# G20/OECD report on approaches for financing and investment in climate-resilient infrastructure

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BUILDING A JUST WORLD AND A SUSTAINABLE PLANET

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# Executive summary

Infrastructure damages caused by extreme weather and slow onset events in the last years demonstrate how infrastructure is affected by climate change, and are expected to become increasingly severe. Enhancing climate resilience of infrastructure will be critical for achieving sustainable development in a changing climate.

Developing countries have an urgent need to expand access to infrastructure services, such as clean water and electricity, to support progress towards the Sustainable Development Goals (SDGs) which can be particularly challenging when they are vulnerable to climate change.

Meanwhile, all countries are faced with the need to manage the increasingly severe impacts of climate change on infrastructure.

Proportionate, targeted measures to integrate climate resilience across the infrastructure lifecycle can strengthen economic returns, protect social services, and reduce risks to public finances. Governments at all levels should *consider investments in upfront climate resilience of infrastructure assets* as it can strengthen the basis of investment returns, and reap cost-benefits for public investment.

Recommendations in this report are broad in nature, and application should be balanced within the context of each country. The specific country circumstances will affect how each recommendation is adapted and applied. Emerging and developing countries in particular may require specific considerations to be made in the application of these recommendations.

**Improving understanding of and enhancing transparency on climate risks**

- Actions that allow governments and investors to *better assess and understand climate risk* should be integrated into investment decisions, and financial structures that support climate-resilient infrastructure should be encouraged.
- By *understanding the role and unique challenges of subnational governments and communities* to provide local climate-resilient infrastructure that protects local businesses and communities, targeted action can be adopted to better address the spatially differentiated impacts of climate change.
- *Risk transfer mechanisms and insurance arrangements* can provide better climate risk assessment and understanding for infrastructure assets, and price climate risk, providing a pathway for quicker recovery funds being made available.
- By improving *sustainability reporting, standards, labels and taxonomies*, greater visibility of physical climate risk could be achieved, and inform investors of climate risk exposure.

**Mainstreaming climate resilience into infrastructure development**

- By *leveraging fiscal allocation, and planning and processes*, governments can better integrate climate resilience into their infrastructure planning. Mechanisms such as National Adaptation Plans (NAPs), Environmental Impact Assessment (EIAs), procurement processes and PPPs could offer opportunities to integrate climate adaptation for infrastructure projects design and planning, and link budgetary allocation.
- *MDB funding and technical assistance* plays a key role in ensuring that climate resilience is better integrated into infrastructure projects in their borrowing countries. The extent to which MDBs and other global funds are structured and made available to developing countries will strongly inform how some of the major infrastructure projects in developing countries are climate resilient.

**Enhancing access to finance**

- Governments can *leverage financial instruments* such as green and sustainability bonds to support financing of climate resilient infrastructure. In addition, innovative financial instruments, such as catastrophe (“cat”) bonds, outcome-based instruments, risk guarantees, and climate resilient debt clauses could provide opportunities for attracting investment.
- Establishing *blended finance mechanisms with climate-oriented objectives* can offer an effective mechanism to support the development of climate resilient infrastructure in developing countries.
- *Public facilities for infrastructure financing*, such as infrastructure-focussed banks, development banks and dedicated funds that have climate mandates, can provide pathways to attract private sector financing into climate-resilient infrastructure.
- Governments can consider *tax incentives for infrastructure assets* that encourage greater climate risk reduction and adaptation measures being taken.
- Mechanisms such as *emission trading* could provide allowances that could secure funding towards climate resilience, as well as *land value capture and asset recycling* can provide a means to fund climate resilience of infrastructure assets using existing infrastructure assets.

# 1 Introduction

Infrastructure is key for supporting a well-functioning society. It has an essential role in ensuring the well-being of people and the functioning of the economy by enabling the circulation of people, goods and information, providing connectivity and key resources such as water or energy, which sustain critical functions for society.

Climate-resilient infrastructure describes infrastructure that is planned, designed, constructed and operated in a way that anticipates, prepares for and adapts to the changing climate, while it can withstand and recover rapidly from disruptions caused by changing climatic conditions throughout its entire lifetime. It concerns both new assets, as well as existing ones, which may need to be retrofitted or operated differently to account for climate change impacts (OECD, 2018[1]).

Infrastructure is capital intensive and long-lived, with some assets having the lifetime of decades or centuries. Decisions made today about the location, design and nature of infrastructure have long-term effects, including whether investments deliver objectives and anticipated benefits over their lifetime, as well as whether they may need to be retrofitted in the context of climate change.

The physical impacts of climate change are becoming increasingly visible, as weather patterns diverge from historic norms (see Box 1). Climate change is exacerbating risks to the provision of infrastructure services, for example due to the flooding of transport links. It is also influencing the demand for infrastructure services. In some places, milder winters and warmer summers, for example, will reduce energy demand in winter and increase in the summer, while rising seas will require improvements in coastal defences.

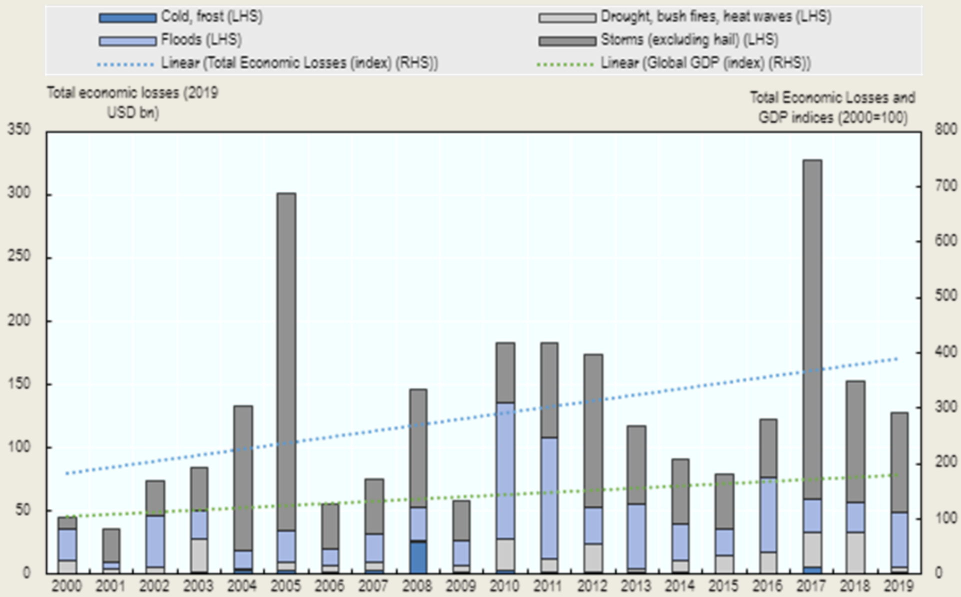
Climate change affects infrastructure assets and their operations in diverse ways, which can be caused by both slow onset events and impacts which occur due to extreme weather events, causing damages and disruptions in a matter of days or hours. Climate change makes infrastructure assets and operations subject to increasingly long disruptions, with ever increasing implications. As most infrastructure assets are interdependent with other systems and a range of societal and economic functions rely on them, the failure of infrastructure can cause a wide range of cascading impacts.

However, infrastructure also plays an essential role in building more resilient economies and societies by reducing their vulnerability to the impacts of climate change. For example, resilient transport networks can facilitate reconstruction following a storm. Protective infrastructure, such as flood barriers, can reduce damage due to extreme events. Where infrastructure continues to provide services despite the impacts of climate change, this allows communities and businesses to continue functioning and to absorb shocks to their assets better.

## Box 1. Economic losses from weather-related catastrophes

Data from Swiss Re's Sigma database indicates that losses from weather-related catastrophes have been increasing at a faster rate than global GDP. This is consistent with an increase in weather-related hazards – such as drought, floods and wildfires – driven by climate change. It is also influenced by improvements in reporting and increases in the value of the assets located in exposed areas. Annual average economic losses from weather-related catastrophes were more than 200% higher in 2015-2019 than they were in 2000-2004 (in constant dollars).

### Figure 1. Losses from weather-related catastrophes




Note: This figure shows reported total economic losses resulting from weather-related catastrophes for all countries between 2000 and 2019 (LHS, in constant 2019 USD billions) as well as the trend in total losses and trend in global GDP (RHS, trend line based on an index with 2000=100).
Source: OECD calculations based on loss data provided by Swiss Re sigma and GDP data reported in the IMF World Economic Outlook database (Swiss Re sigma, 2020[2])

There is a strong economic case for investing in the climate-resilience of infrastructure. While climate-resilience measures can increase the life span of infrastructure, they also play an essential role in protecting investment returns and ensuring business continuity. Investments in climate resilience have shown to have a net-positive impact over time through preventing climate risks and strengthening the basis of investment returns.

Investing proactively to achieve climate-resilient infrastructure systems is cost effective, can save lives and support continued economic growth. For example, one major study found an average of USD 4 of benefits for every USD 1 invested in climate-resilient infrastructure over the lifetime of the asset (Hallegate, Rentschler and Rozenberg, 2019[3]). Analysis in the United States found that adaptation could reduce annual losses to infrastructure by a factor of ten (Neumann et al., 2021[4]). However, this potential has yet to be fully realised. Mobilising finance for climate-resilient infrastructure – and making climate resilience a consideration for all new infrastructure investments – will be critical to achieve climate-resilient infrastructure systems.

The need to increase investment flows for climate-resilient infrastructure exists against the context of a significant overall infrastructure finance gap, and challenging macroeconomic conditions. The economic consequences of COVID-19, and subsequent economic difficulties and geopolitical issues have contributed to rising public debt, inflation and interest rates (OECD, 2023[5]). This has increased the cost of new infrastructure, in particular capital expenditure, limited the capacity of the public to finance new investments, and diverted the attention of the private sector to other areas. Given these pressures, and the urgent need to enhance resilience to climate change, it will be essential to maximise the impact and efficiency of public investment, in parallel to unlocking private investment.

This report examines the rationale for having climate-resilient infrastructure and then the types of risk assessment approaches for climate risk. Regional and local governments, and community considerations will also be made to support climate resilience of infrastructure. It then turns to financial perspectives, looking at the financial flows towards climate-resilient infrastructure, and then aspects that can lead to the mainstreaming of climate-resilient in infrastructure financing. Lastly, it explores how to increase investment flows by looking at the funding and financing of climate-resilient infrastructure.

# 2 The rationale for building climate-resilient infrastructure and investing into it

Greenhouse gases emitted into the atmosphere to date have already led to considerable warming and as a consequence intensified climate risks. Global mean temperatures exceeded pre-industrial levels by over 1.4°C in 2023 (Copernicus, 2023[6]). Most land areas experienced an increase in the frequency and intensity of heavy precipitation events since 1950 (IPCC, 2021[7]). Similarly, the duration, frequency and intensity of droughts increased in many regions of the world since the middle of the past century (Spinoni et al., 2014[8]). Europe experienced its worst drought in 500 years in 2022 (Toreti et al., 2022[9]). The duration of the fire weather season (OECD, 2023[10]) also increased by 27% globally between 1979 and 2019, with notable increases in western North America, southern Europe, Australia, western and central Asia and most of Africa (Jones et al., 2022[11]) (OECD, 2023[10]). Average sea levels to date have risen by 21-24 cm compared to pre-industrial levels (NOAA, 2022[12]).

The various infrastructure investment gap figures that are cited[1] do not explicitly take into account the financing needed for climate resilience (see section 0). Recent estimates on physical assets, energy and land use could amount to USD 9.2 trillion per year between 2021 and 2050 to achieve net zero (McKinsey, 2022[13]). The cost of adaptation for making energy and transportation infrastructure resilience for developing countries (2015-2030) were estimated at USD9-17 billion per year for energy, and USD860 million to USD35 billion per year for transport (UNEP, 2023[14]).

## How infrastructure is being affected by climate change

Climate change affects infrastructure assets and their operations in diverse ways. Climate change impacts on infrastructure include those caused by both slow onset events, which result from hazards that occur and are sustained over long periods of time (e.g. limited water availability due to drought). Or they could be sudden disasters due to extreme weather events (e.g., storms disrupting telecommunications networks), causing damages and disruptions in a matter of days or hours. Different infrastructure sectors are exposed to different climate hazards, and can result in the disruption of services (Table 1). For example, droughts are a particular issue for riverine transport, while having less impact on rail, air and road transport. In contrast, high temperatures may affect road infrastructure at highways and airports, as well as railway lines, while leaving sea and river transport routes largely unaffected (although workers may be substantially affected by extreme heat). Overall, the degree to which climate change poses risks for infrastructure depends on the type of climate hazard and its interaction with the vulnerability and exposure of infrastructure to it.

