

Climate-Informed Public Investment Management Diagnostic Framework: Climate-Change Adaptation and Mitigation

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1. Introduction and rationale

Greenhouse gas (GHG) levels² have continued to rise over recent decades while governments are striving to introduce strategies to reduce GHG emissions. At the same time, climate change and related extreme weather events have been causing economic disasters with increasing frequency and severity. These trends are expected to continue such that climate-related disasters will become a growing impediment to sustainable development with a disproportionate share of the impacts falling on the poor. Increased extreme weather threats are compounded by growing populations, particularly in low-lying flood plains and coastal zones vulnerable to flooding. Annually, hundreds of millions of people are now adversely affected and hundreds of billions of US dollars' worth of public and private property damage is suffered worldwide. The scope and scale of these growing economic disasters represents an increasingly urgent problem for governments to recognize and take measures to defuse this fiscal time bomb.

Climate-related disasters cause damage to private property, public infrastructure and public service delivery, including communications, transportation, utilities and social services. In addition, the economic losses can well exceed the costs of replacing damaged property. For example, where a road bridge is washed away, it not only drains the treasury of the resources to replace it, but where alternative transportation routes are minimal or costly, the economy loses the net private benefits that bridge users would have captured plus the added tax revenue related to the forgone transportation activity. The longer it takes to repair the bridge or provide alternative transport routes, the economic losses accumulate. This raises the question about whether the government could have designed and built a bridge that could withstood the flood or planned alternative transportation routes or mechanisms (use of military pontoon bridges, for example) in case of the loss of the bridge or could have developed rapid repair or replacement capacities. This simple example illustrates that public investment management (PIM) is essentially at the core of designing and financing public infrastructure and service capacity that minimizes the economic losses of expected climate-related disasters. It has to be able to adapt public investment and services to make the economy more resilient to anticipated natural disasters.

At the same time, ever since the 1992 United Nations Framework Convention on Climate Change (UNFCCC) was signed in Rio de Janeiro, countries have collectively and individually been working on climate-change mitigation commitments and mechanisms to reduce GHG emissions. This has involved national and subnational governments, and increasingly, public and private corporations. This movement has evolved into a broader vision of a “green” or “low-

² Annex 1 provides some basic concepts and definitions related to the composition and measurement of greenhouse gases (GHG).

carbon” economy as a means to achieving sustainable and equitable growth.³ Major reductions in GHG emissions by both the private and public sector remain at the core of achieving a green economy. Growth in GHG gas levels with the resultant impacts on climate events remain an urgent issue. This report recognizes that governments have to go beyond climate-change mitigation through regulations and price incentives that largely focus on the private sector and public corporations, and explore the roles and integration of climate-change mitigation into public investments and the PIM system.

This report focuses on how to integrate the consideration of climate-related disasters into the planning, design, appraising, financing, implementing, operating and maintaining public investments. It also considers the need to include any impacts public investments may have on future climate change. This includes how climate-change mitigation goals and strategies become integrated into PIM so that “greener” public investments also contribute to meeting these goals.

The next sections of this chapter give more detail on the frequency and growth of climate-related hazards and disasters, the growing size of the damage and losses, future expected trends in extreme weather events, and the assessment of the resilience and vulnerability of countries and regions to climate related disasters. It also elaborates on the evolving role of public investment design and decision-making in achieving climate-change mitigation. This leads into the next chapter which takes up the urgent need for governments to review their PIM systems to assess how “climate smart” they are, and then, also to follow on with developing the capacities and functions within the ministries of finance and planning as well as other key sector ministries and agencies to ensure that both the core PIM system and climate-change related functions are strengthened and integrated into the PIM system.

1.1. Climate impacts: overview of evidence of frequency and severity of hazards and damage

The second World Bank report *Turn Down the Heat (2014)*⁴ reviews the climate impacts caused by tropical storms, wind, drought, flood and landslide across regions over recent decades. Among the key issues highlighted in this report are the early onset of climate impacts, uneven regional distribution of climate impacts, and interaction among impacts, which accentuates cascade effects. Generally, climate-related disaster events have been rising markedly. A strong link between climate change and tropical storms emerges:⁵

“A steep rise in climate-related disasters by one order of magnitude from about 30 in the early 1960s to more than 300 in the early 21st century (trend: approximately 70 events per decade from 1960–2014) is apparent from the EM-DAT database (see Figure 2.3). The absolute values of this increase should be interpreted with caution, since this signal

³ See for example, UNEP, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers*, 2011. www.unep.org/greeneconomy

⁴ World Bank. 2014. *Turn Down the Heat: Confronting the New Climate Normal*. Washington, DC: World Bank. License: Creative Commons Attribution—NonCommercial—NoDerivatives 3.0 IGO (CC BY-NC-ND 3.0 IGO).

⁵ Section 2.3.1 (page 9) of World Bank. 2014. *Turn Down the Heat: Confronting the New Climate Normal*, op cit

is distorted by an increase in climate-related disaster reporting over the same time frame that is very difficult to quantify. Still, this increase in climate-related disaster reporting is assumed to have happened predominantly before the mid-1990s (and the advent of modern information technology); while the number of disasters counted nearly doubled between the mid-1990s and 2010–2014.”

