 2014 (UNEP, 2016). There are currently insufficient data to assess trends in private sector financing for climate resilience.

Development finance institutions – national, bilateral and multilateral – all play an important role in supporting climate-compatible infrastructure, both by financing infrastructure projects as well as supporting the necessary policy change required to make infrastructure low GHG and climate-resilient. They are also increasingly key players in supporting countries to mobilise-investment, by developing infrastructure pipelines, by investing in new greenfield projects and by de-risking infrastructure investment and mobilising private investors. Amongst the major multilateral development banks (MDBs) infrastructure financing still remains a key activity, accounting for USD 31 billion in 2014 (Miyamoto and Chiofalo, 2016). Some banks – namely, the Asian Development Bank, African Development Bank and Islamic Development Bank, allocated more than half their portfolios to infrastructure in 2014.

Comparing the scale of financing for climate resilience with financing for climate change mitigation is difficult to do, given the former is typically reported in terms of incremental cost (i.e., the additional cost required to make an asset resilient to climate change rather than reporting the total value of the investment made

resilient to climate change) while the latter is reported in terms of total capital cost in the MDB reporting. For example, in 2016, MDBs reported over USD 27.4 billion in climate finance commitments, with USD 6.2 billion going to climate change adaptation (Joint MDB Climate Finance Group, 2017). However, the fact that approximately half of this incremental adaptation finance went towards infrastructure suggests that the total value of climate-resilient infrastructure could be significant, even when compared to mitigation[4].

4. This includes 18% for water and wastewater systems, 18% for energy, transport and other built infrastructure and 16% for coastal and riverine infrastructure (AfDB et al., 2017).



Mainstreaming climate resilience at the project investment level

Mainstreaming resilience into infrastructure pipelines and pathways

All infrastructure sectors will be affected by risks arising from climate change, albeit to varying extents. It will be essential to mainstream climate resilience, in a proportionate way, throughout the full pipeline of projects to ensure that they are consistent with future climate change scenarios.

Infrastructure pipelines translate countries' overall policy objectives into coherent sets of infrastructure projects. Developing these pipelines and supporting institutions can yield the following benefits (OECD, 2018):

- Increase transparency and predictability for private investors.
- Ensure that the cumulative total of projects being planned is consistent with overall objectives.
- Improve sequencing of inter-related projects.
- Inform the development of the supply chain; and

BOX 7 COPENHAGEN: WORKING WITH ECOSYSTEMS TO COST-EFFECTIVELY BUILD RESILIENCE

Cloudbursts (sudden heavy rainfalls) are predicted to become more severe in Copenhagen as a result of climate change. During these periods of heavy rainfall, the drainage capacity of the sewers can be overwhelmed, leading to flooding. A cloudburst in 2011 led to damages of more than EUR 600 million from flooding.

The 2012 Cloudburst Plan identified an initial set of measures would be required to address the rising hazard from increased periods of rainfall. These have been subsequently developed and refined:

- Property-level measures: these measures reduce damages when floods occur, including anti-backflow valves to prevent sewer water from entering basements
- Green space and waterway restoration: this can help to facilitate the flow of water and provide additional amenity value
- Grey infrastructure: a tunnel would be built to enhance drainage capacity in heavily built-up areas, roads are to be redesigned so that they can be used to channel excess rainfall to the sea

The lifetime costs of those measures were estimated at DKK 13 billion (EUR 1.7 billion), with the majority to come from water charges, and the reminder to come from private investments and municipal funds. Overall, the combined measures to address cloudbursts are expected to yield net benefits of DKK 3 billion (EUR 400 million), compared to net costs of DKK 4 billion (EUR 540 million) that would be incurred for the traditional solution.

Source: (City of Copenhagen, 2015).

- Establish responsibilities and delineate accountability for actors relevant to delivering the pipelines, e.g. responsibilities for issuing necessary permits.

Improving the quality and availability of relevant infrastructure projects is a first step in making those projects resilient to climate change. Infrastructure pipelines can help to do this by signalling the availability of bankable projects. For infrastructure in general, the lack of transparent infrastructure pipelines was rated by investors as the second most significant barrier to infrastructure investment, after uncertain and unfavourable policies and regulations (Mercer & IDB, 2017).

OECD analysis found that more progress is required to mainstream adaptation into infrastructure plans (OECD, 2017b). The degree of mainstreaming is also variable, with some identifying additional projects relevant for climate resilience, while others focus more on the enabling conditions for infrastructure. More generally, there is a need to ensure that infrastructure pipelines are publicly available and clear in specifying the targets for infrastructure provision and associated budget (OECD, 2017b).

A strategic approach is required to examine the implications of climate change, along with technological and socio-economic changes, for infrastructure as a whole. A promising area for this is the development of "pathways" of climate-resilient investments (as discussed in section 3). These go beyond lists of potential projects in infrastructure sectors to create sequenced packages of investment that consider interconnections. The use of pathways makes it possible to identify a wider range of options for addressing uncertainty than would be possible when focussing at the level of individual projects. This is still an evolving area, but some emerging practices are shown in Box 8.