## Table 1. Climate risks affecting selected types of infrastructure in different ways

| Infrastructure type | | Climate hazard | Infrastructure impacts |
|---|---|---|---|
| Transport | Land (roads, railways) | Extreme heat | Pavement softening (rutting), thermal rail expansion (buckling) |
| | | Extreme precipitation | Washouts, flooding of roads and railways |
| | | Riverine flooding | |
| | | Storm surges and sea level rise | Inundation and de-stabilisation of coastal road and railway lines |
| | | Storms, high winds | Blockage of roads and railways due to fallen trees and other damaged assets |
| | | Permafrost melt | Buckling and destabilization of roads and railways |
| | Riverine | Droughts | Riverine transport routes (temporarily/seasonally) becoming unnavigable |
| | | Riverine floods | Damage to ports, ships and cargo, riverine transport routes temporarily becoming unnavigable |
| | | Storms, high winds | |
| | Marine | Sea level rise and storm surges | Inundation of ports |
| | | Temperature rise | Changing demand for ports and Artic waters become navigable |
| | | Storms, high winds | Damage to ports, ships and cargo, certain transport routes (temporarily) becoming unsafe |
| Energy | Hydropower | Droughts | Reduced hydropower production, with the possibility of stranded assets if drops in water levels persist |
| | | Floods | Damages to hydropower plants |
| | Nuclear | Droughts and/or high temperatures | Reduced availability of cooling water |
| | | Riverine flooding | Damage to assets, safety issues, pollution |
| | | Sea level rise and storm surges | |
| | Solar | Extreme temperatures | Reduced efficiency of solar panels |
| | Energy sector overall | Extreme temperatures | Increased demand for cooling, increased pressure on the power grid |
| | | Sea level rise, storm surges | Inundation of coastal power plants, transmission and distribution lines |
| | | Wildfires | Damage to power production assets, transmission and distribution lines |
| | | Riverine flooding | Disruption of energy supply due to flooding of transmission lines or power plants |
| | | Storms, high winds | Power outages, damage to power production assets, transmission and distribution lines |
| Telecommunications | | Extreme heat | Overheating of data centres |
| | | Riverine floods | Flooding of data centres, radio/television stations, telecommunications towards, distribution lines, etc, |
| | | Sea level rise and storm surges | |
| | | Extreme precipitation | |
| | | Storms, high winds | Damage to telecommunications towers, distribution lines |
| | | Wildfires | Burning of transmission cables, telecommunications towers |
| Water supply, waste- and stormwater infrastructure | | Extreme heat | Increased evapotranspiration from reservoirs, increased need for water treatment |
| | | Extreme precipitation | Sewage overflows, overtopping of dams, levees and reservoirs, increased need for water storage capacity |
| | | Riverine flooding | Contamination of water sources, overtopping of dams, levees and reservoirs, increased need for water storage capacity |
| | | Droughts | Reduced water supply |
| | | Sea level rise and storm surges | Salinisation of water supply, inundation of water treatment infrastructure |

Note: While this table gives an illustration of potential climate hazards and impacts that can occur for various infrastructure types, it does not provide an all-encompassing list of infrastructure types, climate hazards and impacts

Source: Based on (OECD, 2018[1]) and (IISD, 2021[15])

Infrastructure damages caused by extreme weather events in the last years demonstrate how infrastructure is affected by climate change. Between 2000 and 2020, small island developing states (SIDS) and least developed countries (LDCs) had an average of 23 and 7 natural disasters per 1,000 square kilometres, respectively. This translates to between 10 and 30 times more disasters than experienced in OECD countries (OECD, 2024[16]). In SIDS, the estimated annual damage of coastal flooding amounts to EUR1.54 billion for all SIDS combined, which include direct damage to buildings, infrastructure, and agriculture (EU Joint Research Centre, 2023[17]). In the United States, the number of blackouts caused by extreme weather events increased from 5 to 20 annually in the 1990s to between 50 and 100 in the early 2010s (Castillo, 2014[18]) (Chang, 2016[19]). Table 2 provides a non-exhaustive overview of examples of infrastructure damage caused by climate change-induced extreme events in the recent past.

## Table 2. Selected climate change-induced events damaging infrastructure

| Year | Type of event | Location | Link to climate change | Infrastructure Damage |
|---|---|---|---|---|
| 2018 | Wildfire ("Camp Fire") | United States | Climate change was found to have doubled the extreme weather that facilitated the wildfire (Williams et al., 2019[20]) (Goss et al., 2020[21]) | 19,000 assets destroyed, including homes, hospitals, schools and business buildings (Fischer et al., 2021[22]). |
| 2019 | Storm ("Typhoon Hagibis") | Japan | The typhoon was found to be 67% more likely due to climate change (Li and Otto, 2022[23]) | Levees destructed at 135 locations; 10 trains and 120 carriages damaged in a flooded depot. Due to damages to power and water infrastructure, 22 000 households lacked power, while 133 000 homes were without water for over two weeks (Tulane University Law School, 2021[24]) |
| 2021 | Ahr Valley Floods | Germany | Climate change increased the intensity of the rainfall associated with the floods by 3-19% and heightened their likelihood by 1.2 to 9 times (Tradowsky et al., 2023[25]). | Over 50 bridges, 600 km of rails and three federal highways damaged and out of operation for months. Buildings, the transport infrastructure and sector suffered around EUR 14 billion of direct and indirect damages (Prognos, 2022[26]) |
| 2022 | Drought | Europe | The drought was found to be 5 to 20 times more likely due to high temperatures associated with climate change (Schumacher, 2022[27]) | -30 % lower hydropower generation in the first 6 months of 2022 for the French utility company, EDF, resulting in an income loss of EUR 1.4 billion (S&P Global, 2022[28]). Severe fluvial transport disruptions on the Danube and Rhine Rivers (CCNR, 2023[29]) |
| 2020 | Floods in Jakarta | Indonesia | The flood is assumed to be the highest extreme rainfall since 1866 (Lubis et al., 2022[30]). Such event is considered as exacerbated by climate change by the Indonesia Meteorology, Climatology and Geophysics Agency[2] | 173,000 people were evacuated, 66 people died, more than 60% of the residential areas were submerged, and the economic loss reached over US$700 million. The flood cut off electricity and piped water, severed a number of roads, and shut down one of the city's two airports (World Bank, 2022[31]) |
| 2021 | Storm (Typhoon Odette) | The Philippines | Odette is the second most devastating typhoon since 2011[3].The typhoon increased in speed extremely quickly and affected areas that were almost never touched by typhoons. Such rapid intensification is considered common due to climate change. | 156 cities experienced water shortage, major disruptions to power supply, creating additional pressure on 80% of water systems that rely on power generation. It took months to restore access to basic lifelines, creating additional risks of disease outbreaks due to degraded access to safe water and sanitation, in a context where 210 health facilities were also destroyed. All together Typhoon Odette is estimated to have affected 10.9 million people and caused damages to infrastructures worth USD 556.8 million |

| Year | Type of event | Location | Link to climate change | Infrastructure Damage |
|---|---|---|---|---|
| | | | | (OCHA, 2021[32]) |
| 2024 | Dubai floods | UAE | Warming atmosphere caused by climate change likely caused extreme rainfalls with more than double the annual rainfall in one day, with the heaviest rainfall in 75 years in UAE. | 300 flights cancelled from Dubai International Airport (BBC, 2024[33]), with estimates of USD8 billion of aircraft at risk (Jolly, 2024[34]) |
| 2024 | Rio Grande do Sul floods | Brazil | Combination of climate change, and other causes (Gandra, 2024[35]) | Operations suspended at Salgado Filho International Airport (POA). Public transport, including in Porto Alegre, is severely disrupted.<br>Flood waters have cut off towns across the region, as hundreds of roads have been blocked by flooding across Rio Grande do Sul.<br>Power outages are impacting multiple locations. (CRISIS24, 2024[36])<br>581,000 displaced citizens and 2.3 million are affected (CASA MILITAR DEFESA CIVIL RS, 2024[37]) |
| 2024 | Russia-Kazakhstan floods | Russia | Rapid melting of snow and ice combined with heavy rain. | Power and water supply disrupted<br>125,000 displaced citizens (DW, 2024[38]) |

Source: (CCNR, 2023[29]) (Fischer et al., 2021[22]) (Fisher and Gamper, 2017[39]) (Goss et al., 2020[21]), (Karels, 2019[40]), (OECD, 2014[41]), (Prognos, 2022[26]), (Schumacher, 2022[27]), (S&P Global, 2022[28]), (Tradowsky et al., 2023[25]), (Tulane University Law School, 2021[24]), (Williams et al., 2019[20]).

The severity of climate impacts will vary within countries. For example, cities are particularly impacted by heat waves, as the temperature tends to be higher than in the surrounding areas due to the urban heat island effect. In the past 5 years, almost half of OECD cities witnessed a summer daytime heat island effect of more than 3°C (OECD, 2022[42]). The 2023 G20/OECD report on *Financing Cities of Tomorrow* reports that the growth of cities will need to be adapted towards climate change through massive investment (OECD, 2023[43]) The differing spatial distribution of climate hazards, overlaid atop of different regions and cities' physical, economic and social characteristics, means that there is a strong spatial dimension to consider.

Climate impacts on infrastructure also vary between countries, with developing countries being particularly at risk, due to limited resources and adaptive capacity. Furthermore, inequalities, manifested for example by unequal housing conditions and access to healthcare and infrastructure services exacerbate vulnerabilities in many developing countries to infrastructure disruptions. In 2023, two major dams collapsed after heavy storms around the city of Derna, Libya, leaving at least 4 300 people dead and 40 000 displaced (Zachariah, 2023[44]).

As most infrastructure assets are interdependent with other systems and a range of societal and economic functions rely on them, the failure of infrastructure can cause a wide range of cascading impacts (Vallejo and Mullan, 2017[45]). Similarly, droughts – and associated low water - on the Rhine River in 2018 prevented shipping on 80% of days between June and December (Prognos, 2022[46]), which had severe implications on plants relying on the river for the transport of raw materials and products in Germany's Ruhr region. The interruption of logistics chains for chemical, petroleum products, ores, other raw materials and goods caused a loss of EUR 5 billion to Germany's economy in the second half of 2018 (CCNR, 2019[47]).

Ecosystem damages associated with infrastructure failures can also be significant. After the collapse of two major dams in Derna, polluted sediments and debris flooded parts of the El Kour Natural Park, harming wildlife in Ramsar protected coastal lagoon areas (CEOBS, 2023[48]).

## Benefit-cost analysis of investment into climate-resilience of infrastructure

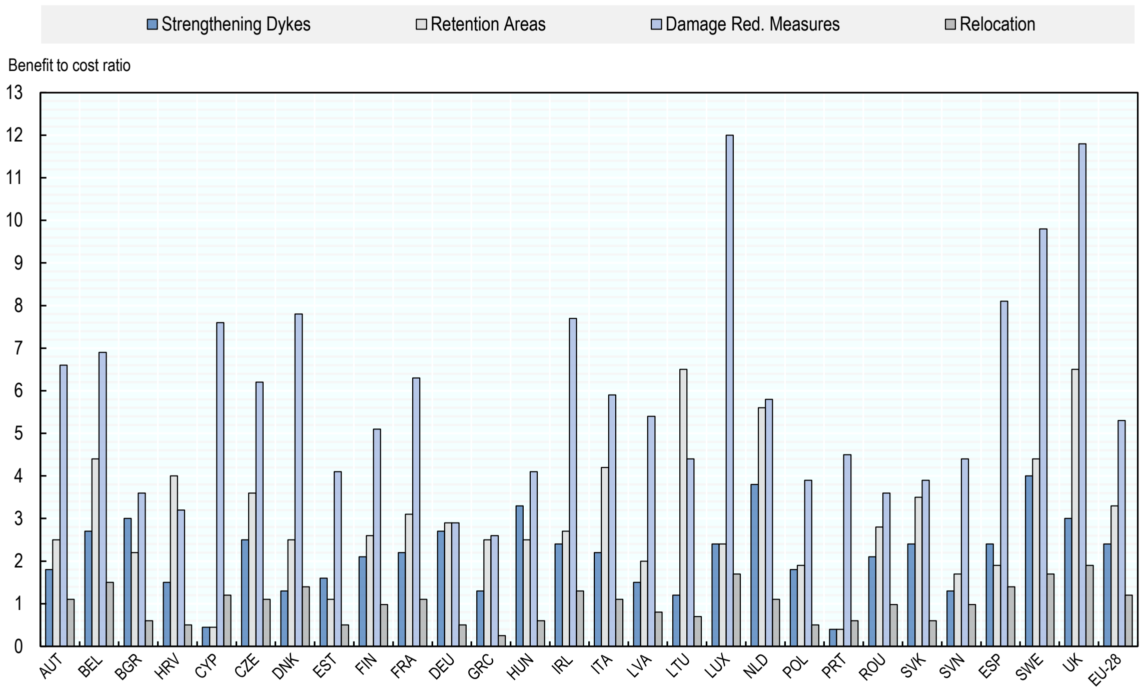
While climate resilience measures can increase the lifespan of infrastructure, they also play an essential role in protecting investment returns and ensuring business continuity. Targeted action to address climate risks can increase costs in the design and implementation phase can result in being cost effective (Hallegatte, Rentschler and Rozenberg, 2019[49]). Spending on infrastructure resilience *ex ante* can reduce repair costs and maintenance needs over time, as well as lower the cost of service disruptions and damages. For example, projects to enhance resilience to wind and water damage in Florida, United States have avoided losses of over USD 81 million when Hurricane Matthew struck in 2016, far outweighing the USD 19.2 million implementation cost of risk reduction measures (C2ES, 2018[50]). Similarly, while making transport infrastructure resilient to future floods is estimated to make up between 3% to 10% of project investment costs, annual future flood damages can be 42% lower (Hall et al., 2019[51]).

In the People's Republic of China (hereafter 'China'), every CNY 1 invested in climate resilient infrastructure could deliver CNY 2 to 20 in return over a 30-year period (Ding et al., 2021[52]). For example, the benefits of investing in "sponge city" infrastructure to enhance the resilience of the city of Wuhan, China to heavy precipitation outweigh the costs more than twice over three decades through the avoided the socio-economic costs of waterlogging, reduced municipal water pollution control costs and increased ground water recharge (Ding et al., 2021[52]).

An estimation of benefits and costs of public investment into four different adaptation measures across Europe was carried out based on a 2°C increase of temperatures from industrial levels: strengthening dikes, establishing retention areas, implementing property damage reduction measures and removing buildings at future flood risk. The use of retention areas shows strong potential to lower impacts in a cost-efficient way. Strengthening existing dyke systems can prevent floods, although there is the potential of transferring risks downstream. Implementing property damage reduction measures have the highest cost-benefit ratio due to limited implementation investments (Figure 2).

In Peru, a benefits and costs analysis was carried out on a number of potential disasters in relation to public investment, and, for example, the rehabilitation of a dyke was estimated at a ratio of 37.5, and prevention and preparedness for mudslides and floods at a benefit cost ratio of 10 (from a 2009 report by UNISDR cited in (CDRI, 2023[53])).

### Figure 2. Benefit-cost ratio values for four adaptation measures for the period 2020-2100, under a 2°C scenario




Note: The costs were calculated as the sum of capital investment costs to implement the measure and maintenance costs. The benefits are the damages avoided by implementing the measure, calculated as the difference between future damages with and without adaptation respectively. Flood losses, costs and benefits are presented undiscounted in general, so that present and future scenarios with and without adaptation can be compared while giving equal weight to each of them. Discount rates are used to evaluate the cost-effectiveness of the investments required for the four adaptation measures considered. The benefit-to-cost ratio, which is the ratio of total benefits to total costs, is also based on discounted values and was calculated for each NUTS2 region and at country and EU+UK level.
Source: Reproduced from (Dottori et al., 2020[54])

Additional social, environmental and economic co-benefits further strengthen the case to invest in climate-resilient infrastructure. While environmental aspects must be carefully monitored to avoid potential trade-offs, climate resilience measures can also bring benefits for the environment. For example, making the Slussen lock around lake Mälaren climate-resilient has given the lake a more natural water balance than the previous lock, benefitting plants and wildlife along the lake and its Natura 2000 protected sites (Vallejo and Mullan, 2017[45]). Nature-based solutions (NbS) offer climate resilience building with a wide-range of social and ecosystem co-benefits. For example, restoring around 6 km of oyster reefs in Mobile Bay, Alabama, United States helped protect the shoreline from coastal erosion by reducing wave energy (by 91%) and height (by 53%), while providing seafood equivalent of half of total oyster harvests in Alabama and lowering nitrogen pollution (World Bank and World Resources Institute, 2022[55]).