Weather-related disasters and costs

In Chapter 2 below, an analysis of the Emergency Events Database (EM-DAT)⁶ is presented that also shows the major increases in frequency and severity of natural disasters. A review of the changes in disasters over the past six decades show that the number of occurrences has increased by a factor of six between the 1960s and post 2000. Even after adjusting the damage costs to constant US\$, the total reported damage cost per decade increases by a factor of twelve and the cost per occurrence increases by a factor of nearly four. Some changes in the composition of damage has also emerged over the decades. Geophysical damage has grown in absolute terms, but has declined in relative importance. Tropical storms have remained more constant as share of the total classified costs at around 30% on average. There has been a significant growth in other water-related damage including tsunamis, coastal flooding and riverine flooding. In the last decade hazards causing water-induced damage caused about 83% of the damage in the classified cases, and when all climate-related hazards are included the share rises to 91%.⁷

While much of the damage to infrastructure, other structures and agriculture is caused by water damage from storms, coastal and riverine flooding, tsunamis, land and mud slides, etc, impacts also arise out of extreme temperatures, drought, and rising sea levels and temperatures, etc. An overview of the *Turn Down the Heat (2014)* findings on the climate impacts of are presented in Annex 1, including affects on agriculture, terrestrial and marine ecosystem. In human terms, natural disasters also result in fatalities, injuries, loss of housing and food sources, job losses, water borne diseases, and major disruptions in health and education services, transportation and communications and utility supplies.

Another important set of perspectives on climate disaster risks facing countries can be gained from the analysis of annual Climate Risk Index (CRI) estimated by GERMANWATCH annually for some fourteen years. This report uses the readily available publications for the eight years, 2012 through 2019.⁸ The CRI is based on a weighted average of a country’s rankings on four indicators (deaths, deaths per inhabitant, US\$ losses, and losses as a share of GDP) caused by weather-related events in a particular year. In addition, a long-term CRI is calculated which gives the weighted average of the annual indicator rankings for the country over a twenty year period. Box 1.1 gives a brief explanation of the calculation of the CRI. For example in 2019, the annual CRI for 2017 and the long-term CRI for 1998-2017 is published for 181 countries. Here, the focus is on the ten worst affected countries in each year and over each twenty year

⁶ Emergency Events Database (EM-DAT) by the Centre for Research on the Epidemiology of Disasters (CRED) at the Universite Catholique de Louvain (UCL)

⁷ Another source of data on natural disasters including climate risks also largely based on EM-DAT data is the report by CRED and UNISDR on *Economic Losses, Poverty and Disasters, 1998-2017*.

⁸ GERMANWATCH, *Global Climate Risk Index 2019, 2018, 2017, 2016, 2015, 2014, 2013, and 2012*, GERMANWATCH, Bonn, <https://germanwatch.org/en/cri>

period for the eight years ending in 2010 through 2017. The reason for this focus is that it illustrates the importance of the impact of extreme weather conditions to cause disasters in countries with extremely low probabilities. For example, a storm strong enough to cause damage may occur once every ten years, whereas one causing severe damage may only occur once every twenty or more years in a particular country. Therefore long-term observations are crucial to developing an understanding about the probability of severe damage being caused by a specific type of extreme weather event. These highly skewed probabilities, it will turn out, are at the core of the difficulty in predicting and planning weather related disasters in a country, and hence, also managing a public investment program and related budgets to keep an economy growing in the presence of large difficult to predict disasters.

Box 1.1 Calculation methods for the Climate Risk Index (CRI)

The CRI for a particular country and year is a weighted average of a country's **ranking** on four indicators arising from weather-related events (storms, floods, and temperature extremes and mass movements (heat and cold waves etc.)) and weights:

Indicator	Weight
1. Number of deaths,	One-sixth
2. Number of deaths per 100 000 inhabitants,	One-third
3. Total losses in US\$ in purchasing power parity (PPP)	One-sixth
4. Losses per unit of Gross Domestic Product (GDP).	One-third

The data on the indicator values is obtained from Munich Re's NatCatSERVICE. For the long-term CRI, each indicator is calculated as the average ranking of a country for that indicator in each of the previous twenty years and then the weights are applied to the average indicator ranking.

Source: GERMANWATCH, *Global Climate Risk Index 2019 : Who suffers Most from Extreme Weather Events? Weather-related Loss Events in 2017 and 1998 to 2017*, GERMANWATCH, Bonn, 27 November 2018, <https://germanwatch.org/en/cri>

The results of the analysis of the 10 most affected countries in each year and over the long term over the eight years for 2010-2017 are presented here:

1. While only 15 countries appear in the 10 worst affected countries based on the long-term CRI rankings over the 8-year period, 50 different countries are ranked in the worst affected countries based on the annual CRI. Few countries suffer consistent disasters in most years, but many different countries can suffer one or more major disasters in a particular year.
2. Of the 15 countries worst affected countries over the long-term, only 8 (Bangladesh, Haiti, Honduras, Myanmar, Nicaragua, Pakistan, Philippines and Vietnam) appear in the top ten in 7 or 8 of the 8 years, and 5 countries (Bangladesh, Pakistan, Philippines, Thailand and Vietnam) had an annual average of between 5 and 15 weather-related disaster events over twenty year periods, while the others in the group of 15 countries

tend to have only one or two events a year. There are a small group of countries that are suffering weather related disasters with a high frequency over the long-term.