Ensuring that public procurement accounts for the benefits of climate resilience

Procurement policies can be used to ensure that publicly financed infrastructure is resilient to the effects of a changing climate. On average, government procurement accounts for 10-25% of countries' GDP (World Bank, 2017). The process used to make procurement decisions for infrastructure have a direct impact on the contractors' incentive and ability to account for resilience. Given the scale of public investment, procurement can also have an indirect impact in shaping the products offered and structure of relevant market places (World Bank, 2017).

BOX 8 EXAMPLES OF INFRASTRUCTURE PATHWAYS

Delta Programme (Netherlands): the Delta Programme is responsible for protecting the Netherlands against flooding and ensuring freshwater supplies. This is of critical importance given that 26% of the country lies below sea level. This programme has adopted the concept of "Adaptive Delta Management", which takes a long-term, flexible approach to make short-term investment decisions that are prepared for a range of possible futures (The Netherlands, 2012).

Colorado River Basin (United States): the Colorado River Basin provides water for 30 million people and is under pressure from growing demand and changing hydrology. Robust Decision Making was used to identify the main drivers of vulnerability, which can then be monitored to identify when options are no longer appropriate and develop dynamic 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 (Groves et al., 2013).

National Infrastructure Commission (United Kingdom): this commission is required to deliver a national infrastructure assessment to each parliament (every 5 years). The assessment takes a "whole system approach" to identify interdependencies and feedbacks, considering a range of possible scenarios for the future. This is informed by integrated models produced by a consortium of seven universities (the Infrastructure Transitions Research Consortium).

The procurement process should account for the value of climate resilience. As discussed above, considering resilience will often entail additional upfront capital or operational expenditures. Potential providers of resilient infrastructure will be at a competitive disadvantage unless the benefits of resilience are accounted for. Decision-support tools, such as cost-benefit analysis, should consider the range of potential benefits of enhanced resilience. In the UK, this was achieved by producing supplementary guidance for the normal appraisal framework (HM Treasury and Defra, 2009). The use of lifecycle costing and "green" procurement can also ensure a level playing-field for resilient approaches.

Procurement policies can facilitate innovation in the provision of climate-resilient infrastructure by specifying objectives rather than mandating the use of specific technologies (Baron, 2016). In such contexts, it is important that the objectives include transparent recognition of climate change when specifying those performance standards, e.g. relating to performance reliability or reduction in flood risk. The development and adoption of recognised standards relating to infrastructure will facilitate this process.

Procurement policies at the urban and other subnational levels of government are also important. On average, subnational authorities account for 59% of public investment in G20 countries, albeit with a wide variation between countries. Research commissioned by the Greater London Authority found that it would be consistent with their legal duties to integrate climate resilience into their procurement (LCCP, 2009). Given the potential complexity of the topic, and capacity constraints, it recommended the sharing of good practices between subnational governments. However, efforts are underway to increase uptake.

More transparency is needed about the extent to which climate risks are included in public procurement frameworks. UN Environment (2017) finds that the use of sustainable public procurement is increasing, and that two-thirds of the countries they examined consider climate change mitigation. This study does not consider adaptation or resilience.

Screening infrastructure projects for climate risks

Financing institutions and public funders are increasingly using risk screening as part of their approval processes for new infrastructure projects (see Box 9). The use of mandatory screening for projects complements the voluntary disclosure of climate risks by organisations, which is discussed in section 3. Some major risk screening initiatives include (AECOM, 2017):

- The European Union examines major projects co-financed by the European Structural and Investment Funds for the 2014-2020 period to consider climate risks. Projects being

BOX 9 INTEGRATING CLIMATE RISKS INTO PUBLIC INFRASTRUCTURE PLANNING

Queensland and Tasmania (Australia): these states require cabinet submissions for government projects to consider potential climate risks. The Queensland Climate Ready Infrastructure initiative requires local governments to consider climate change adaptation when applying for infrastructure grants to the Queensland Government.

COAG (Australia): the Council of Australian Governments requires state and territory governments' strategic plans for infrastructure in capital cities to cover climate change adaptation. Infrastructure funding is linked to meeting these criteria.

West Coast Infrastructure Exchange (Canada and USA): was established by the states of California, Oregon and Washington in the United States and British Columbia in Canada. WCX aims at developing innovative methods to finance and facilitate the development of infrastructure in the region by developing a framework for infrastructure investment and principles for certification. The consideration of resilience and climate risks features among the WCX's standards for infrastructure projects (WCX, 2012).

National Investment Plan (Costa Rica): the Costa Rican national investment plan for 2015-18 required all new infrastructure projects to meet resilience objectives.

screened have a total value of approximately EUR 70-100 billion of investment.

- The European Investment Bank (EIB) has developed and applied a climate-risk screening tool as part of its 2015 Climate Strategy.
- The Inter-American Development Bank (IDB) has committed to screening all projects for climate risks from 2018, having already undertaken pilot studies in a number of countries.
- The World Bank systematically screens its lending for exposure to climate and disaster risks, and has developed a set of tools to support that process: https://climatescreeningtools.worldbank.org/.