### Box 2. How climate risk can impact the performance of infrastructure assets in markets

Utilities are now being affected by climate risk through their financial performance in markets. Utilities that are exposed to extreme weather events, in particular wildfires, are experiencing drops in their share prices due to the potentially substantial liability claims if their infrastructure is found to have started a wildfire. A study found that companies facing high transition risk which are not proactively responding have been valued at a discount in recent years (Qing et al., 2024[56]).

In relation to this, shares of companies that are more exposed to transition risk or imminent government intervention is priced in the stock market, and not direct risks from climate change itself. Thus, climate risk could be more prominent in terms of impacting stock market performance through transition risk, then physical climate risk itself (Faccini, Matin and Skiadopoulous, 2023[57]) (Raimonde and Chediak, 2024[58]).

While more research is necessary and information asymmetry remains an issue for the stock markets, certain infrastructure assets such as utilities could be affected by climate risk exposure. In addition, policy actions could also have an impact on share prices of infrastructure assets. However, if the impact of physical climate risk were to increase, this could evolve too.

Source: (Qing et al., 2024[56]) (Faccini, Matin and Skiadopoulous, 2023[57]) (Raimonde and Chediak, 2024[58]).

Furthermore, it is costly to delay action. Postponing climate resilience measures in infrastructure can lock in infrastructure damages and service disruptions, as well as costs incurred for repair and retrofit needs. In low- and middle-income countries, the cost of delaying climate resilience investments in infrastructure by ten years was estimated at an additional USD 1 trillion (Hallegate, Rentschler and Rozenberg, 2019[3]). In the United States, it is estimated that road repairs due to increasing temperatures would reach a cumulative USD 200 to 300 billion in the absence of adaptation measures by 2100 (Chinowsky, 2022[59]).

Early adoption of climate resilience measures can thus help avoid future costs and offer comparative advantages by providing robust and reliable infrastructure services. There are two critical elements to the climate-resilient infrastructure financing challenge:

- Making climate-resilience a consideration for all new infrastructure investments: targeted, proportionate early action to mainstream climate resilience into infrastructure projects adds an average of 3% to baseline infrastructure investment needs in the case of power, transport, and water and sanitation infrastructure investments in low- and middle-income countries (Hallegate, Rentschler and Rozenberg, 2019[3]). As such, this challenge is predominantly about mainstreaming climate-resilience into business-as-usual finance flows and decision-making, rather than the total volume of finance required.
- Investing in infrastructure that targets climate resilience: additional infrastructure investments will be required to address climate impacts. This includes the construction of protective infrastructure (such as flood defences), as well as new investments required to address weaknesses in existing infrastructure systems (for example, by burying transmission lines or adding redundancy to transport networks). Additional finance will be needed for these investments.

Integrating climate resilience into infrastructure assets influences the business case for investing in those assets. This is context specific, but generally there is a trade-off between capital costs and revenues. Integrating climate resilience can (modestly) increase capital costs, but it should lead to more reliable revenues, lower maintenance requirements, lower risk which can support insurance provision, and potentially higher co-benefits. However, the capital costs are visible, while the benefits will materialise over time. As a result, these benefits are not fully valued in public and private decision making. Consequently, investment in resilience looks like a cost to be minimised rather than a source of value to be realised.

The additional cost of making assets more climate resilient will depend on the type of hazard and asset. Increasing flood resilience of a road through bigger drainage pipes or trenches requires a small percentage of construction costs, while increasing flood resilience of a railway by elevating it requires 50 percent of its costs (Hallegate, Rentschler and Rozenberg, 2019[3]).

### Box 3. Climate resilience as a vital element of resilient, sustainable and quality infrastructure

Climate-resilient infrastructure is an essential element of the broader efforts to achieve resilient infrastructure. Broader infrastructure resilience includes resilience to non-climate-related natural hazards (such as earthquakes) but also human-induced risks (such as terrorist attacks or industrial accidents) (OECD, 2021[60]). This broader resilience capacity is defined by OECD as the “ability to resist, absorb, recover from or successfully adapt to adversity or a change in conditions” (OECD, 2014[61]).

Resilience is an essential part of sustainable and quality infrastructure investment and development. Thus, while these concepts overlap, sustainable and quality infrastructure respectively represent broader concepts than climate-resilient infrastructure. Sustainable infrastructure includes built and/or natural systems that provide a range of services in a manner that ensures economic, social, environmental sustainability throughout the entire infrastructure lifecycle (from planning to decommissioning and repurposing), in line with the Sustainable Development Goals (OECD, 2021[60]). Sustainable infrastructure is thus a broader concept, encompassing considerations of usefulness, viability, efficiency, technical stability, financial sustainability, good governance, while being environmentally and socially sustainable, and contributing to both climate change adaptation and mitigation goals. Quality infrastructure represents an even broader concept, which, besides being aligned with the Sustainable Development Goals and contributing to their delivery, aims to maximise the economic, social, environmental, and development impacts of infrastructure (OECD, 2021[62]). Furthermore, it focuses on raising the economic efficiency of infrastructure throughout its lifecycle, while integrating environment and social considerations and enhancing resilience. The OECD has been championing quality infrastructure through several initiatives, including support for the development of the G20 concept for quality infrastructure investment.

Source: (OECD, 2014[61]), (OECD, 2021[60]), (OECD, 2021[62]).

On the other hand, some resilience-building interventions which apply new technology or use advanced material can even lower capital expenditure while improving climate-resilience. One example is a modular bridge solution that encase the deck structure of a bridge in stainless steel. This approach results in a significantly longer design life of up to 100 years with lower maintenance costs—a performance well beyond that achieved with the traditional in situ reinforced concrete. Construction costs are also lower because a standardised formwork (including reinforcement) can be delivered to a site in a container, with deck casting conducted in a single pour, as opposed to the longer times and complex formwork needed for traditional in situ structures (Hallegate, Rentschler and Rozenberg, 2019[3]).

All in all, increasing finance for climate-resilient infrastructure fits within the broader challenge of filling the infrastructure finance gap (see Box 3). Additional investment will be required every year for infrastructure investment: there are widespread needs to replace and retrofit ageing infrastructure, in particular. Developing countries have an urgent need to expand access to infrastructure services, such as clean water and electricity, to support progress towards the Sustainable Development Goals (SDGs). This can be particularly challenging in low-income countries that are particularly exposed to climate change.

A key driver of infrastructure investment needs is the transition to net zero which will require significant increases and reallocation of investments to decarbonise key infrastructure sectors, including through large-scale rollout of renewables and electrification of the transport sector. On top of this, developing countries need to expand their infrastructure to assure the provision of essential services - especially for water, sanitation and electricity. The OECD report *Investing in Climate, Investing in Growth* (2017) estimated that USD 6.9 trillion of investment in infrastructure is required annually on average between 2016 and 2030 to meet development and climate needs globally. More recent analysis by IEA has estimated that the transition to clean energy alone will require USD 4.5 trillion of investment per year by the early 2030s (IEA, 2023[63]).

### Box 4. Mobilising institutional investment for infrastructure

Mobilising private investment will be critical for filling the overall infrastructure finance gap, given the scale of financing needs and continuing pressures on public budgets. Institutional investors have been identified as a key finance source for two key reasons: the scale of assets under management (estimated at USD 53 trillion in 2022 for pension assets). (OECD, 2023[64]) and the potential for matching long-term infrastructure assets to long-term liabilities. Institutional investors surveyed by the OECD with approximately USD 9.8 trillion of assets under management in 2022 allocated USD 302.6 billion (representing 3%) to infrastructure investments. (OECD, 2024[65])

The following areas have been identified for unlocking this potential:

- Increased standardisation, where feasible, in terms of contractual terms, data, technical specifications, etc
- Bundling of infrastructure investments to match investor needs
- Improve the enabling environment for investment in infrastructure, including capacity, strong institutions and having an independent judicial system
- Governments can develop the market for infrastructure through the development of project pipelines and giving greater predictability of policy
- Examine the risk allocation and risk sharing between public and private sectors to ensure investable projects. In developing countries, use blended finance instruments to match the risk and return expectations of institutional investors.

Source: OECD (2020), Green Infrastructure in the Decade for Delivery: Assessing Institutional Investment, Green Finance and Investment, OECD Publishing, Paris, https://doi.org/10.1787/f51f9256-en.; G20/OECD Report on the Collaboration with Institutional Investors and Asset Managers on Infrastructure - OECD
OECD (2023), Pension Markets in Focus 2023, OECD Publishing, https://doi.org/10.1787/28970baf-en.
OECD (2024), Report on Long term Investing of Large Pension Funds and Public Pension Reserve Funds 2023.

There is no recent, comprehensive and global dataset on infrastructure finance flows and the gap that needs to be filled. A study by the Global Infrastructure Hub estimated that global infrastructure investment was USD 2.3 trillion in 2015 (Global Infrastructure Hub, 2017[66]). In 2022, G20 governments budgeted USD 978 billion for infrastructure investment, which is around 1% of GDP. A further USD 424 billion was invested by the private sector into infrastructure projects globally, with 71% of tracked private funding going to projects in high-income countries.

Another source of finance is corporate private investment in infrastructure, such as private utilities financing projects from their own balance sheet. Corporate finance exceeds project finance in some sectors, but there are no data available on overall trends. Based on the data available, it is likely that global infrastructure investment remains below the levels required, as projects that are bankable are not sufficiently developed in particular in emerging and developing countries.

The Climate Policy Initiative examined the extent to which finance flows for infrastructure were consistent with five core principles of climate resilience, such as ensuring that the project design is informed by physical climate risk assessments (CPI, 2022[67]). These principles build on (Mullan and Ranger, 2022[68]) and are aligned with the approach of this report. This analysis found that USD 31 billion of infrastructure finance went towards climate resilient projects in 2019/2020, accounting for a small fraction of overall infrastructure investment. At a city level, similar analysis has found that only 9% of total urban climate finance is going towards climate adaptation, with the remainder going towards mitigation (CCFLA, 2021[69])).

These estimated flows for climate-resilient infrastructure are a fraction of overall needs. Hallegatte, Rentschler and Rozenberg estimate mainstreaming climate resilience increases the costs of power, transport, and water and sanitation infrastructure projects by 3% relative to the overall infrastructure investment needs. Applying this increase to the estimated USD 6.9 trillion required for total infrastructure investment (OECD/The World Bank/UN Environment, 2018[70]) would equate to USD 207 billion per year. In addition, financing additional infrastructure towards weather-related disasters, such as flood defences, and addressing existing infrastructure assets are likely to generate significant costs. For example, upgrades to flood protection in London alone are estimated at USD 20 billion over the course of this century (DEFRA and EnvAgency, 2023[71]).

# 3 Assessing and understanding climate risks

Assessing climate risks is the first step in the process of building climate-resilient infrastructure. As defined by the IPCC, climate risks result from interactions of climate hazards (caused by a climate change-related event or trend), with the vulnerability (the susceptibility to harm) and exposure of assets and people to them (IPCC, 2014[72]).

Most OECD countries have produced national climate risk assessments, which include the infrastructure sector albeit to different extents (OECD, 2018[1]). Climate risk data is often not downscaled enough to inform infrastructure risk assessment at the asset level. Given the strong spatial dimension of future climate risks and vulnerabilities, it is relevant to adopt a place-based approach to understand local impacts. The OECD's work on providing subnational climate hazard data makes an important contribution to close this knowledge gap (see the OECD Laboratory for Geospatial Analysis).

### Box 5. Integration of climate impacts and disaster risks into policies for the planning

Case studies show that the most common way to integrate climate impacts and disaster risks into policies is to include climate resilience objectives and measures in their multi-year National Adaptation and Development Plans, drawn up in accordance with international climate adaptation targets as well as national objectives and priorities. This is the case for Brazil, Canada, France, Japan, Mexico and Türkiye, which have in place national policies addressing climate change in various sectors to provide strategic direction.

Central to these plans is the strategic integration of infrastructure resilience policies which strengthen infrastructure systems against climate-induced stress, such as extreme weather events and sea-level rise. This linkage also ensures that infrastructure development and maintenance consider the evolving climate risks, thereby safeguarding vital assets and services.

National adaptation plans are often transversal, as they integrate and coordinate actions across different sectors and levels of the public administration. Key challenges in drawing up and operationalising such plans are the coordination of actions across different levels of the government, as illustrated by the case of Switzerland and Mexico, and for resource allocation, as illustrated in the cases of Brazil and Russia.

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section I: Integration of climate impacts and disaster risks into policies for the planning

Besides understanding current climate risks, it is also important to assess future projected risks. In the context of climate change, the frequency and intensity of climate impacts is expected to change. Although projections of future climate hazards are largely available across OECD countries, their integration in hazard models, which are usually place-specific, remains limited (OECD, 2023[10]).

When analysing risks to infrastructure assets, it is important to map the interdependencies between infrastructure assets and networks. This goes beyond domestic interconnections, but also includes cross-border interdependencies and interconnections as climate change does not recognise boarders. As climate change impacts can cascade through infrastructure systems, understanding how infrastructure networks get affected through interdependencies is crucial for minimising climate change impacts (OECD, 2018[1]). To understand these interdependencies and potential shared risks, collaborations between infrastructure operators is essential. Examples of this include the EU's Critical Infrastructure Warning Information Network, which helps exchange information on different kinds of hazards and vulnerabilities, as well as strategies and measures that can reduce risks to critical infrastructure (OECD, 2018[1]) (European Commission, n.d.[73]). Stress testing can also provide a tool to identify how infrastructure will operate under future climate scenarios as a conceptual framework assessing where systems may fail due to severe or plausible disruptive events (both episodic or prolonged), assessing the ability of systems both to withstand, as well as to overcome these disruptions (Linkov et al., 2022[74]) (OECD, 2018[1]). Applied to understand interconnectedness in systems, it can be used to understand cascading impacts triggered by climate change in infrastructure networks and beyond (Linkov et al., 2022[74]).

### Box 6. Integration of climate impacts and disaster risks into policies for the planning

Plans and policies in countries focus on water management, such as is the case of the Brazilian Sowing Water and Water Security programmes, that are aimed at factoring in the effects of climate change on water availability and quality. By linking water management policies to resilient infrastructure, countries can create adaptive and robust systems that safeguard communities, ecosystems and economies from the increasingly unpredictable effects of a changing climate.