3. Out of the 50 countries that ranked in the 10 most severely affected countries over the 8 years, 30 countries only made the top-10 once, 14 countries were in top-10 twice, and only 5 countries made the top-10 between 3 and 5 times (namely, Dominica, Pakistan, Philippines, Madagascar and Vietnam). Again, very few countries are severely damaged regularly, but many countries (50 out of the 181 in the database) appear at least once in eight years in the top 10 most severely damaged countries. Interestingly, Mozambique appears twice in eight years, and now in 2019 gets hit by two severe tropical cyclones, Idai hitting the Beira area in March and then again Kenneth hitting the Pemba area in April, both of an intensity above any historical records. Again, extreme, low probability weather events are hard to predict.

As a crude approximation, for example, if the approximately 180 countries in the database were grouped into 100 having a 1/25 chance of having weather-related events putting them in top 10 CRI each year, 60 countries having a 1/15 chance, and the remaining 20 countries having a 1/10 chance, then this would result in the low-probability group yielding 4 a year, the medium-probability also 4, and the high-probability only 2. By contrast, over the long term (20 years, here), the high-probability group would dominate the top-ten long-term CRI group. This illustrates why each year a few of the large low-probability group have the unpleasant “unexpected surprise” of a major weather-related disaster.

4. While absolute levels of losses can be multi-billion dollar amounts in large countries such as India and the United States, some extremely high estimated losses have occurred relative to GDP. For example, Dominica, 216% of GDP in 2017 and 40% in 2015, Vanuatu, 77% in 2015, Puerto Rico, 63% in 2017, Haiti, 17% in 2016, Fiji, 13% in 2016 and Thailand, 12% in 2011.^{9,10,11} These extreme cases are clearly rare, but they result in the country long-term CRI ratings changing so dramatically that they enter the 10 most severely affected countries over the long term. For example, the damage in Puerto Rico in 2017 was so severe that it moved down over a hundred ranking positions from 2016 and 1997-2016 CRIs to be ranked number one in both the annual 2017 and 1998-2017 CRIs.

⁹ IMF estimates of the reproducible fixed capital stocks of countries over 2000-13 average over 200% of GDP based on IMF *Investment and Capital Stock Dataset 2015*. For low-income developing countries, government capital stock averaged 93.9% of GDP and private capital stock, 107.7%, while for advanced economies, government was 51.3% and private sector was 153.6% of GDP. These estimates exclude non-depreciable assets such as land and other natural resources, inventories, and intangibles such intellectual property, which typically result in total capital exceeding 300% of GDP. Disaster losses mainly capture the damage to infrastructure and other property including agricultural land, crops and livestock. It is therefore possible that a severe natural disaster can have economic losses in excess of 100% of GDP.

¹⁰ Acevedo, Sebastian, “Gone with the Wind: Estimating Hurricane and Climate Change Costs in the Caribbean,” IMF Working Paper, WP/16/199, October 2016 reports in Table 2 on 148 hurricane disasters to Caribbean Islands over 1950-2014 with the 20 largest causing losses averaging 81.7% of GDP and with 5 of these over 100% of GDP.

¹¹ Table 6 of CRED and UNISDR on *Economic Losses, Poverty and Disasters, 1998-2017* reports the top 10 climate-related disasters ranked by loss as a share of GDP: all ten are Caribbean islands with losses ranging from 69% to 797% of GDP.

5. Another indicator of the impact of the impact of low probability extreme events is the rapid change in rank position of countries in the top 10 most affected countries in a year. For example, 14 countries moved by over 100 ranking positions and a further 18 country cases moved by more than 50 ranking positions.

Later in Chapter 2, it will become evident that the appraisal of public investment projects in the context of climate-related hazards depends heavily on understanding the relationship of the probability of extreme weather events to the potential losses from damage to sectors (transportation), projects (a road segment) and specific assets (a particular bridge, for example.)

1.2 Current state and expected trends in climate-related hazards

The World Meteorological Organization (WMO) report on *The State of the Global Climate in 2018*¹² continues to confirm the global warming trend with the average global temperature for 2018 set to be the fourth highest on record and the past 4 years, the warmest on record.

Greenhouse gas (GHG) concentrations in 2017 reached new highs and indications are that they continued to rise in 2018. The ocean heat content remained close to its 2017 high, and the arctic sea ice extent was well below average throughout 2018 with record-low levels in the first two months of the year. Global Mean Sea Level (GMSL) for the period from January to July 2018 has been around 2 to 3 mm higher than for the equivalent period in 2017 and are rising at about 4mm per year as a global average.

High frequencies of extreme weather events continue to be reported in the WMO Report. The number of tropical cyclones was above average in all four Northern Hemisphere basins, with 70 reported by 20 November, compared to the long-term average of 53. There are also reports of severe rainfall and floods (including Japan, south-west India, and East Africa), heatwaves (with record high temperatures in parts of Europe, Japan and Korea), droughts (especially Eastern Australia, Uruguay and Argentina), extreme cold (in Europe), and wildfires (especially in British Columbia and California.)