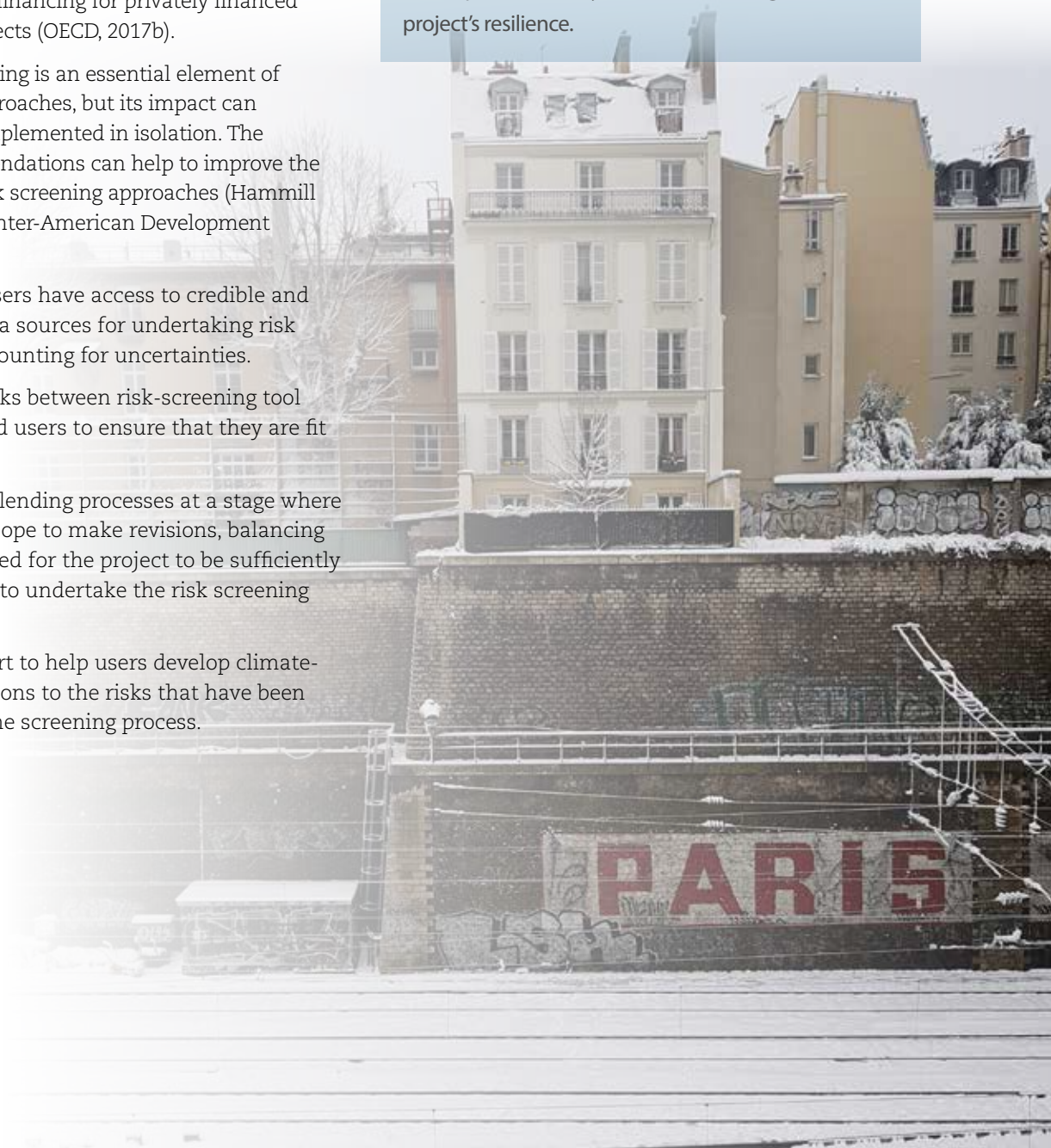
Risk screening by public institutions can influence joint public-private investments: in developing countries, with development and state-owned banks contributing around 21% of the financing for privately financed infrastructure projects (OECD, 2017b).

Climate risk screening is an essential element of mainstreamed approaches, but its impact can be limited if it is implemented in isolation. The following recommendations can help to improve the effectiveness of risk screening approaches (Hammill and Tanner, 2011; Inter-American Development Bank, 2014):

- Ensure that users have access to credible and consistent data sources for undertaking risk screening, accounting for uncertainties.
- Strengthen links between risk-screening tool developers and users to ensure that they are fit for purpose.
- Integrate into lending processes at a stage where there is still scope to make revisions, balancing against the need for the project to be sufficiently well-specified to undertake the risk screening process.
- Provide support to help users develop climate-resilient solutions to the risks that have been identified in the screening process.

BOX 10 RISK SCREENING BY IDB INVEST

The IDB's private sector investment arm, IDB Invest, now systematically screens all investment proposals to identify climate vulnerabilities. A two-stage process is used for this screening. The first step undertakes a rapid assessment to identify whether the vulnerability to climate risks is high, medium or low. Projects that are scored as high or medium are then subject to a more detailed assessment. The detailed assessment examines, inter alia, whether the project documentation has considered climate change impacts and made any necessary revisions. If necessary, the bank collaborates with the project developers to identify measures to strengthen the project's resilience.