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section I. Integration of climate impacts and disaster risks into policies for the planning

Once climate risks are mapped and assessed, it is crucial to ensure their consideration into planning and decision-making process across the whole lifecycle of infrastructure. Several tools emerged to facilitate the mainstreaming of climate resilience across various stages of the life cycle of infrastructure. Prior to defining individual projects, governments at all levels can prepare and develop climate-resilient national, regional or urban development plans, and accompanying spatial plans and master plans to strategically define what can be built, and where it can be built. This ensures that climate risks are considered as part of the overall built environment, allowing for interactions with other infrastructure and non-infrastructure assets to be understood (OECD, 2023[75]; OECD, 2023[43]). Coordination across levels of government is essential for spatial planning as subnational governments have the key competencies in this area (OECD, 2017[76]) (OECD, 2014[77]). At the project appraisal phase, for example, an Environmental Impact Assessment (EIA) can be conducted, which – among other environmental impacts – assesses whether a project exacerbates climate change impacts elsewhere, as well as their vulnerability to climate change. In the European Union, directive 2011/92/EU introduced mandatory EIAs to be conducted for certain large-scale projects, which was amended with 2014/52/ EU, strengthening the focus on climate change adaptation and resilience in the screening, scoping and assessment phases of projects (Vallejo and Mullan, 2017[45]) (European Committee of the Regions, n.d.[78]).

A key challenge in planning and decision making for infrastructure resilience is uncertainty. One source of uncertainty are the inherent challenges of modelling climate change across different socio-economic and emissions scenarios. To manage decision-making under uncertainty, adaptive and flexible planning approaches have been developed, which can respond to changing climate impacts over the infrastructure's lifetime, enabling adjustments to be made. Scenario planning, for example, aims to accommodate for a range of potential conditions in the futures, such as real options analysis (OECD, 2018[1]). In adaptive planning, multiple actions, including alternative pathways for policy development and investment are developed in the planning phase. Based on pre-defined trigger points, decision-makers can shift to different options, i.e. alternative pathways dependent on how circumstances evolve. The Thames Estuary 2100 project was the first time the adaptive pathways approach was used. Following the construction of the Thames Barrier which currently protects the city of London in the United Kingdom from coastal and tidal flooding, further adaptation measures (e.g. a moveable or permanent tidal barrier to drain the river) will be taken when certain levels of sea level rise are reached (Hall et al., 2019[51]).

### Box 7. Mainstreaming climate-resilient infrastructure through a national development plan: the case of the Philippines

Mainstreaming climate resilience into national development plans can provide an important starting point for including climate resilience into infrastructure development. The Philippine Development Plan (PDP) 2023-28 is a foundational document delineating the policies and projects aimed at fulfilling the nation's objectives over the next six years. The PDP serves as a cornerstone for guiding budget allocations and ensuring alignment with these articulated objectives, thereby accentuating its significance, particularly concerning infrastructure, a significant budgetary component. A full chapter of the PDP is dedicated to the expansion and upgrading of infrastructure, with the aim to embed climate resilience in infrastructure design. The PDP also entails a chapter to further strengthen climate and disaster resilience within the country. Such policy objectives outlined in the plan – particularly those concerning infrastructure – set out a management framework for the country's major infrastructure projects and support local and national stakeholders in prioritising their investments. With the National Economic Development Agency (NEDA) currently working on target indicators to monitor the implementation of the plan, there is a unique opportunity to ensure the goals presented in the PDP are translated into specific targets. As part of the Sustainable Infrastructure Programme in Asia (SIPA), the OECD works with the Philippines to support the country in improving the quality and sustainability of new and existing infrastructure through capacity-building, including on climate resilience.

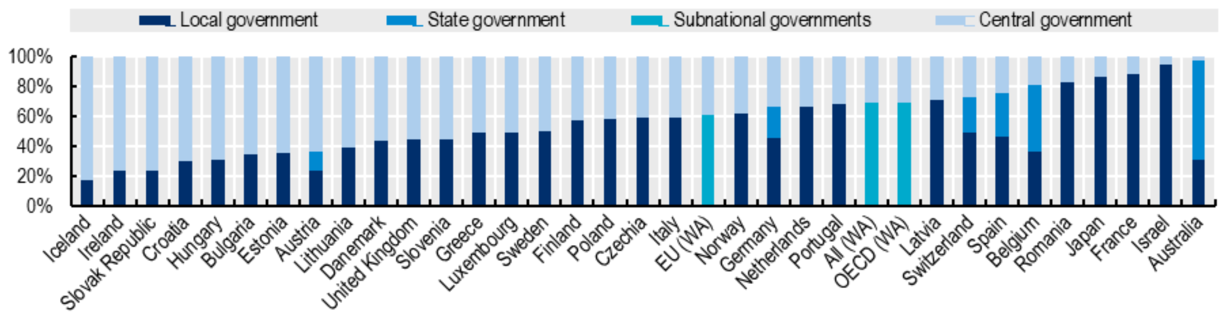
Source: Source: (NEDA, 2023[79]) (OECD, forthcoming[80])

# 4 Role of subnational governments and community considerations for climate-resilience of infrastructure

All levels of government have an essential role to deliver climate-resilient infrastructure, but subnational governments have a particularly important role. They have key competencies related to infrastructure – spanning from planning and permitting to procurement, construction, operations and maintenance (OECD, 2024[16]). In the OECD they account for 69% of climate-significant public investment (Figure 3).

### Figure 3. Subnational governments are key investors in climate-resilient infrastructure

Climate-significant public investment by level of government in OECD and EU countries, 2019




Note: Covering 32 EU and OECD countries. WA = weighted average.
Source: (OECD, n.d.[81]), Subnational Government Climate Finance Hub, www.oecd.org/regional/sngclimatefinancehub.htm

Local climate resilience actions can be especially challenging to fund. Much climate-resilient infrastructure are "local public goods" that are needed to protect private assets (e.g., housing, businesses, vehicles, etc.), so local tax revenue from those beneficiaries will have a key role to help fund this infrastructure – as will targeted capital grants from upper levels of government, especially for communities most in need (OECD, 2024[16]).

In addition to public funding, private finance will have an essential role to spread the costs of local climate-resilient infrastructure over time. However, access and use of finance by regional and local governments for supporting long-term investments can vary considerably across and within countries. Subnational governments can sometimes not access affordable (or any) finance due to strict fiscal frameworks that can limit their ability to raise revenue and accrue debt (OECD/UCLG, 2022[82]). Even where frameworks are more conducive to supporting quality investment, access to finance can still be limited by other factors (e.g., capital markets, creditworthiness, financing costs, small project size, currency exchange risks) (OECD, 2022[83]).

Community engagement is a critical element for achieving climate-resilient infrastructure systems. When considering community considerations for climate-resilience of infrastructure, three main avenues could be taken into account:

- Monitoring of social impacts of infrastructure including through community engagement
- Engaging with local communities to understand their needs for infrastructure, how these needs will be affected by climate change and the development of approaches to enhance climate resilience.
- Contractual mechanisms to protect affected communities.

### Box 8. Initiatives to foster community engagement to facilitate the updating, planning and implementation of climate-resilient infrastructure

Practices reported include monitoring of social impact of infrastructure, consultation with local communities affected or potentially affected by the climate risk of infrastructure assets, and contractual mechanisms to protect affected communities.

Community engagement remains a secondary priority for many surveyed countries. However, some examples such as France regarding the involvement of the Région Sud as a pilot to develop national projects for ecological planning show that the active participation and leadership of regions and communities, plays a crucial role in managing climate impact and designing climate-resilient infrastructure.

Countries responded with different examples of consultations with stakeholders, especially at the local level, to identify needs and solutions and foster bottom-up approaches to climate resilience.

Regarding climate resilient infrastructure, Brazil has already implemented a Community Risk Plan, while China – with support from the World Bank – has developed a Low-carbon and Climate-resilient Residential Community model in a subdistrict of Shanghai, and the UK has developed a Local Partnerships Adaptation Toolkit as part of an effort to coordinate locally and at different levels of government.

The World Bank-financed 'Green Energy for Low-carbon City in Shanghai Project' in Changning District has successfully attracted financial support from various entities, including the World Bank, the Global Environment Facility, commercial banks, and local government. This community-driven initiative, with its focus on energy-saving renovations and emergency power supplies, serves as a model for sustainable transformation.

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section II. Initiatives to foster community engagement to facilitate the updating, planning and implementation of climate-resilient infrastructure

By affecting assets and basic services, direct and indirect infrastructure damages have major social impacts. Damages to infrastructure assets can also disrupt the movement of people. In 2012, Hurricane Sandy restricted the travel of 5.4 million passengers (Vallejo and Mullan, 2017[45]). After Hurricane Katrina in 2005, 2.7 million people were left without electricity (Hall et al., 2019[51]). Similarly, the 2021 Typhoon Rai (Odette) in the Philippines left 269 cities and municipalities without electricity, while 348 suffered from network interruptions (OCHA, 2021[32]). During the 2009 heatwave in Australia, half a million people were left without power in Melbourne as the heat stress caused power outages in the electricity transmission network (McEvoy, Ahmed and Mullett, 2012[84]). The recent floods in South Brazil have resulted in large scale service disruption of infrastructure services, with operations suspended at Salgado Filho International Airport (POA), public transport, including in Porto Alegre, being severely disrupted, flood water cutting off towns across the region, power outages in multiple locations, and 581,000 displaced citizens (CASA MILITAR DEFESA CIVIL RS, 2024[37]). Communities can be affected severely as a result of such interruptions.

It is estimated that each USD 1 billion invested in flood resilient infrastructure in the United States could create 40 000 jobs (Khan, McComas and Ravi, 2020[85]). This creates potential employment opportunities for communities.

Nature-based solutions (NbS) offer climate resilience building with a wide-range of social and ecosystem co-benefits. Through enhancing human wellbeing and the quality of life in diverse ways, social co-benefits are often drawn out as an important advantage various NbS measures bring. NbS provide protection for people from climate risks and other natural hazards. Mangroves, for example, protect around 15 million people every year from flooding (Menéndez et al., 2020[86]). In the United States, the USD 60 million "Living Breakwaters" project grows oyster reefs off the coast of Staten Island to provide protection for residents from storm surges and coastal flooding in the nearby metropolitan area around New York City (IUCN, 2020[87]).

Helping to reduce the urban heat island effect, NbS can reduce excess mortality from heat exposure. As green roofs can lower indoor air temperatures by 1.5-3 °C, a simulation study found that the installation of green roofs on all buildings with elderly residents would reduce heatwave-related mortality in 2030 by up 63% in the city of Szeged, Hungary and by up to 71% in the municipality of Çankaya, Türkiye (Marvuglia, Koppelaar and Rugani, 2020[88]). Similarly, trees are estimated to lower temperatures by 7-15°C through shade and evapotranspiration, thus mitigating the urban heat island effect (UNEP, 2021[89]), while providing health benefits due to cleaner air. Indeed, trees in only ten of the world's megacities are estimated to provide a health benefit of USD 482 million annually due to reduced air pollution (Endreny et al., 2017[90]). In Barcelona, Spain, 200,000 trees in the city were estimated to have removed 5,000 net tonnes of CO2 and 305 tonnes of polluting compounds in 2008 (Ajuntament de Barcelona, 2013[91]) (Cohen-Shacham et al., 2016[92]). Moreover, urban green areas are estimated to remove 1.97 to 3.8 g of ozone per m2 every year (Aevermann and Schmude, 2015[93]) (Le Coent et al., 2021[94]). Furthermore, as green roofs can lower sound transmission by 10-20 dB, several NbS measures deliver health benefits by lowering noise levels (Liberalesso et al., 2020[95]).

Despite the potential of NbS to facilitate climate resilience building in the infrastructure sector, their use remains scattered and mainly applied at pilot scales. As a recent study by the European Environment Agency warned, despite the continued promotion of NbS in several policy frameworks, such as the EU Green Infrastructure Strategy or EU Biodiversity Strategy (EEA, 2021[96]), the application of NbS in the EU remains limited and mostly constrained to small-scale projects (EEA, 2023[97]). Indeed, out of nearly 1400 NbS projects in the EU and the United Kingdom, nearly three quarters of them covered less than 1 $km^2$ (EIB, 2023[98]). While this may be the appropriate scale for certain NbS (e.g. green roofs, green facades, etc.), this demonstrates that current NbS projects are mostly implemented on small spatial scales and needs to become more inclusive.

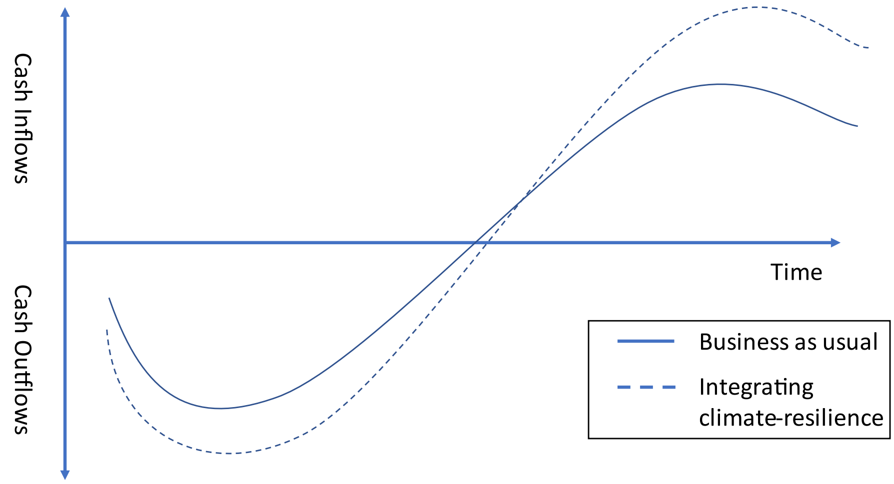
# 5 Mainstreaming climate resilience into infrastructure finance

For an infrastructure project to be financially viable, the projected revenues need to be sufficient to cover operating costs (OPEX) and provide a return on the investment for the capital expenditure (CAPEX) commensurate with the level of risk. The attractiveness of an investment is therefore enhanced by shorter lead times before operation, lower CAPEX, lower OPEX, lower risk and/or higher projected revenues.

This consideration applies to publicly funded infrastructure too, although public projects are usually assessed based on their expected social costs and benefits over the lifetime of the asset, even if the benefits do not directly accrue to the government. For example, public investment in flood defences is partly justified based on the expected reductions in flood damage over time, even where those benefits accrue predominantly to property owners. As with privately financed infrastructure, increases in the expected social benefits and/or reductions in upfront costs will improve the likelihood that a project will be viable.