The continuing build up on GHG concentrations and related atmospheric temperature rises have led to extreme weather conditions over recent decades. In 2017, GHG concentrations reached new highs, with CO₂ at 405.5±0.1 parts per million (ppm), CH₄ at 1,859±2 parts per billion (ppb) and N₂O at 329.9±0.1 ppb. These values constitute, respectively, 146%, 257% and 122% of pre-industrial levels (before 1750).¹³ CO₂ concentrations having been increasing at the rate of 2.1ppm over the ten years to 2015. Higher GHG concentrations tend to lead to higher temperatures and more extreme weather events. Efforts have been made to check which of the observed extreme weather events can be linked to climate change. Table 1.1 lists a selection of record-breaking

¹² World Meteorological Organization, *The State of the Global Climate in 2018*, WMO Provisional statement on the State of the Global Climate in 2018, 29 November 2018, <https://public.wmo.int/en/media/press-release/wmo-climate-statement-past-4-years-warmest-record>

¹³ WMO 2018 Report op cit.

meteorological events over 2000-2012.¹⁴ These extreme weather events are reliably related to extreme temperatures and rainfall or lack thereof. The confidence level with which these events can be linked to climate change is provided based on the underlying study of the event. In addition, most studies of the evolving global climate point to the expectation of increasing intensity of tropical cyclones (higher wind speed and greater precipitation) as the oceans temperatures rise. Studies have also identified “hotspots” in global regions such as South Asia where climate-change impacts are expected to be severe. Box 1.2 illustrates expected hotspots for climate-change impacts in South Asia.

Box 1.2. Climate impacts in hotspots in South Asia

“For countries with severe hotspots—Bangladesh, India, and Sri Lanka—the negative impacts are predicted to be even greater. Translated into gross domestic product (GDP) per capita, changes in average weather are predicted to reduce income in severe hotspots by 14.4 percent in Bangladesh, 9.8 percent in India, and 10.0 percent in Sri Lanka by 2050 under the carbon-intensive scenario compared to the climate of today. The Northern and North Western provinces of Sri Lanka emerge as the top two hotspots, followed by the much less densely populated North Central Province (table 4.9). Northern Province is home to a large number of poor and displaced people. The effects of climate change will add a challenge to this long-term recovery. The highly urbanized and densely populated Western Province, which includes Colombo, is also predicted to experience a 7.5 percent decline in living standards by 2050. This has huge economic implications for the country, especially since the province contributes more than 40 percent of Sri Lanka’s gross domestic product (GDP). Among the districts, Jaffna emerges as the top hotspot, followed by Puttalam in North Western Province and Mannar and Kilinochchi in Northern Province (table 4.10). Given that 5 of the 10 most vulnerable districts of Sri Lanka are in Northern Province, changes in average weather and vulnerability must be considered for future planning and development activities there. Gampaha, which is among the 10 most vulnerable districts, is also the second-most-populous district in the country and was declared one of the worst-affected districts in the recent droughts”.

Source: Mani, Muthukumara; Bandyopadhyay, Sushenjit; Chonabayashi, Shun; Markandya, Anil; Mosier, Thomas. 2018. South Asia’s Hotspots: Impacts of Temperature and Precipitation Changes on Living Standards. South Asia Development Matters. Washington, DC: World Bank. © World Bank. <https://openknowledge.worldbank.org/handle/10986/28723> License: CC BY 3.0 IGO.

¹⁴ Table 1 in World Bank, *Turn Down the Heat: Why a 4°C warmer world must be avoided*. Washington D.C.: World Bank Group, 2012 <http://documents.worldbank.org/curated/en/865571468149107611/Turn-down-the-heat-why-a-4-C-warmer-world-must-be-avoided>

The IPCC Special Report on Global Warming of 1.5°C (IPCC SR15) reported that the average global temperature for 2006-2015 was 0.87°C above a pre-industrial baseline.¹⁵ For comparison,

Table 1.1 Selection of record-breaking meteorological events since 2000, their societal impacts and qualitative confidence level that the meteorological event can be attributed to climate change. Adapted from Ref.¹