Integrating climate resilience into PPPs

Public-Private Partnerships (PPPs) are an important delivery route for infrastructure: in 2016, USD 71 billion of investment was committed in PPPs in emerging and developing economies, predominantly for provision of electricity and roads (World Bank PPI database). The details of these contracts vary, but the essence is that they are long-term, fixed contracts. PPPs work best when the contracts are as complete as possible: in other words, when risks are clearly identified and allocated to the different parties. Table 4 provides a summary of recommendations for ensuring that the PPP process facilitates resilience.

The underlying issue for climate resilience is to ensure that risks relevant to climate change are identified and allocated correctly. The general principle for PPPs is that risks should be allocated to the parties who are best able to manage those risks. The management of risks can consist of efforts to reduce the risk through changes in design or operation, and the use of financial instruments to transfer risks to other parties. The risks from climate change are particularly difficult to manage because they are uncertain. Because of this uncertainty, passing the risk to the private sector can be expensive, but keeping it in the public sector reduces the private sector's incentive to manage the risks.

A central practical issue is the extent to which climate change impacts are covered by relief, compensation or "force majeure" clauses in PPP contracts. These clauses partially or entirely indemnify the concessionaire against risks that are exogenous and unpredictable or unforeseeable. In practice, risks covered by these clauses represent potential financial liabilities held by the government. Only a few OECD countries, including Australia and United Kingdom, treat weather events separately from "force majeure". In the United Kingdom, concessionaires are not eligible for financial compensation following hydro-meteorological events. The risks from climate change are uncertain, but, in some cases, they are now foreseeable based on the available scientific evidence (IPCC, 2014).

In addition to this, there can be a mismatch of time horizons between the concessionaire and the infrastructure asset. The concessionaire is only incentivised to consider the performance of the asset during the contract term. Bridges, for example, can have a useful life of 100+ years, while typical contracts are only 20-30 years. As a result, if there are increasingly severe impacts of climate change later in the design life of the project, they would not be considered by the private party, and would need to be addressed by the government in the planning, design and contracting phase.

Despite the importance of clarifying risks, no OECD country has explicitly incorporated climate resilience into their PPP frameworks (Vallejo and Mullan, 2017). This is also the case for a set of 16 emerging and developing economies, including Brazil, China, India, Indonesia and South Africa (World Bank, 2016). However, it is important to note that climate resilience may, nonetheless, be considered in the development of PPP projects. For instance, resilience against many types of existing hydro-meteorological risks may already be mainstreamed into project technical design processes and be considered existing best practice, as is often the case of hydropower or dam projects. The challenge is to ensure that these processes adequately consider how risks may evolve in the future, as well as how they have been experienced in the past. While progress at the national level may be slow, initiatives are taking place for specific projects and sectors (see Box 11 for an example).

BOX 11 COLOMBIA'S 4TH GENERATION ROAD CONCESSION PPP

The La Niña floods of 2010-2011 led to economic losses estimated at USD 6 billion, of which 38% arose from damage to infrastructure. Roads under concession suffered damage of USD 88 million leading to disputes between road concessionaires and the government about which parties bore responsibility for covering these damages. In response to this, the national infrastructure agency enhanced and clarified insurance requirements, with technical support from the World Bank. The contract for the latest tranche of new roads clearly allocates climate risks to the concessionaires, on the basis that they will be best placed to manage those risks. Concessionaires have to hold sufficient insurance to cover their expected Probable Maximum Loss. The risk of insurance premiums increasing in future due to climate change rests with the private sector.

Source: (CEPAL and BID, 2012; World Bank, 2016).

Table 4 **Recommendations for incorporating climate resilience into the PPP process**

	Potential measures by PPP phase
Project Identification & PPP Selection Phase	Examine whether the risks from climate change affect the appropriate choice between PPPs and other mechanisms for providing infrastructure services
Project Preparation Phase	Ensure that the technical and service standards applied to the project consider climate resilience
	Design the tender specification to provide room for innovative approaches to climate-resilient infrastructure provision
PPP procurement phase	Ensure that the process of evaluating tenders accounts for resilience benefits, including by considering net benefits over the life of the asset, rather than the term of the contract
Implementation and contract management phase	Identify, analyse and clearly allocate the potential climate risks (and resulting contingent liabilities) resulting from climate change in the contract. Key terms include "uninsurability" provisions, "force majeure" clauses
	Use insurance, or proof of financial capacity, to ensure that the concessionaire is able to bear the risks allocated in the contract
	Encourage disclosure of climate-related risks, and transparency about risk management, throughout the life of the contract
	Collaborate throughout the contract to facilitate adaptive management in light of changing climate conditions

Source: Adapted from (PPIAF, 2016).