The stylised diagram (Figure 4) below shows how these factors can affect the cash flow of infrastructure assets by strengthening climate resilience over the lifecycle of an asset. The initial preparatory work to understand vulnerability to climate risks and develop adaptation options can increase upfront costs and, potentially, increase the timeline for the project. Longer timelines decrease the expected return from the project. However, these upfront costs should be more than offset by the positive impact on future cash flows. Revenues will be more predictable as there is less likelihood of unanticipated disruption and lower economic losses. Revenues may also be higher if the perception of increased reliability and lower risks lead to increased demand relative to alternatives. Climate-resilient infrastructure should also be at less risk of damage or premature obsolescence due to future climate change impacts. In principle, this reduction in risk should result in lower financing costs and/or lower insurance premiums towards damages over the life cycle of the infrastructure asset.

**Figure 4. Stylised impact of climate resilience on project cashflow**




Source: (Chavarot et al, 2023[99])

However, as demonstrated by (OECD, 2018[1]) (CPI, 2022[67]), consideration of climate resilience remains the exception rather than standard practice. A key underlying challenge is that physical[4] risks are not consistently considered by decisionmakers in the public and private sectors. As such, there is no incentive to make the upfront investments when the benefits of those investments are not perceived as relevant. This can be due to a lack of capacity and awareness to understand and manage climate risks, or it can be that the benefits of increased resilience do not translate into cashflow due to weaknesses in the enabling environment and insufficient data on the business case for investing into climate-resilience. For example, these weaknesses can include insufficient regulation, inappropriate design codes and moral hazard arising from the expectation of government bail outs if a climate-related disaster occurs.

International examples of good practices demonstrate how the enabling environment can be strengthened to help make climate resilience the norm, by targeting the barriers that prevent the economic benefits of climate resilience being reflected in investment decisions and having incentives that would support greater investment. The following four areas will be critical for driving increased finance flows for climate-resilient infrastructure: transparency and awareness, mainstreaming climate resilience into public funding, examining regulation of privately-owned infrastructure and examining risk financing arrangements.

## Increasing transparency and awareness of climate-related risks in investment decisions

Increased transparency on climate-related risks will help investment decisions integrate physical climate risks and potential future costs, and hence provide a market signal to better manage the relevant risks. Material climate-related risks may not yet be considered by investors due to the perceived complexity of those risks and the lack of comparable data and metrics. The following tools and mechanisms can help to address these challenges.

### *Disclosure*

Requirements on infrastructure operators to disclose climate-related risks have been used to raise awareness within organisations, while also facilitating efforts to understand interdependencies between infrastructure networks. In the UK, the Climate Change Act includes the Adaptation Reporting Power, by which the government can require utility companies to undertake a risk assessment and publish how they intend to manage those risks. An evaluation of the most recent round of reports found that the quality of these reports was generally high and that there was evidence that it was leading to increased preparedness in the infrastructure sector (CCC, 2022[100]).

Broader efforts within the financial sector to disclose climate-related risks should also provide an impetus to make physical climate risk visible. Analysis by (EDHECInfra, 2023[101]) found that physical climate risks could reduce the net asset value of infrastructure portfolios by an average of 4% and 27% in a worst-case scenario.[5] The Task Force on Climate-related Financial Disclosure (TCFD) recommendations provided a voluntary basis for reporting (TCFD, 2017[102])[6]. These have informed the development of the International Financial Reporting Standards (IFRS) Sustainability Disclosure Standards, which are intended to be integrated into regulatory frameworks across jurisdictions. These focus on financially material information, so would cover infrastructure-related risks insofar as they are expected to be financially material. The European Union's European Sustainability Reporting Standards have a broader perspective, as they also cover the impact on the environment ("double materiality") and a broader set of environmental, social and governance factors.

Most listed companies carry out sustainability reporting. This is not standardised in most cases but includes elements of climate resilience. In many cases, it reflects TCFD recommendations. Climate resilience can be informed through governance, strategy and risk management of the TCFD recommendations. Critically, it requests organisations to disclose their processes for identifying, assessing and managing climate risk (TCFD, 2021[103]). Such sustainability reporting provides important disclosure of an organisation's level of engagement and management of climate risk. Applying such reporting to infrastructure assets would support improved reporting on climate resilience.

Further action would help to translate these disclosure requirements into greater visibility of physical climate risk. An analysis of reporting done based on the TCFD recommendations found that less than half of them covered physical climate risks. Furthermore, the treatment of risks was partial, with reports only tending to cover a subset of potential climate hazards. Disclosures were not readily comparable between institutions due to different metrics and assumptions (Zhou and Smith, 2022[104]). Addressing these gaps will require the development of common metrics and assumptions, building on the work that has already been undertaken (EBRD and GCECA, 2018[105]). It will also require efforts to provide underlying data and information on climate-related hazards, such as regularly updated hazard maps.

### Box 9. Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment

Several survey participants are also increasingly advancing towards regulatory reform that fosters sustainable activities' classification, risk identification and mitigation, and mobilisation of capital. Importantly, in several countries these efforts are already translating into the development of national sustainability taxonomies, such as the Sustainable Taxonomy of Mexico, the Russian Taxonomy of Green and Adaptation Projects. Similarly, the UK's is developing a Roadmap towards mandatory climate-related disclosure, and Türkiye's has already issued its own Sustainability Reporting Standard, and has started preparations for a National Green Taxonomy. Indonesia has made important progress in integrating ESG measurements across the infrastructure life-cycle.

Note: Case studies in this report are provided under the responsibility of each report.
Reference: Presidency Annex A, Section V. Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment.

### *Standards, labels and taxonomies*

Robust analysis of the exposure of infrastructure assets to physical climate risks is a crucial element for mainstreaming climate resilience into infrastructure finance. A growing ecosystem of private data providers has emerged to help make risk visible in investment decisions. However, recent analysis has found that results from different providers are inconsistent, even when using the same analytical approach (Hain, Kölbel and Leippold, 2022[106]). Efforts to facilitate the sharing of data and best practice methodologies would facilitate better understanding and consistency in the analysis of climate risk over time.

The Physical Climate Risk Assessment Methodology (PCRAM) provides a common approach for analysing the impact of physical climate risks on infrastructure investments (Mott MacDonald, n.d.[107]). This approach is also intended to provide a common language for discussing physical climate risks between the infrastructure and financial sectors. PCRAM translates physical climate risks and adaptation measures into key performance indicators, such as (financial) internal rate of return and life cycle costs, across possible future scenarios. The Institutional Investors Group on Climate Change is further developing PCRAM.

Infrastructure standards and labels also have a critical role in making the resilient dividend visible. Standards that integrate climate resilience provide a signal that climate risks have been identified and managed. In so doing, they provide a means for operationalising resilience requirements within contracting processes. However, further efforts are required to mainstream climate resilience across standards covering the infrastructure life cycle (Cançado and Mullan, 2020[108]). Moreover, resilience is considered in sustainability standards that regulate the issuance and subscription of various capital market instruments from which infrastructure projects receive financing (Box 11).

### Box 10. Examples of global initiatives relevant to climate-resilient infrastructure

Resilience is being integrated into the following initiatives to improve the quality of infrastructure investments:

- Belt and Road Initiative
- Blue Dot Network
- "Clever" Green building certification system
- Coalition for Disaster Resilient Infrastructure
- Debt Management and Financial Analysis System.
- FAST-Infra
- Impact and Responsible Investing for Infrastructure Sustainability (IRIIS)
- PIDA Quality Label of the African Union
- PPP Fiscal Risk Assessment Model (PFRAM)
- Private Infrastructure Development Group (PIDG)
- SOURCE
- UNEP Sustainable Infrastructure Partnership

Note: Initiatives cited in this box are indicative and are not endorsed by the G20.

Green finance taxonomies provide a positive signal for investment in climate-resilient infrastructure. The EU Taxonomy for Sustainable Activities provides criteria by which investments, including infrastructure, can be identified as contributing significantly to climate change adaptation. The base requirement is to identify and address climate risks, while also encouraging use of Nature-based Solutions (NbS) or green-blue infrastructure.

## Box 11. Improving climate resilience of infrastructure through GSS bonds' standards and guidelines

Standards and taxonomies that bring forward climate resilience in infrastructure finance can be further mainstreamed through their application in sustainable bonds issuance. There are a growing number of guidelines that are used by debt markets to regulate the issuance and the subscription of bonds that achieve green and social objectives, including climate adaptation and resilience.

For instance, green, social and sustainability (GSS) use-of-proceeds bonds are popular debt instruments that allow investors to contribute to the green transition, as well as social causes, by using bonds' proceeds to finance eligible projects. The sustainable debt market has grown substantially in the last 15 years, reaching in 2023 H1 a total of USD 4.2 trillion of issuance to date, with green bonds accounting for the majority of issuances.

In the framework of these bonds, issuers employ issuance standards and guidelines to ensure sound green and/or social credentials of financed projects, attributing them to detailed eligible sector categories, often leveraging relevant taxonomies. In general, GSS bond principles promote a contextual and flexible approach for identifying green and social activities that can contribute to sustainability goals of issuers and investors.

Private sector issuance standards include the International Capital Market Association (ICMA) Sustainable Finance Principles and Guidelines for green and social bonds, and the Climate Bonds Initiative (CBI) Climate Bonds Standard and Certification for green bonds. Such voluntary guidance is aimed at defining the nature, scope and characteristics of GSS instruments, and setting a framework for the identification, financing, monitoring and impact reporting of eligible projects towards which the proceeds of GSS bonds are directed.

Adaptation and resilience related activities are classified in both ICMA and CBI green bond standards by dedicated eligible project categories, even though underlying definitions are not as standardised. Establishing standardised guiding principles and taxonomies in climate resilience and adaptation funding is crucial, as they provide clarity for defining eligible projects and ensure comparability for investors. Moreover, standards need to be linked to finance to enable effective allocation of funds to projects with maximum resilience and adaptation benefits, facilitating transparent tracking of progress and fostering collaboration among stakeholders.

Sustainable infrastructure as an asset class can be at the core of various projects that receive funding through GSS bonds issuance, because, by nature, it covers multiple eligible project categories in terms of applicability of labels. This is true especially in climate adaptation and resilience project categories, since the characteristics of sustainable infrastructure projects match with adaptation and resilience definitions employed by private sector standards for use-of-proceeds bonds.

In general, using climate resilience related standards and taxonomies in financial markets applications might benefit both the financing mechanisms in questions, since they entail a strong sustainability aspect, and the standards themselves, as a financing application might increase their development, focus and applicability.

Source: (Climate Bonds Initiative, 2023[109]).

The application of mandatory climate risk screening tools provides a further tool for identifying and managing climate-related risks. A critical tool for governments is the application of climate risk screening within Strategic Environmental Assessment and Environmental Impact Assessment (EIA) processes. EIAs are often mandatory for key infrastructure sectors (e.g., EU's Environmental Impact Assessment Directive (2011/92/EU amended by 2014/52/EU is required for nuclear power plants, long-distance railways, motorways, express roads, waste disposal and dams), however, inclusion of climate risk is not always a given (Mayembe et al., 2023[110]). Thus, better integration of climate risk within EIAs would contribute to climate resilience becoming a more default consideration for infrastructure projects.

### Box 12. How EIAs can impact the design of climate-resilient infrastructure

In the Philippines, the National Economic and Development Authority (NEDA) mandates all infrastructure projects to undergo an EIA, and that EIA must incorporate climate resilience, as required by the Ministry of Environment. While the criteria for climate resilience itself is not yet robust, the main concern for NEDA is to be able to assess whether or not the project is climate resilient.

The project evaluation is based on the alignment of the project with the national and regional development priorities as well as the strategic priorities of line ministries. The appraisal criteria include environmental and social impacts.

The Environmental Management Bureau of the Department of Environment and Natural Resources (DENR) is responsible for conducting a review of the EIA, the environmental risk analysis, and the proposed risk reduction measures. This review covers the integration of climate change adaptation measures and disaster risk reduction. The DENR then issues an Environmental Clearance Certificate, which is required to start construction works.

In South Africa, the Port of Durban's EIA included a climate risk assessment, leading the Port to adapt the original design to protect it from sea level risk and an environmental management plan to address heavier rainfall and wind.

Source: OECD sources

## Integrating climate resilience into public funding

Public funding arrangements for infrastructure may need to be revised to ensure they are conducive to the mainstreaming of climate resilience into infrastructure finance. Critical areas for achieving this include budget allocations, project appraisals and procurement.

Climate change will affect budgetary needs for infrastructure. The role of the budget process in supporting climate resilience is not systematically considered. Moreover, there is a lack of data on how well budgetary processes and outcomes align to climate resilience (Mullan and Ranger, 2022[68]). Consequently, infrastructure may be provided at the lowest upfront cost rather than maximising net benefits over the lifetime of the asset. There can also be distortions if different institutions share funding responsibilities. For example, the European Structural and Investment Funds cover capital costs, but regional and local authorities cover operations. Green budgeting approaches are not yet widespread.

A country's national adaptation plan is a key avenue in which to ensure that climate change adaptation is a key priority, and adaptation measures are mainstreamed through budget allocation for their implementation. By identifying infrastructure sectors that can contribute to adaptation, this can create a clearer link with climate resilience.

Public sector approaches for project appraisal and procurement should consider the performance of projects over their entire life cycle, including the effects of climate change. For example, the United Kingdom has developed supplementary guidance for integrating climate change adaptation into policy appraisal decisions, including methods for accounting for uncertainty (HM Treasury, 2023[111]). A growing number of countries, including EU member states, Japan and the United States, have adopted life cycle costing within their procurement frameworks. Procurement processes can also facilitate innovation by specifying performance standards rather than requiring use of specific technologies or approaches.

Public-private partnerships (PPPs) are long-term contracts in which the private sector delivers and funds public infrastructure, sharing the associated risks (OECD, n.d.[112]). The success of PPPs in delivering climate-resilient infrastructure depends crucially on how climate-related risks are allocated within the contract. Failures to adequately define risks in advance, misallocation of risks and differences between the *de facto* and *de jure* allocation of risk have all been found to undermine resilience (OECD, 2018[1]). Efforts to build capacity for climate-resilient PPPs are under way. For example, the Global Centre on Adaptation developed a training course and certification on this theme for infrastructure practitioners (GCA, n.d.[113]). The World Bank's PPP Legal Resource Centre provides an inventory of resources for designing and implementing climate-resilient PPPs. In any of these efforts, an open and competitive procurement of projects and anti-corruption measures will be essential to ensure a robust foundation for infrastructure development.