Region (Year)	Meteorological Record-breaking Event	Confidence in attribution to climate change	Impact, costs
England and Wales (2000)	Wettest autumn on record since 1766. Several short-term rainfall records ²	Medium based on ³⁻⁵	~£1.3 billion ³
Europe (2003)	hottest summer in at least 500 years ⁶	High based on ^{7,8}	Death toll exceeding 70,000 ⁹
England and Wales (2007)	May to July wettest since records began in 1766 ¹⁰	Medium based on ^{3,4}	Major flooding causing ~£3 billion damage
Southern Europe (2007)	Hottest summer on record in Greece since 1891 ¹¹	Medium based on ^{8,12-14}	Devastating wildfires
Eastern Mediterranean, Middle-East (2008)	Driest winter since 1902 (see Fig. 20)	High based on ¹⁵	Substantial damage to cereal production ¹⁶
Victoria (Aus) (2009)	Heat wave, many station temperature records (32–154 years of data) ¹⁷	Medium based on ^{8,14}	Worst bushfires on record, 173 deaths, 3,500 houses destroyed ¹⁷
Western Russia (2010)	Hottest summer since 1500 ¹⁸	Medium based on ^{8,13,14,19}	500 wildfires around Moscow, crop failure of ~25%, death toll ~55,000, ~US\$15B economic losses ¹⁸
Pakistan (2010)	Rainfall records ²⁰	Low to Medium based on ^{21,22}	Worst flooding in its history, nearly 3000 deaths, affected 20M people ²³
Colombia (2010)	Heaviest rains since records started in 1969 ²⁶	Low to Medium based on ²¹	47 deaths, 80 missing ²⁶
Western Amazon (2010)	Drought, record low water level in Rio Negro ²⁷	Low ²⁷	Area with significantly increased tree mortality spanning 3.2 million km ²⁷
Western Europe (2011)	Hottest and driest spring on record in France since 1880 ²⁸	Medium based on ^{8,14,29}	French grain harvest down by 12%
4 US states (TX, OK, NM, LA) (2011)	Record-breaking summer heat and drought since 1880 ^{30,31}	High based on ^{13,14,31,32}	Wildfires burning 3 million acres (preliminary impact of \$6 to \$8 billion) ³³
Continental U.S. (2012)	July warmest month on record since 1895 ³⁴ and severe drought conditions	Medium based on ^{13,14,32}	Abrupt global food price increase due to crop losses ³⁵

¹ D Coumou and S Rahmstorf, *Nature Climate Change* 2, 491 (2012).

² L.V. Alexander and P.D. Jones, *Atmospheric Science Letters* 1 (2001).

³ P. Pall, T. Aina, D.A. Stone et al., n 470, 382 (2011).

⁴ S.K. Min, X. Zhang, F.W. Zwiers et al., n 470, 378 (2011).

⁵ A.L. Kay, S.M. Crooks, P. Pall et al., *Journal of Hydrology* 406, 97 (2011).

⁶ J Luterbacher and et al., s 303, 1499 (2004).

⁷ P.M. Della-Marta, M.R. Haylock, J. Luterbacher et al., *Journal of Geophysical Research* 112 (D15103), 1 (2007); P. A. Stott, D. A. Stone, and M. R. Allen, n 432 (7017), 610 (2004).

⁸ D. Coumou, A. Robinson, and S. Rahmstorf, (in review); J. Hansen, M. Sato, and R. Ruedy, *Proc. Nat. Ac. Sc.* (early edition) (2012).

⁹ J. M. Robine, S. L. K. Cheung, S. Le Roy et al., *Comptes Rendus Biologies* 331 (2), 171 (2008).

¹⁰ World Meteorological Organisation, Report No. WMO-No 1036, 2009.

¹¹ D. Founda and C. Giannakopoulos, *Global and Planetary Change* 67, 227 (2009).

¹² F. G. Kuglitsch, A. Toreti, E. Xoplaki et al., *Geophysical Research Letters* 37 (2010).

¹³ G.S. Jones, P.A. Stott, and N. Christidis, *JGR* 113 (D02109), 1 (2008).

¹⁴ P.A. Stott, G.S. Jones, N. Christidis et al., *Atmospheric Science Letters* 12 (2), 220 (2011).

¹⁵ M. Hoerling, J. Eischeid, J. Perlwitz et al., *Journal of Climate* 25, 2146 (2012); A. Dai, *J. Geophys. Res.* 116 (D12115), doi:10.1029/2010JD015541 (2011).

¹⁶ Ricardo M. Trigo, Célia M. Gouveia, and David Barriopedro, *Agricultural and Forest Meteorology* 150 (9), 1245 (2010).

¹⁷ DJ Karoly, *Bulletin of the Australian Meteorological and Oceanographic Society* 22, 10 (2009).

¹⁸ D. Barriopedro, E.M. Fischer, J Luterbacher et al., s 332 (6026), 220 (2011).

¹⁹ F.E.L. Otto, N. Massey, G.J. van Oldenborgh et al., *Geophys. Res. Lett.* 39 (L04702), 1 (2012); S Rahmstorf and D. Coumou, *Proceedings of the National Academy of Science of the USA* 108 (44), 17905 (2011); R Dole, M Hoerling, J Perlwitz et al., *Geophys. Res. Lett.* 38, L06702 (2011).

¹⁵ **Notes on IPCC calculation of human-induced warming:** The IPCC SR15 Technical Summary noted that “Human-induced warming reached approximately 1°C (±0.2°C likely range) above pre-industrial levels in 2017, increasing at 0.2°C (±0.1°C) per decade (high confidence)”. They also noted that “Since 2000, the estimated level of human-induced warming has been equal to the level of observed warming with a likely range of ±20% accounting for uncertainty due to contributions from solar and volcanic activity over the historical period (high confidence).”

the average increase above the same baseline for the most recent decade 2009-2018 was $0.93 \pm 0.07^\circ\text{C}$, and the average for the past five years, 2014-2018 was $1.04 \pm 0.09^\circ\text{C}$. Note that both of these periods include the warming effect of the strong El Niño of 2015-2016.