Project development support, risk mitigation frameworks and blended finance for bankable climate-resilient infrastructure projects

A key factor affecting commercial and private investors' decision to invest in climate-resilient infrastructure is bankability: whether a project has a sufficient number of key attributes (e.g. adequate collateral, acceptable risk exposure, future cash flow) to make it commercially attractive.

Several barriers may constrain or hamper the bankability of infrastructure projects in general which are also relevant for new projects that will need to be climate-proofed. These include, inter alia, high real and perceived risks associated with these investments, weaknesses in the enabling environment, poor project preparation and/or market sounding. Creating a supportive enabling environment will be critical to driving more climate-resilient infrastructure investment (see section 3).

A particular challenge for funding climate-resilient infrastructure is that many of the benefits may be hard to monetise, particularly for protective infrastructure such as flood defences. There are, however, growing examples of instruments and mechanisms being implemented to translate the potential benefits of climate-resilient infrastructure into adequate revenue streams (see Box 9 for examples).

An optimal risk-sharing allocation is crucial to ensuring bankability for suitable projects (Rana, 2017). This determination is typically undertaken at the outset of the project, during the project conceptualisation and design phase. The resilience agenda brings a new dimension to this - given the need to consider how the allocation of climate-related risks will affect actors' incentives to manage these risks. Within that context, public finance providers can use a range of tools to allocate risks effectively and bridge the bankability gap for climate-resilient infrastructure. One such tool is project preparation support, in the form of technical and financial assistance to project owners or concessionaires. This is particularly important given the potential additional complexity of considering climate resilience in infrastructure development.

Blended finance can be used to support investment in climate-resilient infrastructure. In this context, development finance is used to mobilise additional commercial and private finance by improving the risk-return profile of investments and helping un-bankable projects become economically viable (OECD, 2018b). Blended finance is not an asset class: an effective blended finance transaction typically structures traditional financial instruments in such a way as to attract commercial capital. Therefore, blended finance can operate on both sides of the

risk-return spectrum. For instance, blended finance can use credit enhancement instruments such as insurance and guarantees to take on some project risks. Alternatively, a project or portfolio of climate-resilient infrastructure projects can be structured to increase the returns received by commercial investors, thereby encouraging them to take on a high level of risk. It is worth noting that blended finance approaches often combine financial support with a technical assistance facility, which can provide project preparation support.

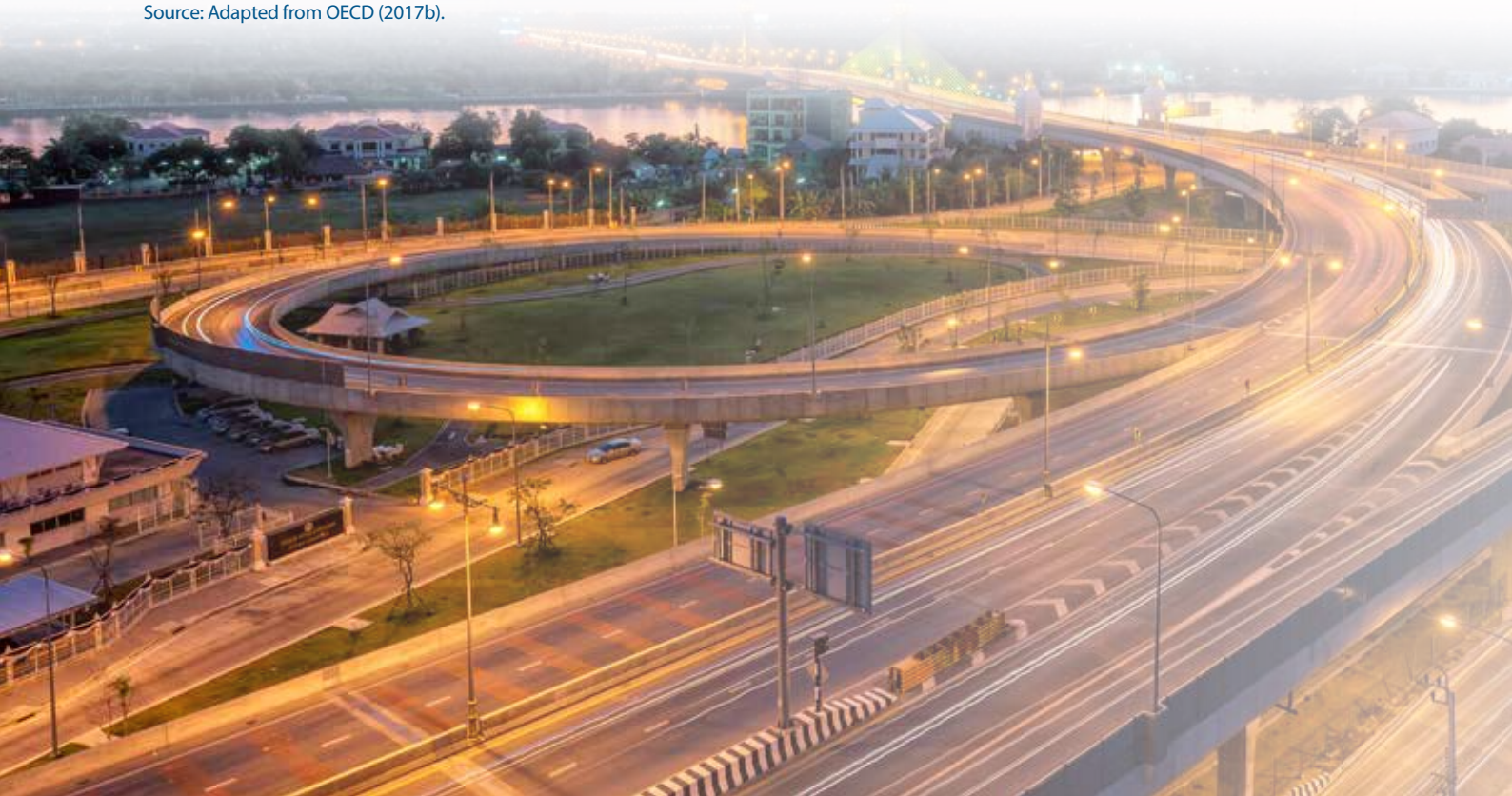
A co-ordinated approach between institutions will be essential to address systemic bottlenecks and demand for capital for climate-resilient infrastructure. Given the long-term nature of infrastructure investments, financing is likely to be contingent on factoring in resilience towards further expected or likely climate change within the long-term time horizons and depreciation periods of infrastructure projects. Expanded safeguards that integrate resilience aspects are likely to play a key role in this regard, by providing a standard for financing by private/commercial financial actors.