### Box 13 Policies to promote a comprehensive risk assessment that allow for the estimation of exposures and the identification of financial vulnerabilities

The assessment method of climate risks related to projects are developed internally, such as in the cases of Brazil, Saudi Arabia and the UK. Canada applies ISO 14091 norm climate assessment criteria, and Italy applies European Central Bank's Guide on climate-related and environmental risks.

In the infrastructure sector, requiring thorough climate risk evaluations during infrastructure project planning, design, and implementation ensures resilience against climate change impacts. Integrating assessments helps identify vulnerabilities, anticipate hazards, and incorporate adaptation measures, while adherence to established standards ensures consistency. This fosters resilient infrastructure, safeguarding communities, economies, and ecosystems against uncertainties posed by a changing climate.

Another practice is the issuance of catastrophe bonds, such as those issued by Mexico, which represent an innovative way to manage natural disaster risk by transferring some of the risk to financial markets and therefore reducing the government's fiscal burden in the event of a catastrophic event but also pricing risk as well (see section Examining risk financing and risk sharing arrangements to ensure incentive for risk management and enable rapid recovery, on catastrophe bonds).

Note: Case studies in this report are provided under the responsibility of each country.
Source: Presidency Annex A, Section III. Policies to promote a comprehensive risk assessment that allow for the estimation of exposures and the identification of financial vulnerabilities.

## Economic regulation of privately-owned infrastructure

Many OECD countries have natural infrastructure monopolies – such as water supply and sanitation networks, or electricity distribution – that are owned, provided and managed by private utility companies. Given their monopoly position, these private utilities are subject to economic regulation of service standards and price levels. This is becoming increasingly common since the wave of privatisations in the 1980s and 1990s.

Regulated utilities' incentive and ability to invest in climate-resilient infrastructure will depend upon the regulatory regime that they are subject to. Various regulatory models are used but the overall aim is typically to achieve a balance of service quality and price, while allowing investors to earn a reasonable return. For example, in the US, state Public Utility Commissions (PUCs) determine prices, allowable investments and service standards for privately-owned utilities providing electricity, gas, telecoms and water (Monast, 2021[114]).

The following elements of the regulatory framework could be examined to support investment by regulated utilities in climate-resilient infrastructure:

- Allowable investments: ensuring that the rules determining whether investments are reasonable account for the value of increased climate resilience
- Performance standards: examine the rules that are in place to determine whether they are suitable for a changing climate, both in terms of risks to infrastructure provision (e.g. loss of service) and also risks from infrastructure provision (e.g. failures of dams or wildfires from electricity distribution networks)
- Additional requirements: regulators can also support efforts to make physical climate risks visible through requirements to undertake stress tests, identify interdependencies and develop adaptation plans.

As with other aspects of regulatory policy, there is a need to balance competing objectives such as between affordability and reliability. The risk-based approach provides a basis for making trade-offs and communicating clear expectations, objectives and targets to guide investment decisions.

## Examining risk financing and risk sharing arrangements to ensure incentive for risk management and enable rapid recovery

The allocation of climate-related risks, both contractually and in practice, provides a critical driver for investments in climate resilience. These risks include damage to infrastructure assets from climate extremes, loss of service (e.g. power cuts) and premature obsolescence of assets that were not designed to account for climate change. Unclear or misallocated risks can generate moral hazard and thereby reduce the incentive to invest in adaptation and exacerbate the cost of climate extremes by delaying reconstruction. These can represent contingent liabilities for governments, even if the infrastructure is privately owned. The OECD Recommendation on Building Financial Resilience to Disaster Risks outlines best practices for managing the financial consequences of extreme events.

The insurance sector has significant expertise in risk assessment and risk management that can be transferred through the process of acquiring insurance. The purchase of insurance coverage will normally involve both an assessment of climate (and other) risks to the asset as well as the provision of advice on how infrastructure operators can mitigate that risk through investments in adaptation and risk reduction, which also results in the pricing of the risk. This can contribute to risk being address through prevention measures.

### Box 14. Managing costs to ensure sufficient funding for the repair and restoration of climate-related damages and losses to public infrastructure

Countries have been developing a number of approaches to address damages. First, the establishment of special funds at national and regional levels to finance climate damages, including dedicated or general-purpose reserves or contingency funds, contingent credit, and insurance or other forms of risk transfer. Examples such as the EU Solidarity Fund, the Chiapas State (Mexico) Trust Fund for Integral Disaster Risk Management, the special provisions for climate damage recovery in Russian Emergency Response Funds, or the UK Flood and Coastal Innovation Fund show that addressing climate risk and infrastructure losses through dedicated funds is a versatile solution that can address local, national, and regional needs depending on the country or region's exposure and vulnerability to climate risk.

Second, countries are creating and implementing empowering solutions for local governments and stakeholders, like the St. Petersburg new flood protection measures (DAM), Türkiye's Climate and Disaster Resilient Cities Project (funded by the World Bank), or the UK government's investment in flood and coastal erosion schemes through the Frequently Flooded Allowance.

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section IV. Managing costs to ensure sufficient funding for the repair and restoration of climate-related damages and losses to public infrastructure

The appropriate model for allocating risks between parties will be context specific. The OECD's Principles for Private Sector Participation in Infrastructure reiterates the general principle that risks should be allocated to the party best able to assess and manage those risks. In the context of climate resilience, this implies that relevant risks should be identified and clearly allocated through contractual and legal provisions. The legal allocation of risk should align with the ability of different parties to bear the risks. This includes PPPs which allocate risks between the public and private sector (see Integrating climate resilience into public funding).

Governments (national or subnational) can acquire indemnity-based property insurance coverage from private insurance markets to protect against damages to individual public buildings and publicly-owned infrastructure assets (and other public assets) (OECD, 2022[115]). Insurance coverage for individual buildings or infrastructure assets is usually available from domestic insurance companies or foreign insurers (if permitted under the insurance regulatory regime). In some cases, ministries responsible for managing public assets are required or encouraged to purchase adequate insurance coverage from private markets (e.g., Colombia, Viet Nam).

In a few countries, a public insurance arrangement has been established to provide insurance coverage for publicly-owned assets, including infrastructure assets. In Australia, Comcover insures the public assets of the federal government and collects premiums from the ministries responsible for those assets. A number of state governments in Australia have established similar arrangements. In the Philippines, a public insurer (Government Service Insurance Service (GSIS)) provides insurance coverage for all public properties owned by both national and local levels of government. All government agencies and government-controlled operations are required to acquire insurance for their assets from GSIS. GSIS transfers some of the risks that it has assumed to international reinsurance markets. In Iceland and France, programmes established to support the availability of insurance for natural hazard (and other disaster) risks provide coverage for publicly-owned assets (including infrastructure assets) as well (in Iceland, the acquisition of this coverage by public asset owners is mandatory).

Many governments (implicitly) self-insure these risks. To that end, they do not make any ex ante arrangements to manage the financial impacts of climate-related catastrophes on public assets (i.e. any damage or losses are funded using budgetary tools or ex post debt financing). The transfer of public infrastructure risks to private insurance or reinsurance markets will be most beneficial for countries that face constraints in fiscal capacity or access to debt markets as post-disaster reconstruction of public infrastructure can entail significant costs that, if uninsured, would have to be borne by the public sector. Public insurance arrangements that pool public asset risks could allow for countries to achieve greater risk diversification prior to transferring those risks to private reinsurance markets, which should result in reduced insurance costs.

The insurance sector has a critical role to play in enhancing the efficient management of climate-related risks and encouraging climate resilience in various ways (OECD, 2023[116]). Most obviously, the acquisition of insurance coverage by private or public owners of infrastructure assets provides, in exchange for a premium, a source of funding to respond to any damages and losses that might be incurred as a result of a weather-related catastrophe such as a storm or flood. Quick access to funding can support speedier rehabilitation of damaged infrastructure assets and reduce the level of service disruption (and income loss in the case of revenue-generating assets). For example, Philippine cities are purchasing parametric insurance through a joint insurance pool to reduce insurance costs and ensure rapid disbursement of pay-outs following disasters (Box 15).

### Box 15. Philippines City Disaster Insurance Pool

The Philippines sits in one of the world's most disaster-prone areas, exposed to many climate hazards such as typhoons, floods and droughts. In the wake of disasters, funding is needed for humanitarian response and rebuilding for greater resilience. While Philippine cities have access to disaster recovery funds, quickly mobilising funding can be a challenge. Delays in early recovery measures can hurt short-term wellbeing and long-term recovery.

With technical assistance from the Asian Development Bank, the Philippine Department of Finance developed the Philippine City Disaster Insurance Pool (PCDIP) to provide rapid post-disaster pay-outs for local governments. It enables city governments to jointly buy insurance through a single platform, which reduces the price of premiums by sharing risk, sharing set-up costs, increasing funding stability, and reducing capitalisation requirements. Capitalised by an ADB loan, the PCDIP is tailored to the specific needs and capacities of city governments to deliver timely payments and build financial sustainability in the long run. The PCDIP also operates as a knowledge sharing and capacity building platform.

The insurance works as follows:

- An external provider provides risk modelling to set each city's premiums.
- City governments buy parametric insurance based on the type of natural hazards they perceive as a threat and select the frequency and size of pay-outs they would like to receive, given the funding available for premium payments. Parametric insurance allows for more rapid disbursement than traditional non-parametric insurance because parametric insurance pays out based on physical features of the disaster (such as wind speed) rather than damages suffered (which can take more time to determine).

- Once a disaster strikes, an independent scientific agency verifies the parameters driving pay-outs. Pay-outs can be expected in no more than 15 business days of qualifying disaster events.

A pilot consisting of ten cities is underway, the first such scheme in Southeast Asia. The increased predictability of and access to payouts is expected to boost cities' fiscal resilience and create more fiscal headspace for post disaster response and recovery.

Source: OECD (2022), G20-OECD Policy Toolkit to Mobilise Funding and Financing for Inclusive and Quality Infrastructure Investment in Regions and Cities, https://doi.org/10.1787/99169ac9-en

Insurance can have a critical role in putting a price on climate-related risks. The premium charged for insurance coverage is usually a reflection of the level of risk and can provide an incentive for infrastructure operators to invest in risk reduction in order to benefit from a reduction in premiums charged. It should be noted that insurance is one among many approaches to funding rehabilitation of damaged infrastructure. Some infrastructure operators (public and private) may choose to manage those costs through self-insurance (including savings or reserves) or risk financing (loans and debt).

### Box 16. Insurability of physical climate risk for infrastructure assets

When faced with potential damages and losses linked to climate change hazards, infrastructure owners and operators have the option of purchasing insurance to transfer some of that risk to insurance markets. The increase in frequency and severity of extreme weather events is affecting the insurability of these risks as the cost of insurance increases to potentially unaffordable level to account for the increase in loss frequency and severity.

In residential property insurance markets, this has become a major issue in some regions, as the cost of coverage for flood, storm and wildfire losses has become unaffordable (Foroohar, 2024[117]) or unavailable. In EU, EIOPA has also raised the alarm for home coverage. (Smith, 2024[118])

However, coverage and the need for insurance for infrastructure assets depends on the ownership and the location of the asset. Publicly-owned infrastructure assets in developed countries are often not insured through private insurance markets given the implicit guarantee from the government and the capacity of governments to self-insure. Private infrastructure owners will generally purchase insurance and – while not immune to the challenges occurring in residential property insurance markets – likely have greater capacity to absorb higher retentions and invest in risk reduction in order to lower insurance costs. Private infrastructure owners will often acquire construction insurance during infrastructure development and work with insurers to undertake risk assessment and build-in climate resilience.

There are some particular areas where there have been difficulties for utilities in accessing insurance coverage. PacifiCorp, a utility that serves six western states including Oregon and California faces a potential USD 8 billion in damages after being accused of contributing to a deadly 2020 blaze by failing to shut off power lines, among other factors. Pacific Gas & Electric — California's biggest utility —filed for bankruptcy in 2019 faced with an estimated USD 30 billion in fire liabilities. There is also the prospect of increasing litigation costs for such utilities that are exposed to wildfire risk. (Platt and McCormick, 2024[119])

There have also been some challenges in accessing insurance coverage for renewable energy projects. In 2019, a storm pelted hail of more than two inches to the Midway Solar Project in Peco County, Texas, damaging 400,000 solar panels and an estimated USD 70-80 million in damages. (Aragon and

Schreiber, 2024[120]) Each year, the insurance industry has continued to see reports of hail claims totalling USD5 million to USD80 million on solar farms and claims seem to be occurring with greater frequency. In 2022, the renewable energy insurance industry experienced recording breaking losses upward of USD300-400 million related to hail damages. It is estimated that property insurance premium related to solar sector is up 15-45% in US, and it is becoming difficult to find a USD10 million or higher limit from a single carrier, and many are capping their aggregate limit at USD5 million (Pritchard and Compton, 2023[121]).

A recent report has raised the issue of risk models not reflecting the longer term climate change sufficiently, the single year policy renewals which disincentivises taking a long-term view, as well as the lack of consideration on secondary perils, such as wildfires and storms, as they prioritise peak perils such as hurricanes (Smith and Bryan, 2024[122]).

Note: In some countries, catastrophe risk insurance programmes have been established to respond to a lack of affordable insurance, such as Flood Re in UK, and the National Flood Insurance Program in the US (see: https://www.oecd.org/daf/fin/insurance/Enhancing-financial-protection-against-catastrophe-risks.pdf).
A fund has been established to deal with a lack of insurance for Cali power utilities: https://www.cawildfirefund.com/
Source: This box benefited from discussions with global insurance brokers.

A catastrophe (cat) bond is a debt instrument that allows the cedent (the insured, issuer) to get funding from the capital market, and is in most cases issued by re/insurers. If and only if catastrophic conditions, such as an earthquake or hurricane, occur does the payout occur. From an economic point of view, the instrument insures the cedent (issuer) against the loss from catastrophic events (called peril) by shifting risks to the holders who bet on the non-occurrence of catastrophic events. When the cat bond is issued by a sovereign or other public entity, the insurance against natural disasters can be considered an adaptation policy (Ando et al., 2022[123]).

The largest public sector cat bond (cedent) issuers are in the US (cumulatively USD5.6 billion as of 2022), followed by Mexico, Chile and Türkiye. The benefit of cat bonds, relative to traditional insurance, is that due to the risk being transferred to a wider set of investors, counterparty risk is eliminated, even for a large payout event. For low and middle income countries, where fiscal capacity may be limited, cat bonds can allow funding for recovery to be more quickly disbursed. However, investors' average return to cat bonds in coupon is around two to four times the expected loss (Artemis, n.d.[124]). Since 2016, all the sovereign catastrophe bonds the data set compiled by Artemis have been intermediated by the World Bank. By providing the service of an SPV, the World Bank simplifies the procurement process as setting up an offshore SPV could be a legal barrier for countries. Anecdotally, the reputation and experience of the World Bank also contribute to narrowing the spread.