Going forward, there is still a global target of limiting global warming effects to 1.5°C by 2050, which exceeds current levels.¹⁶ Even in this “best case” outcome, there is an expectation that countries will face increases in extreme weather events in terms of frequency and/or intensity (tropical cyclones, extreme rainfall or drought, extreme temperatures, etc.) and rising sea levels along with damage to both terrestrial and ocean ecosystems. Clearly, if the 1.5°C level is exceeded, the expectation is for countries to experience even more severe extreme weather events in the future.

1.3 Vulnerability and resilience to climate-change-induced hazards

Over recent decades and going forward, public investment happens in the context of climate-induced hazards. This means that public investment has to take into account more urgently the need to estimate the losses that the investment in a transportation, communication or utility system, infrastructure or other facility may suffer over its operating life as a result a climate-related or other natural disaster. Such losses clearly reduce its expected net economic benefits that are the basis for its justification, but they also represent a challenge to seek adaptations to the project or asset that may make it more resilient to the hazard and reduce the expected losses significantly.

It is already evident from the climate disaster risk information and from on the ground experience that the same hazard, a tropical cyclone, for example, has different impacts and economic losses depending on a range of location-specific factors such as: the nature of the landscape (flood prone or not), the population in the area, the resilience of the infrastructure to withstand the hazard, the preparedness and behavior of the population and authorities in response to the threat of the hazard, etc. Ultimately, the vulnerability of a location and its infrastructure and other facilities depend upon these resilience factors. Hence, while it is critical to know the impacts of extreme weather events (lives affected, property damaged and service delivery disrupted), it is also clear that the losses incurred are not only a function of the severity of the hazard, but are particular to the resilience factors of the property and people in the location affected. As is elaborated on in Chapter 2, these relationships ultimately allow for economic loss functions to be developed for specific projects and locations as a function of the severity of the hazard and the probability of that hazard severity occurring over the future.¹⁷ At the same time, before the vulnerability of sectors and projects can be developed by a government to such a

¹⁶ The IPCC SR15 report found that limiting warming to 1.5°C above pre-industrial implies reaching net zero CO_2 emissions globally around 2050 and concurrent deep reductions in emissions of non- CO_2 forcers, particularly methane. Decadal predictions suggest an increasing risk of temporary exceedance of 1.5°C above preindustrial conditions.

¹⁷ A general framework for analyzing climate-change related adaptations at a high level is available at AECOM, Economic framework for analysis of climate change adaptation options: Framework specification, Australian Department of Climate Change and Energy Efficiency. <https://www.environment.gov.au/system/files/resources/21810fe1-5333-420a-b1ae-6c45b8a14139/files/economic-framework-adaptation-options.pdf>

refined and sophisticated level, different indicators have been developed that either separately give an indication of the resilience of the sector/project and location or jointly indicate the vulnerability based on past hazards and costs of disasters.

There are a number of tools or indicators that rate natural hazard risks and/or resilience of the country or location. Annex 5 provides a listing and overview of a range of Climate Risk Screening Tools. These include:

World Bank Climate and Disaster Risk Screening Tools,¹⁸ which includes a risk rating at both national/policy level and project level. A key component is an institutional adaptive capacity rating to assess the local institutional ability to manage or mitigate the risks arising from hazards.

ThinkHazard!¹⁹ provides a high-level “traffic light” risk rating for countries and locations within a country for a range of natural hazards. It also suggests ways of gaining more advanced information or strategies with adapting to the hazard in that location.

ND-GAIN Country Index²⁰ summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. While it is a country level index, it includes measures of the “adaptive capacity” of a sector in a country and the “readiness” of the country to undertake adaption to mitigate risks. Box 1.3 describes the composition of the ND-GAIN score for a country.

¹⁸ For details and use of tools go to <https://climatescreeningtools.worldbank.org/>

¹⁹ Global Facility for Disaster Reduction and Recovery (GFDRR), ThinkHazard!, <http://thinkhazard.org/en/>

²⁰ Notre Dame Global Adaption Initiative, *ND-GAIN Country Index*, University of Notre Dame, <https://gain.nd.edu/our-work/country-index/rankings/>

Box 1.3 ND-Gain Country Index

The **ND-GAIN Country Index** is composed of two key dimensions of adaptation: vulnerability and readiness.

Vulnerability measures a country's exposure, sensitivity and capacity to adapt to the negative effects of climate change. ND-GAIN measures overall vulnerability by considering six life-supporting sectors – food, water, health, ecosystem service, human habitat, and infrastructure. Vulnerability depends upon three components and thirty six indicators:

Exposure: Degree to which a system is exposed to significant climate change from a biophysical perspective. It is a component of vulnerability independent of socio economic context. Exposure indicators are projected impacts for the coming decades and are therefore invariant overtime in ND-GAIN.

Sensitivity: Extent to which a country is dependent upon a sector negatively affected by climate hazard, or the proportion of the population particularly susceptible to a climate-change hazard. A country's sensitivity can vary over time.