A particular area of interest relates to the potential of insurance or guarantee products that could be developed for climate-resilient infrastructure. Insuring new and existing infrastructure against future risks due to climate change could be a factor in reducing financing costs through risk mutualisation. Premiums, or availability, of such insurance would need to reflect climate resilience aspects, as a potential avenue to both internalise resilience into the project finance, while reducing actual financing cost. However, this is dependent upon the availability and commercial viability of such products.

Table 5 **Instruments and approaches to mobilise private investment**

	Potential role
Project development facilities and technical assistance	Support the development of bankable infrastructure projects
Co-investment platforms and funds	Pool capital to directly finance infrastructure Pool public and private capital
Debt subordination	Reduce risk for private investors, as the public sector takes on the highest risk tranches
Guarantees	Improve the credit rating of investment projects
Project development facilities and technical assistance	Supports the development of bankable infrastructure projects

Source: Adapted from OECD (2017b).



BOX 12 MOBILISING FINANCE FOR CLIMATE-RESILIENT INFRASTRUCTURE

Land development taxes (Morocco): The city of Casablanca is in the process of extending its water network and flood protection measures to meet the demands from rapid urbanisation. Part of this is funded by contributions from property developers who are financing a growing share of total investment, from 7% in 2004 to 54% in 2014. The contribution is a share of the price of the property when sold, ranging from 0.7% of the selling cost for social housing to 1.3% for luxury apartments and buildings, and contributions are waived when the developments take place in underprivileged neighbourhoods. Special conditions have also been set to adjust the contribution to the pace of urban expansion, and to harness major urban developments.

The Reef and Beach Resilience and Insurance (Mexico): The Nature Conservancy (TNC) and Swiss Re, with support from the Mexican state and local government, are linking insurance with the protection of a coral reef off the coast of Cancún. Coral reefs offer protection against storm damage from waves, yet their condition has deteriorated in recent years due to a variety of human-induced pressures. It is estimated that a one-meter loss of reef height could translate into 1,300 square km of inland flooding and USD 20 billion in lost infrastructure in Mexico. Local businesses dependent on tourism, such as hotels, will pay in to a collective trust that monitors the condition of the 60 km stretch of reef. A portion of the trust will go towards a premium for a parametric insurance policy that covers the designated stretch of reef. If the storm is sufficiently severe to trigger the insurance policy, the payout will cover the necessary rehabilitation efforts.

Environmental Impact Bond (US): In September 2016, the Washington, DC Water and Sewer Authority (DC Water) issued an Environmental Impact Bond (EIB) to finance nature-based storm water infrastructure. The EIB uses a "Pay for Success" approach to provide up-front capital for environmental programs, where payment by the public sector to the private entity is based on measured outcomes. In this case, DC Water had examined the use of nature-based solutions, but lacked the up-front capital investment needed for deployment. They were also concerned about taking on debt for the project as nature-based infrastructure for flood management had not yet been tested in the area. The EIB issued a 30-year tax-exempt municipal bond, which will allow DC Water to pay interest near its municipal rate. In addition, EIB structure provides investors with a financial premium if the project outperforms its target, and it provides DC Water with a corresponding financial risk share payment if the project underperforms. The structure allows DC Water to pilot the cost-effectiveness of nature-based solutions for urban flood management.

Source: (EPA, 2017; The Nature Conservancy, 2018; OECD, 2015b).