# 6 Mobilising additional finance for resilient infrastructure systems

The scale and severity of climate change impacts will shape demands and needs for infrastructure services. There is thus a need to incorporate climate-resilient considerations in investment decisions and the management of infrastructure assets, and mobilise additional finance to meet these changing needs and demands. For example, changes in tourism patterns driven by climate will shape demands for transport links. Increased drought risk will require packages of measures that could include increased storage capacity, reclaiming water, demand-reduction management practices and renovation of pipes to reduce leakages. Mainstreaming resilience at the project level is necessary but not sufficient to achieve the needed transformation and awareness towards the risk. This section explores opportunities to shape and deliver a strategic approach to unlocking both public and private finance for the additional investments needed to achieve climate-resilient infrastructure services.

## Developing a pipeline of investable projects

### *Leveraging planning and coordination for climate resilience*

Strong infrastructure planning processes provide the foundation for identifying the needs that will arise from a changing climate. In the Netherlands, for example, the Delta Programme identified the need to strengthen 1500km of flood defences by 2050, as part of a broader package of measures. In Paris (France), the local authority undertook a planning exercise to identify the measures required to address the consequences of increasingly severe and frequent heatwaves, which identified the potential for using Nature-based Solutions to reduce urban temperatures.

Overall, there is a need to strengthen strategic planning processes and link them to the development of pipelines of bankable projects. This is also in line with G20 Compendium of Quality Infrastructure Indicators Principle 4 on budget committed to disaster and climate risk resilience. In Ghana, the Global Centre on Adaptation's National Infrastructure Investment Pipelines process brought in expertise from MDBs at the outset of the planning process to ensure that the results would be useful for building a project pipeline. In the UK, the National Infrastructure Commission has integrated resilience into their regular assessments of the UK's infrastructure needs. In general, infrastructure pipelines should be integrated with broader development plans at the relevant spatial levels.

Integrating climate resilience from the outset of the infrastructure planning process provides increased flexibility to identify possible needs for climate-resilient infrastructure. As such, this can therefore facilitate the implementation of innovative or cross-cutting approaches, such as Nature-based Solutions. It can also facilitate mainstreaming climate resilience at the project level, because these processes are able to make use of the data and information gathered during the planning process, rather than having to start with a blank sheet for each project.

**Box 17 Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment**

Effective co-ordination between government and non-government actors is essential to plan and implement investments at the right scale and to harness shared competencies and capacities across governments, civil society and the private sector (OECD, 2022[83]) (OECD, 2014[77]). New co-ordination mechanisms are being deployed to support climate-resilience in many countries. In France, for example, the 'Contracts for the Success of the Ecological Transition' (*Contrats pour la réussite de la transition écologique*) brings together the local, regional and central government to co-define objectives, projects and financing through inter-municipal co-operation bodies (Agence nationale de la cohésion des territoires, n.d.[125]).

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section V. Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment

### *Technical assistance for project preparation*

Translating plans for new infrastructure into bankable projects can require a lengthy, complex and uncertain project preparation process, but is at the crux of addressing the infrastructure investment gap, especially in emerging and developing countries. This can be particularly the case for climate-resilient infrastructure, given the need to incorporate climate data into the project design. Technical support, including project preparation facilities, provide technical and/or financial support for this process, thereby reducing the risk of projects being stuck on the drawing board and helping to generate a pipeline of bankable projects. They also provide an opportunity to integrate climate resilience from the outset of the project development, when there is generally more flexibility to make changes.

Governments can support the development of financially viable infrastructure investments through the provision of technical assistance and guidance for project developers. For example, the United States Environmental Protection Agency hosts the Water Infrastructure and Resiliency Finance Center, which helps local communities to identify and implement options for financing resilient infrastructure. This initiative includes networking between local authorities, providing training and links to potential funding mechanisms.

Scaling-up the resources and effectiveness of project preparation facilities would help to drive increased investment flows for climate resilient infrastructure (Independent Expert Group, 2023[126]). For example, the Global Infrastructure Facility provides project preparation support for projects that deliver development impact. The Facility was initiated by the G20 and now has financial support from seven countries and the World Bank. It partners with developing country governments and MDBs to cover infrastructure planning, as well as project definition, structuring and procurement. It is committed to ensuring that projects that it supports are aligned with climate change objectives. The World Bank Tokyo Disaster Risk Management Hub, managed by Global Facility for Disaster Reduction and Recovery (GFDRR), also provides technical assistance for mainstreaming disaster risk reduction in preparation and implementation of infrastructure projects financed by the World Bank, and has supported over 110 countries since its establishment in 2014.

Currently, most MDBs have project preparation facilities that support sustainable infrastructure and address green transition ambitions including climate resilience.

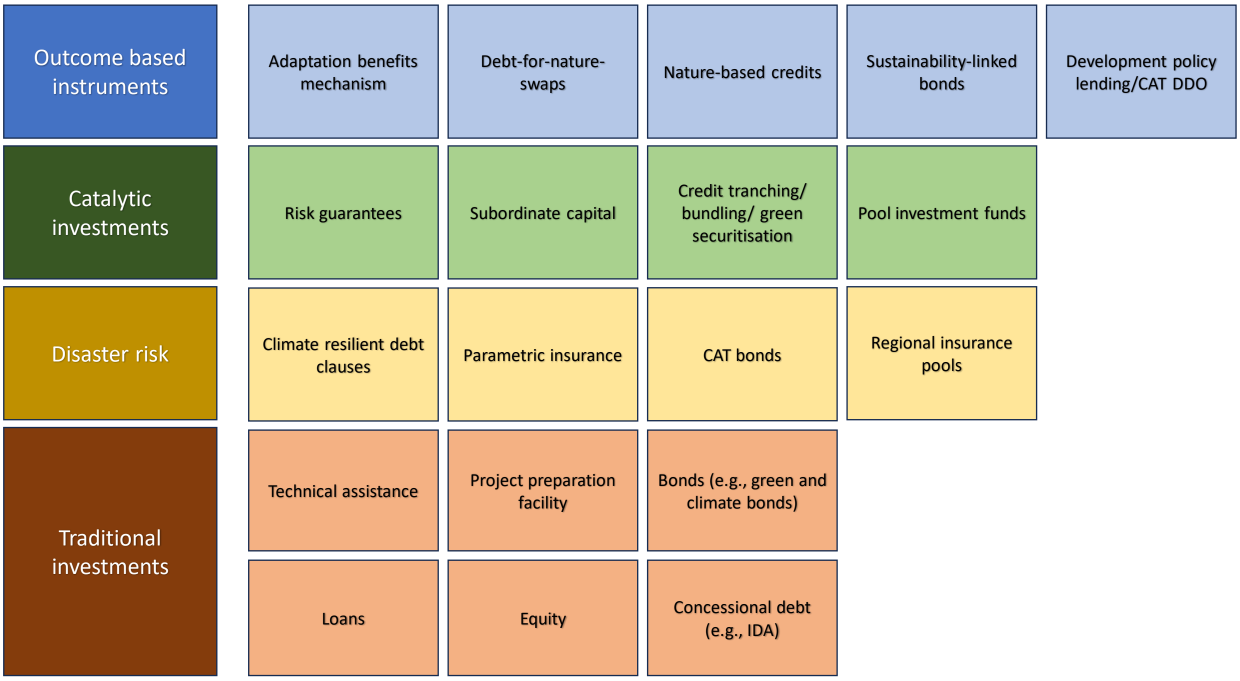
### *Structuring financial products for climate-resilient infrastructure*

Figure 5 presents some of the potential financing instruments that are available for climate adaptation and resilience, and can be considered as part of a mix of instruments that are available and can support strengthen adaptation and resilient approaches to infrastructure (Sivaprasad, Pande and Tan, 2024[127]). It is not exclusive to infrastructure assets, but provides a list of potential financing vehicle for climate resilient infrastructure and recovery from natural disasters. Outcome-based instruments incentivise certain results, ensuring that financing is channelled to the intended outcome. Debt-for-nature swaps allow countries to receive debt waivers to prioritise quantifiable conservation targets or adaptation benefits mechanisms which provides fiscal credits which was pioneered by the African Development Bank.[7]

Catalytic instruments leverage commercial capital through the use of concessional capital, which is a form of blended financing structure that reduces the risks for commercial capital providers. Risk guarantees such as the Asian Development Bank's Innovative Finance Facility for Climate in Asia and the Pacific.

Disaster risk instruments (see Box 15 and Box 16) are insurance products that provide quick capital access and debt relief after a disaster. Catastrophic bonds (cat bonds) in particular are popular high-yield debt instruments that enable risk sharing for climate risk. Climate resilient debt clauses allow lenders to agree to a temporary moratorium on loan repayments in the event of a pre-agreed disaster event. World Bank will be broadening its scope of climate resilient debt clauses to include all existing World Bank loans for the most vulnerable countries.

## Figure 5. Some examples of adaptation and resilience financing stack




Source: WEF, Climate adaptation and resilience needs more innovative funding (https://www.weforum.org/agenda/2024/02/climate-adaptation-and-resilience-innovative-funding/).

**Box 18 Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment**

Countries are addressing climate risks management through innovative financing instruments that foster investment towards climate resilient projects, including infrastructure. Italy, the European Commission and Indonesia are focusing on new ways to bring resilience-related investment and expenditures among mainstream financing mechanisms, in order to catalyse investment and maximise available capital for resilient infrastructure.

Moreover, innovative budgeting approaches, such as green budgeting from the European Commission, are helping in redirecting public investment, consumption and taxation to green priorities and away from harmful subsidies. Practices can include increasing transparency and awareness of climate-related risks; use of standards, guidance, labels and taxonomies; and reviews regulatory standards that affect limits and levels of private financing.

Responses to the survey highlight that many countries have begun to establish public facilities for infrastructure financing, ranging from regional targeted facilities like the Australian Infrastructure Financing Facility for the Pacific (AIFFP), debt or equity funds such as Brazil's National Fund for Climate Change (Fundo Nacional sobre Mudança Climática) and Saudi Arabia's National Infrastructure Fund, or targeted national development banks like the Canada Infrastructure Bank and the UK Infrastructure Bank. Following market trends, some countries, including local authorities, have also issued green and sustainability bonds (Brazil, Canada, Mexico, Russia).

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section V. Practices to scale up financing for climate-resilient infrastructure by promoting and incentivising private sector participation and reducing barriers to private investment.

### *Expanding use of green/resilience bonds*

Green, social and sustainability (GSS) bonds are financial products that enable investors to channel financing towards the achievement of sustainability objectives, while also ensuring stable financial returns. These instruments are well-established in financial markets, having gained substantial trading volume within the last decade due to high market preference.

GSS bonds finance sustainable activities by employing proceeds to fund infrastructure projects that achieve positive green and/or social impacts (see also Box 11). Among GSS bonds, green bonds hold the largest issuance and subscription shares by representing almost 85% of the GSS bonds market (Luxembourg Stock Exchange, 2023[128]), and fund projects that range from climate change mitigation to biodiversity conservation. The popularity of the GSS bonds has been growing over the past decade, given it provides a ready investment opportunity into sustainable finance.

Adaptation and resilience projects are generally eligible for green bond financing, but they are not as frequently utilised as their mitigation counterparts, with one analysis finding that only 4% of green bond issuance (by value) was linked to adaptation (S&P Global, 2023[129]). A different analysis found that in 2022, 13% of GSS bonds and 23% of issuers screened by the Climate Bonds Initiative were identified as having some degree of resilience-related use-of-proceeds (Climate Bonds Initiative, 2022[130]).

Expanding the use of green bonds will require addressing the limited knowledge and capacity to assess climate risk and identify eligible projects, as screening criteria for resilience related activities are high-level, complicating the identification of eligible projects. Moreover, even when resilience projects are identified, they often do not reach the minimum bond issuance size required by investors, or are issued in soft currencies, not matching investors' preferences (Global Center on Adaptation, 2021[131]). These challenges can be especially acute for subnational governments who may have constraints on borrowing, and lower technical and financial capacity.

Blue bonds provide another potential instrument for financing climate-resilient infrastructure. These bonds are financial instruments funding projects and initiatives aimed at promoting sustainable marine and ocean-related conservation activities, are one of the possible types of adaptation bonds. Within this bond category, sovereign entities are among most active issuers, funding various projects aimed at strengthening marine conservation and resilience. Climate-resilient infrastructure projects can receive funding from blue bonds, provided that they comply with standards and taxonomies employed by issuers to screen the eligibility of projects (see Box 19).

## Box 19. Cases of adaptation, resilience and blue bonds that could inform climate resilience of infrastructure assets

**The Netherlands green bonds and blue projects**

The Netherlands' sole green bond, issued in 2019 and raising EUR 15.6 billion, focuses on climate change adaptation, one of the pillars of the Netherlands environmental strategy in the context of both national and international initiatives. The bond holds the CBI Certification Mark.

The related green bond framework aligns with the proposed EU Taxonomy criteria regarding flood risk prevention and protection, and nature-based solutions for flood and drought risk prevention and protection, on top of addressing the applicable Do No Significant Harm criteria and Minimum Social Safeguards on a best-efforts basis.

Some financed projects can be defined as 'blue', since they are part of the Delta Programme, which ensures that flood risk management, freshwater supply, and spatial planning will be climate-proof and water-resilient by 2050.

Practically, expenditures include reinforcing flood defence infrastructure, monitoring and management of water levels, water distribution infrastructure and related measures to anticipate on higher water levels, and are consistent with SDGs 6 and 13, and with the EU Taxonomy Environmental Objectives of Climate Change Adaptation and Sustainable use and protection of water and marine resources.

**Fiji sovereign adaptation bond**

In 2017, by issuing a USD 19.5 million green bond, Fiji became the first developing economy to issue a sovereign green bond. The related framework was developed in compliance with the ICMA Green Bond Principles and accounted for eligible use-of-proceeds such as resilience to climate change, water efficiency, and sustainable management of natural resources, among others.

In practice, 91% of proceeds were allocated to climate adaptation activities, and the financed projects tackled construction and renewal of water collection, treatment and supply infrastructure, forest management, and afforestation, among others.

The issuance of such bond created a business case for climate change adaptation, in a developing economy where often the private sector is hard to mobilize to collect large-scale financing.