Adaptive Capacity: Availability of social resources for sector-specific adaptation. In some cases, these capacities reflect sustainable adaptation solutions. In other cases, they reflect capacities to put newer, more sustainable adaptations into place. Adaptive capacity also varies over time.

Readiness measures a country's ability to leverage investments and convert them to adaptation actions. ND-GAIN measures overall readiness by considering three readiness components – economic, governance readiness and social. It is based on nine indicators.

Economic: Captures the ability of a country's business environment to accept investment that could be applied to adaptation that reduces vulnerability (reduces sensitivity and improves adaptive capacity).

Governance: Captures the institutional factors that enhance application of investment for adaptation.

Social: Captures the factors such as social inequality, ICT infrastructure, education and innovation that enhance the mobility of investment and promote adaptation actions.

A country's ND-GAIN Score varies from 0 to 100 and is composed of a vulnerability score (0 to 1 for low to high vulnerability) and a readiness score (0 to 1 for low to high readiness):

$$\text{ND-GAIN score} = (\text{Readiness score} - \text{Vulnerability score} + 1) * 50$$

1.4. Evolving climate-change mitigation strategies and policies

Despite ongoing efforts to implement climate-change measures over recent decades, GHG levels and related global mean temperatures continue to rise with resulting impacts on seawater temperatures and levels, and other extreme weather-related events. According to the most

recent World Meteorological Organization report for 2019,²¹ GHG levels reached record levels in 2018 (carbon dioxide, methane and nitrous oxide at 147%, 259% and 123% above their pre-industrial period levels) and are expected to rise further in 2019. The global mean temperature for 2019 was 1.1 ± 0.1 °C above pre-industrial levels. The year 2019 is likely to have been the second warmest in instrumental records.

In this context, the efforts at international, national and subnational levels to introduce emission reduction programs have continued since the UNFCCC was signed in 1992 leading to the Kyoto Protocol being signed in 1997 and coming into force in 2005. There have been ongoing efforts to extend the initial commitment period that ended in 2012 through 2020 and beyond with a series of UN Climate Change Conferences. Importantly, the climate-change negotiations have been underpinned by the background research work of the three working groups of Intergovernmental Panel on Climate Change (IPCC), which have produced technical background reports, guidelines and assessment reports. The fifth assessment of climate-change mitigation was completed in 2014,²² and the sixth is currently under preparation. A key product of these ongoing efforts are methods to establish national GHG inventories, which are key measuring the emission reduction contribution of countries and to assessing the impact of different programs and policies to achieve GHG emission reductions.

The GHG reduction mechanisms that emerged from the work of the IPCC and its member countries included the cap-and-trade of emission allowances or emission trading systems (ETS) as well international trading in allowances and the clean development mechanism to reward efficiency gains, fuel switching and the use of renewable energy to lower GHG emissions. At the same time, countries starting in 1990 have been introducing carbon taxes and other mechanisms to put a price on GHG emissions. In addition to the official government based ETSs, voluntary carbon markets as well as more recently green bond markets have emerged. Building and land use regulations are also being modified to impact GHG emissions. All these policy and financial mechanisms to induce GHG emission reductions have fallen back on the core structures developed to measure and report national GHG inventories. These have included the sector classifications for different types and sources of GHG emissions (such as the energy production and use in static industrial production and in transportation, industrial processes and product uses, agriculture, forestry and other land use and waste processing) and emission factors to convert activity levels to GHG emissions.^{23,24}

An important underpinning of the GHG reduction mechanisms has the creation and adoption of GHG Protocol developed by the GHG Protocol Initiative.²⁵ This is a suite of standards and

²¹ World Meteorological Organization, *WMO Statement on the State of the Global Climate in 2019*, WMO-No. 1248, Geneva 2020

²² IPCC, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014

²³ IPCC, *Revised 1996, 2006 and 2019 refinement IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1., General Guidance and Reporting*. Task Force on National Greenhouse Gas Inventories

²⁴ An example is the basic structure of a carbon tax that estimates the quantity of GHG emissions in a business taxable in a period by the level of a specified activity in the period multiplied by a prescribed emission factor.

²⁵ The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and others convened by the World Resources Institute (WRI), a U.S.-based

guidelines for corporations (private and public), national and subnational governments, communities, and projects to measure, account and report GHG emissions. The core Corporate Standard was first published in September 2001.²⁶ The GHG Protocols effectively operationalize the technical guidance and reporting developed by the IPCC. Importantly, the GHG Protocols have been extended to cover corporate value-chain accounting, product life cycle (or “carbon footprint”) accounting and mitigation or GHG emission reduction accounting.

Value-chain or product life-cycle GHG emissions are typically broken into direct (scope 1) and indirect (scopes 2 and 3) emissions.²⁷ Direct or scope 1 emissions are the GHG emissions from the facilities and transport vehicles of the entity. Scope 2 emissions of an entity are the indirect downstream GHG emissions arising from the electricity, steam and other heating or cooling purchased by the entity. Scope 3 emissions of an entity are the indirect upstream and other downstream GHG emissions related to the use of products or services supplied by the entity, and related to the supply of goods and services purchased by the entity, respectively. This is important from a project appraisal perspective in accounting for the direct emissions from an entity financial perspective and accounting for the full direct and indirect emissions from an economic appraisal perspective. In addition, the Mitigation Goal and the Policy and Action Standards for accounting and reporting on national and subnational emission reductions are clearly important in the context of all climate-change mitigation programs.²⁸ In the context of project appraisal, it is important as it deals with the basic issue of the incrementality of GHG emission reductions, which is crucial to valuing the economic gains that from emission reductions attributed to a project.