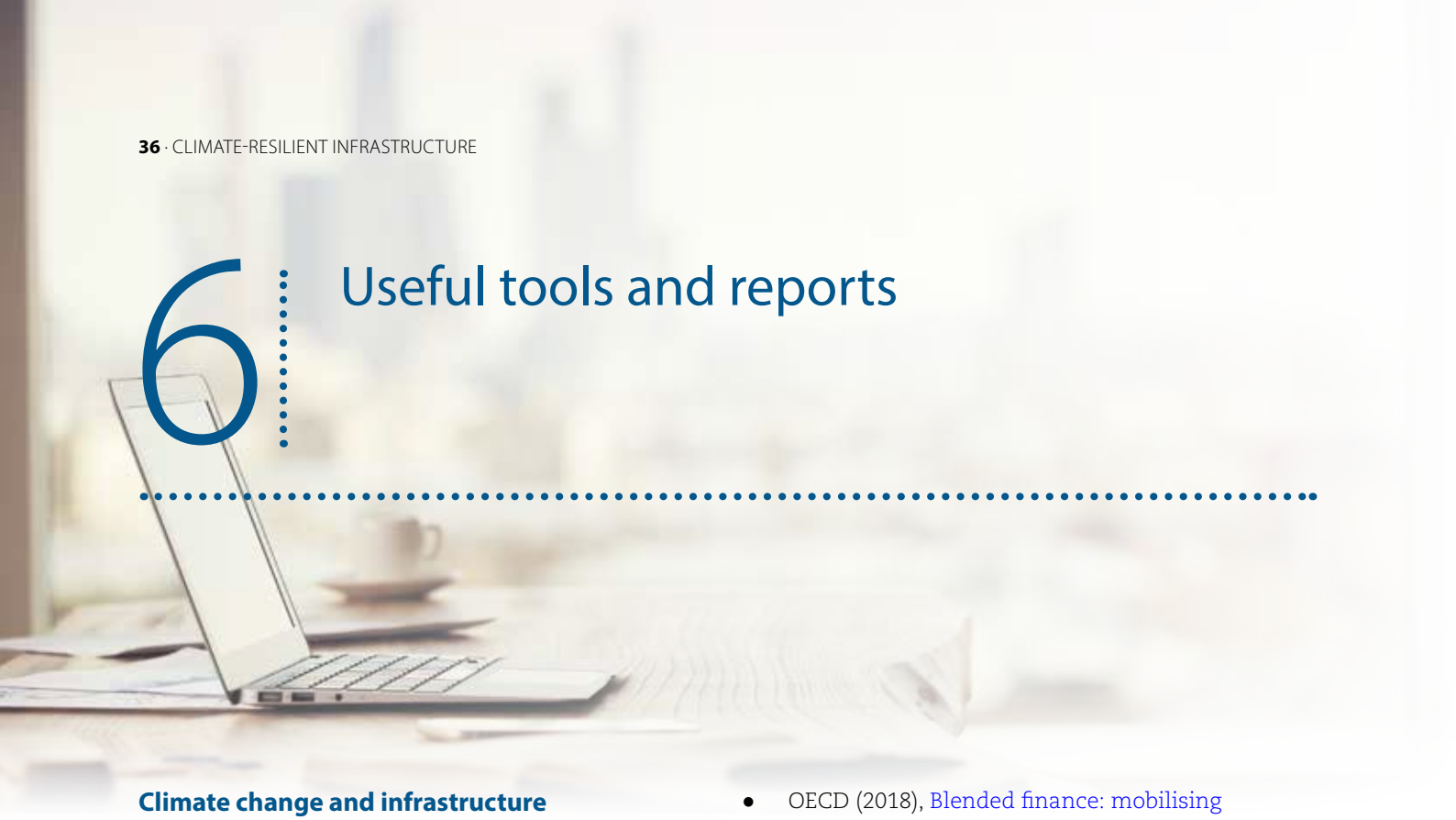


5 Coverage of infrastructure in national climate risk assessments in OECD and G20 countries

	Author	Year	Sectoral focus			Climate hazard focus			Nature of assessment	
			Multi-sectors	Transport only	Water only	Multi-hazard	Coastal change only	Flooding only	Qualitative	Quantitative
ARGENTINA	Working Group (Ministry of Interior and Transport as intermediary)	2012	x			x			x	
AUSTRALIA	DCEE	2011					x			
	DCC	2009	x	x			x		x	x
	ATSE	2008	x			x			x	
AUSTRIA	Federal Ministry of Agriculture, Forestry, Environment and Water Management	2013	x			x			x	
BELGIUM	National Climate Commission	2010	x			x			x	
BRAZIL	Ministry of Environment	2016	x			x				x
CANADA	Natural Resources Canada	2014	x			x			x	Case studies
CHILE	National Environment Commission	2010	x			x			x	
CHINA	Qin, D. (ed)	2015	x			x			x	
CZECH REPUBLIC	Ekotoxa Ltd., Ministry of the Environment	2015	x			x				x
DENMARK	Danish Nature Agency	2012	x			x			x	
ESTONIA	Ministry of the Environment	2017	x			x				x
FINLAND	Ministry of Agriculture and Forestry	2013				x				x
FRANCE	Ministry of Ecology and Sustainable Development	2009	x			x				x
GERMANY	Federal Environment Agency	2015	x			x			x	
GREECE	Bank of Greece	2011	x			x				
HUNGARY	Farago, T; Lang, I; Csete, L. (eds)	2010	x			x				x
ICELAND	Ministry of Environment	2010	x			x				x
INDIA	Ministry of Environment & Forests	2010			x	x			x	
INDONESIA	Ministry of National Development Planning/ National Development Planning Agency (BAPPENAS)	2012	x			x			x	
IRELAND	Irish Climate Analysis and Research UnitS (ICARUS) for the Environmental Protection Agency	2010	x							x
ISRAEL	Ministry of Environmental Protection	2008	x			x				x