Source:
*State of the Netherlands (2020), Green Bond Report. Ministry of Economy (2019), The Fiji Sovereign green bond 2019 update.*

The Nature Conservancy (2023), Belize Blue Bonds for ocean conservation.

### *Blending public finance to support private investment*

The strategic use of public resources can be used to improve the risk-return profile for infrastructure investments. This can take the form of government guarantees, equity stakes and concessional debt finance. For developing countries, this includes blended finance, which is defined by OECD as "the strategic use of development finance for the mobilisation of additional finance towards sustainable development in developing countries". Blended finance is primarily made available by MDBs and donors, that while they contribute to basic development, they also look to establish the market foundations that will eventually attract private investors (Migliorati, 2020[132]). Blended finance focuses on achieving development and impact through the mobilisation of private capital. Blended finance is considered catalytic because, by mobilising capital, it creates a direct causality that unlocks further mobilisation and potential investment (OECD, 2018[133]). Blended finance has been recognised as a key driver for climate resilient infrastructure in the G20-Finance in Common Joint Event in May 2024 too.

In OECD countries, governments use tools such as guarantees to make investing in domestic infrastructure more appealing for private investors and to support subnational governments' access to finance. For example, the UK Infrastructure Bank administers government guarantees to qualifying projects, with an aim of mobilising private finance. It also provides access to other concessional finance for private sector and local authorities.

At the international level, initiatives such as the Private Infrastructure Development Group (PIDG) can enable blended financing to be more systematically mobilised, linking donor funding more directly to private sector capital mobilisation. The latest annual strategy for PIDG commits to only funding infrastructure projects that contribute to climate adaptation, resilience and/or mitigation.

When private sector financing is accompanied by early adaptation goals and implementation efforts to address this, blended finance can be an effective process to ensure adaptation is well supported. In particular, blended finance can be used as an incentive to mainstream adaptation elements into project development. For this, early engagement would be a key requirement, as well as the types of financial instrument used in such instance.

Grants can be used to support the integration of adaptation in early stages of projects, and also improve the return for climate-climate resilient infrastructure. This could be by providing funding for feasibility studies or supporting early-stage adaptation when cash flow can be uncertain. Private financing will be protected by a junior tranche that is provided by concessional finance and a mezzanine tranche that is provided by concessional public financing (OECD, 2023[134])

### *How MDB and global funds are supporting climate resilience*

Multilateral Development Banks (MDBs) have committed to addressing climate resilience through a number of avenues. MDBs issued the MDB Just Transition High-Level Principles in October 2021 articulating how MDBs will support the just transition referenced in the Paris Agreement (MDBs, 2021[135]).[8] The High Level Principles specifically cite the need to support the delivery of climate resilient strategies.

In their Joint Report on Multilateral Development Banks' Climate Finance, (MDB, November 2023[136]), MDBs report on their climate adaptation work. The MDB methodology was updated in 2022 to clarify that adaptation is no longer viewed purely as an add-on to development investment, but rather as an imperative for putting development on the path for resilience. In 2022, USD25.2 billion was committed for climate change adaptation finance, with USD22.7 billion, or 90%, committed to low- and middle-income economies. Sub-Saharan Africa received the largest MDB adaptation finance at USD8.7 billion and South Asia receiving USD3.9 billion. In terms of sectors, adaptation finance of MDBs has gone 30% to the energy, transport and other built environment and infrastructure, thus confirming that a large proportion of adaptation financing being applied through infrastructure projects.

In addition to the financing that is provided by MDBs, MDBs are supporting climate resilience through knowledge sharing and technical assistance. This has been For example, World Bank has developed Climate Toolkits for Infrastructure PPPs. These include both an umbrella and sector-specific toolkits to help facilitate investment in low carbon and resilient infrastructure. In a similar vein, the Inter-American Development Bank developed the Climate Resilient Public-Private Partnerships: A Toolkit for Decision Makers which was updated in 2024 (only Spanish version available).

Entities such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF) are global vehicles that have been established to deliver concessional climate finance, and are designated multilateral climate funds servicing the parties to the UNFCCC. The Climate Investment Funds (CIFs) implement their funding through MDBs to support climate action. GCF has a specific fund Infrastructure Climate Resilient Fund (ICFR) which supports Sub-Saharan Africa with USD 240 million in junior equity by providing catalytic first loss equity to catalyse investment from the private sector.

In addition, A Loss and Damage Fund was established at COP28 to compensate for losses and damages from natural disasters caused by climate change. The Fund will be administered by the World Bank and is a financial instrument aimed at addressing consequences and fostering recovery from climate-induced disasters.

## Identifying relevant funding streams

Finance for climate-resilient infrastructure depends upon securing sufficient funding to repay the capital costs, cover ongoing operations and maintenance and providing a return to investors (if applicable). Insufficient funding can undermine climate resilience by preventing projects from going ahead, but also by leading to insufficient maintenance that reduces asset lifetimes and increases vulnerability to climate change impacts (Hallegate, Rentschler and Rozenberg, 2019[3])

Funding mechanisms will depend upon the type of asset and broader context, but the funding streams relevant for climate-resilient infrastructure will generally be the same as those for any type of infrastructure and subject to the same considerations. These funding streams typically include (OECD, 2022[83]):

- **Taxes** – provision of grants and subsidies from general taxation, earmarked tax revenues. These revenues may be transferred between levels of government.
- **User charges** – payments from beneficiaries of the infrastructure services provision, such as road tolls, utility tariffs, sales of services
- **Ancillary revenues** – advertising, sale of data, property income (e.g. rents from retail in transport hubs)
- **Land value capture** – capturing some of the increment in property values that results from infrastructure provision.
- **International transfers** – Overseas Development Assistance (ODA), climate finance, philanthropy.

Filling the funding gap for climate-resilient infrastructure may need to depend largely on taxes and user charges given the scale of investment required. Shifting the burden of infrastructure provision to user charges can support efficiency and generate additional resources, but the distributional impacts need to be identified and managed. For example, by combining water pricing with targeted subsidies for low-income households.

Transfers can be particularly relevant for climate-resilient infrastructure by helping to address financial constraints faced by those communities most affected by climate change. At the national level, this includes transfers to subnational authorities. At the international level, climate finance is a valuable resource for supporting climate-resilient infrastructure investment in developing countries. Between 2016-2021, 31% of public climate finance for adaptation went to two infrastructure sectors: water supply and sanitation (21%) and transport and storage (10%) (OECD, 2023[134]). Average public climate finance for these sectors is around USD 5.4 billion per year, predominantly provided as concessional loans.

### *Public funding for resilience benefits*

Governments are directly supporting the provision of climate-resilient infrastructure through grants and subsidies to cover upfront capital costs. This can be through the provision of dedicated funding streams for climate resilience, or by prioritising climate-resilient proposals when allocating grants for infrastructure. The EU Structural and Investment Funds includes grants for infrastructure provision in member states. In keeping with the EU's commitment for 30% of the budget to support climate action, some of the grant programmes have criteria that favour climate-resilient proposals. The US Inflation Reduction Act (IRA) included more than USD 1 billion of funding for incentives and grants to support the installation of climate-resilient infrastructure. Canada has established a CAD 2 billion Disaster Mitigation and Adaptation Fund that provides subsidies for the construction or retrofitting of resilient infrastructure.

**Box 20 Fiscal measures made available for and to support climate resilient infrastructure**

Case studies show that the most common fiscal measures to incentivise action to improve resilience are tax benefits for issuers of debentures in the infrastructure sector, and tax reforms that address climate resilience across sectors, such as in the case of Brazil. Others, including Mexico, have introduce ecological taxes that reduce climate change impacts of assets, including infrastructure, and that are administrated at the state level, rather than by the central government.

In some countries, such as Japan and Italy, fiscal measures addressing resilient infrastructure needs are financed through the issuance of sovereign green bonds or transition bonds, that direct the proceeds towards the financing of state expenditures promoting the green transition, and including infrastructure investment that promotes renewable energy and clean transportation.

Another instance of emissions reduction is the European Union Emission Trading System, which has been recently integrated by a parallel system covering fuel combustion in buildings, road transport and additional sectors not covered by the original system. Such a scheme, by auctioning emission allowances, ensures that a share of the revenues will be used to support vulnerable households and micro-enterprises through a dedicated Social Climate Fund, and to fund climate action and social with the remaining revenues.

This mechanism indirectly encourages the adoption of resilient infrastructure practices by favouring investments in cleaner, more sustainable technologies and infrastructure projects. Additionally, by aligning the ETS with infrastructure resilience goals, the EU can promote the transition towards climate-resilient infrastructure while simultaneously reducing carbon emissions.

Note: Case studies in this report are provided under the responsibility of each country.
Reference: Presidency Annex A, Section VI. Fiscal measures made available for and to support climate resilient infrastructure

Governments could also support the delivery of “resilience services” following the model of Payments for Ecosystem Services. Projects that reduce stormwater runoff, such as through the provision of green infrastructure, generate credits. These credits have a market value because they can be sold to other property owners who can use them to meet their own regulatory requirements for stormwater management. In principle, this approach could be extended to other forms of positive externality – such as reducing urban heat island effect or providing protection from other forms of flood risk. This has been implemented in some areas for measures to reduce stormwater runoff and, hence, the risk of surface flooding. The District of Columbia (US) has implemented a Stormwater Retention Credit Trading Programme, for example.

Improve and diversify sources of funding to enhance subnational government creditworthiness. Local revenue sources generate cash flow that can be used directly for resilience investments or for supporting borrowing. Subnational governments may seek to enhance the use of existing and innovative funding instruments to that link to climate resilience, such as land value capture (OECD, 2022[83]) (OECD, 2023[43]). In Korea, for example, the Floor-Area-Ratio incentive systems grants developers greater development rights in exchange for cash that is earmarked for local infrastructure development, including for resilience (OECD, 2024[16]).

### *Harnessing land value capture for climate-resilience investments*

Some forms of investment in climate resilience will result in increases in the value of nearby land. For example, the construction of flood defences can increase the value of homes nearby, which may no longer be subjected to a risk of flooding events. Nature-based Solutions for flood management can also create amenity value, for example through the creation of urban green space. Capturing some of these gains can provide local governments with an important source of revenue to pay for climate resilience (OECD, 2022[83]).

The term "land value capture" refers to various taxes, user charges and fees, and other revenue sources that seek to capture this gain. These instruments existing in most countries in some form or another, but a majority of countries lack a legal definition of, or justification for land value capture (OECD/Lincoln Institute, 2022[137]). The OECD and the Lincoln Institute of Land Policy have developed a taxonomy of land value capture instruments. This highlights five main types of land value capture (2022[137]):

- **Infrastructure levy**: taxes or fees levied on landowners possessing land that has gained value due to government-initiated infrastructure development.
- **Developer obligations**: cash or in-kind contributions that defray costs for additional infrastructure or services that need to be provided due to private development.
- **Charges for development rights**: cash or in-kind contributions payable in exchange for development rights or development potential above a set density baseline.
- **Land readjustment**: the practice of pooling fragmented land parcels for joint development, with owners transferring a portion of their land for public use.
- **Strategic land management**: the practice of governments actively buying, developing, selling and leasing land to advance public needs and recoup value increments borne through public action.

All these land value capture instruments can be relevant for climate resilience. Infrastructure levies, for example, can be applied to property owners benefiting from public infrastructure that is created to protect existing assets facing increased climate risks. Similarly, developer obligations and charges for development rights, can be applied to help ensure that up-front investments are being made to protect new assets. An example of an infrastructure levy exists in Germany, where urban renewal measures – including for climate adaptation – are charged back to local land-owners (Box 21).

### Box 21. Infrastructure levy for urban renewal measures in Germany

In Germany, the urban renewal measures levy (Städtebauliche Sanierungsmaßnahmen) applies in designated renewal areas. Local governments implement these charges and receive the revenues by recovering the land value increase. Landowners, tenants, leaseholders and other affected parties have the right to participate in consultations. The levy is widely used and accepted. Examples where a landowners pays a levy include:

- Green and open spaces for climate protection and adaptation;
- The construction or expansion of renewable energy systems;
- Renewed infrastructure to reduce the pollution and noise from buildings, businesses and traffic facilities; and
- The equipment of areas with playgrounds and sports fields.

Source: OECD (2022) Global Compendium of Land Value Capture Policies

However, the correct valuation of assets remains a challenge in some countries, and may require the appropriate legislation in particular for EMDEs.

### *Asset recycling*

Asset recycling is the process of selling or divesting assets with the aim of using the proceeds to fund another investment. This provides short term funding, but does not generate any "additional" funding over the long-term as future income from the assets is foregone (OECD, 2022[83]). Asset recycling can be used to support climate finance and in particular climate resilience, which may have difficulty attracting financing that requires an identified revenue stream.

Asset recycling involves the private sector partner taking over the financing risk, and the public owner supporting the transaction through information and data sharing. However, for climate finance related transaction and climate resilience related one, the public sector partner may need to take on a bigger share of the financial risk. This could enable the unlocking of financing towards climate resilience through the participation of the public sector by risk sharing. World Bank has developed an Asset Recycling Guidelines to support activities in asset recycling.

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# Notes

1 These includes the investment needed to achieve the SDGs and net zero respectively from World Bank (Rozenberg and Fay, 2019[139]) and (OECD/The World Bank/UN Environment, 2018[70]).

2 Climate change cause of Greater Jakarta floods, BMKG says - City - The Jakarta Post

3 Philippines: strongest typhoon | Statista

4 Physical climate risks encompass the risks arising from the consequences of climate change. These can include direct consequences, such as damage to assets, but also indirect consequences such as changing patterns of demand for infrastructure services.

5 At the microeconomic level, the cost of physical risks within the current policy (CP) scenario represents, on average, 4.4% of the total net asset value (NAV) of the assets in the reference database by 2050, with important variations across sectors. The average maximum loss is -27% with the effect of extreme climate events negative across all sectors, impacting the NAV of transport (-10% on average with a maximum of -97%) and the energy and water resources sector (-7% on average, with a maximum of -40%) the most.

6 At the request of the G20, the Financial Stability Board (FSB) created the TCFD to develop recommendations on the types of information that companies should disclose to support investors, lenders, and insurance underwriters in appropriately assessing and pricing a specific set of risks—risks related to climate change in 2015.

7 Debt-for-development swaps and climate resilient debt clauses are financial instruments that have been discussed by the G20 International Financial Architecture Working Group this year.

8 MDBs committed to the High Level Principles are African Development Bank, Asian Development Bank, Asian Infrastructure Investment Bank, Council of Europe Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, Islamic Development Bank, New Development Bank and World Bank Group.

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