	Author	Year	Sectoral focus			Climate hazard focus			Nature of assessment	
			Multi-sectors	Transport only	Water only	Multi-hazard	Coastal change only	Flooding only	Qualitative	Quantitative
ITALY	Ministry of the Environment and the Sea	2014	x			x			x	
JAPAN	Central Environment Council	2015	x			x			x	
KOREA	Ministry of Environment	2010	x			x				x
LATVIA	Ministry of Environmental Protection and Regional Development	2017	x			x				x
LITHUANIA	Ministry of Environment	2015	x			x			x	
LUXEMBOURG	Ministry of Sustainable Development and Infrastructure	2014	x			x				x
MEXICO	Ministry of the Environment and Natural Resources	2013			x		x	x		x
NETHERLANDS	PBL Netherlands Environmental Assessment Agency	2012	x			x			x	
NEW ZEALAND	New Zealand Government	2008	x			x			x	
NORWAY	Ministry of the Environment	2010	x			x			x	
POLAND	Ministry of the Environment	2013	x			x				x
PORTUGAL	Portuguese Republic	2010	x			x			x	
RUSSIA	Roshydromet	2017	x			x			x	x
SAUDI ARABIA	KSA	2015	x				x		x	
SLOVAK REPUBLIC	Ministry of the Environment	2014			x				x	
SLOVENIA	Ministry of the Environment	2010	x			x				x
SOUTH AFRICA	Davis, C. (ed)	2011	x			x			x	
SPAIN	Ministry of the Environment and the University of Castilla La Mancha	2005	x			x				x
SWEDEN	Swedish Metrological and Hydrological Institute	2015	x			x			x	
SWITZERLAND	Federal Office for the Environment	2017	x			x			x	
TURKEY	Ministry of Environment and Urbanization	2012	x			x				x
UNITED KINGDOM	Committee on Climate Change	2016	x			x				x
UNITED STATES	Environmental Protection Agency	2017	x			x				x

6 Useful tools and reports



Climate change and infrastructure

- Asian Development Bank (2015), Economic Analysis of Climate-Proofing Investment Projects
- IPCC (2012), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)
- IPCC (2014), 5th Assessment Report: Climate Change 2014: Impacts, Adaptation, and Vulnerability
- Vallejo and Mullan (2017), Climate-resilient infrastructure: getting the policies right
- Campillo, Mullan and Vallejo (2017), Climate change adaptation and Financial protection
- OECD (2017), Investing in Climate, Investing in Growth, OECD Publication
- IADB (2017), Policy Evaluation Framework on The Governance of Critical Infrastructure Resilience in Latin America
- OECD (2014), Boosting Resilience through Innovative Risk Governance

Green finance

- OECD (2012) Towards a Green Investment Policy Framework
- OECD/CDSB (2015) Climate change disclosure in G20 countries: Stocktaking of corporate reporting schemes
- OECD (2017), Investment governance and ESG factors
- OECD (2018), Blended finance: mobilising resources for sustainable development and climate action in developing countries
- OECD (2018), Making Blended Finance Work for the Sustainable Development Goals

Sectoral adaptation

- IEA (2015). Making the energy sector more resilient to climate change
- ITF (2016), Adapting Transport to Climate Change and Extreme Weather
- OECD (2018), Financing Water: Investing in Sustainable Growth
- OECD (2013), Water and Climate Change Adaptation
- UIC (2010), Adaptation of Railway Infrastructure to Climate Change

Websites and online platforms

- Adaptation Learning Mechanism - compendium of good practices and knowledge on adaptation – http://www.adaptationlearning.net
- Climate-Adapt - European climate adaptation platform - http://climate-adapt.eea.europa.eu/
- Climate & Disaster Risk Screening Tools - toolkit designed to support the screening of World Bank investments - https://climatescreeningtools.worldbank.org/
- World Bank Climate Change Knowledge Portal - central hub information, data and reports about climate change around the world - http://sdwebx.worldbank.org/climateportal/



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Climate-resilient Infrastructure

A co-ordinated policy response is needed to ensure that new and existing infrastructure networks are resilient to climate change. This Policy Paper outlines a framework for achieving this based on the experiences in OECD and G20 countries. It shows how governments and businesses can collaborate to mobilise investment for climate-resilient infrastructure.

This Policy Paper was prepared as an input document for the G20 Climate Sustainability Working Group under the Argentine G20 Presidency.

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December 2018