It is important to review briefly the results of the various climate-change mitigation programs over recent decades in order to get a clearer picture of how public investment policy and practice fits into this picture and can possibly make an additional positive contribution to GHG emission reductions. The International Carbon Action Partnership (ICAP)²⁹ reports annually on the status of ETSs. ICAP reports that as of 2020 there 21 systems with an ETS in force in one supranational jurisdiction (EU ETS), five countries³⁰, sixteen provinces and states (in US,

environmental NGO, and the World Business Council for Sustainable Development (WBCSD), a Geneva-based coalition of 170 international companies. Launched in 1998, the Initiative’s mission is to develop internationally accepted greenhouse gas (GHG) accounting and reporting standards for business and to promote their broad adoption.

²⁶ The Greenhouse Gas Protocol, *A Corporate Accounting And Reporting Standard (Revised Edition)*, World Resources Institute (WRI) et al; GHG Protocol, *Global Protocol for Community-Scale Greenhouse Gas Emission: An Accounting and Reporting Standard for Cities*, WRI et al; GHG Protocol, *The Greenhouse Gas Protocol for the U.S. Public Sector: Interpreting the Corporate Standard for U.S. Public Sector Organizations*, WRI et al; GHG Protocol, *The GHG Protocol for Project Accounting*, WRI et al

²⁷ GHG Protocol, *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*, WRI et al; GHG Protocol, *GHG Protocol Scope 2 Guidance*, WRI et al; GHG Protocol, *Technical Guidance for Calculating Scope 3 Emissions*, WRI et al; GHG Protocol, *Product Life Cycle Accounting and Reporting Standard*, WRI et al

²⁸ GHG Protocol, *Mitigation Goal Standard: An accounting and reporting standard for national and subnational greenhouse gas reduction goals*, WRI et al; GHG Protocol, *Policy and Action Standard: An accounting and reporting standard for estimating the greenhouse gas effects of policies and actions*, WRI et al

²⁹ ICAP was founded in 2007 to provide a forum and technical assistance to governments and public authorities to implement emission-trading systems (ETS).

³⁰ Kazakhstan, Korea, Mexico, New Zealand and Switzerland

Canada and China) and seven cities (in China and Japan).³¹ ETS systems cover a limited, but growing share of global GHG emissions. Starting in 2005 with the EU ETS³² when the coverage of global emissions was 5%, coverage rose to 9% in 2020, and is expected to grow to 14% in 2021 with the introduction of national ETS in China and with the expansion of the RGGI³³ for the states in the US northeast. Within ETSs, the range of sectors covered limit the share of total emissions included in the system, and importantly, not all emitters in a sector are necessarily brought into the system. Nearly all systems include the power sector and most the industrial sectors. The EU ETS covers power, industry and domestic aviation and covers only 45% of total emissions. The highest emissions coverage is in Quebec at 82% with the addition of buildings and domestic transport but excluding aviation. Switzerland has the lowest coverage of total emissions at 10% and targets the same sectors as the EU. New Zealand targets all sectors, but its ETS only covers 51% of total emissions.

The World Bank looks at climate-change mitigation programs more broadly by surveying all programs that put a price on GHG emissions by establishing ETS or carbon markets, implementing carbon taxes or the use of other regulatory mechanisms that effectively put a charge on GHG emissions.³⁴ Carbon taxes have been implemented by some 23 countries and a further 9 subnational jurisdictions starting with Finland and Poland in 1990. Some seven other jurisdictions mainly in Canada and Australia use other carbon pricing regulatory mechanisms. It is estimated that in 2019 the carbon tax and other price mechanisms raised the share of global emissions covered from 9% to 15%, and in 2020, if the national ETS is implemented in China, 20% should be covered by 57 jurisdictions. There are more jurisdictions planning or considering the use of carbon pricing mechanisms: these include some 96 of the 185 Parties that have submitted their Nationally Determined Contributions (NDCs) to the Paris Agreement that represent 55% of global GHG emissions. There is also room for many jurisdictions to broaden their coverage as well as raise the price of carbon to make them consistent with achieving the Paris Agreement goals. In 2019, the average carbon price ranged from \$1 to high in Sweden of \$127 per tCO₂e, and 51% of covered emissions were priced at less than \$10 per tCO₂e.

In addition to the compliance carbon markets already mentioned, voluntary carbon markets have developed over the past 20 years that allow private investors, governments, non-governmental organizations, and businesses to purchase voluntarily carbon offsets to offset their emissions. The supplier and seller of the credits undertakes a verified project to reduce, sequester or avoid emissions. Common project types relate to forest improvements (REDD+), wind energy, landfill methane, large hydro etc. A range of standards, commonly the Verified Carbon Standard, the Gold Standard or the Climate Action Reserve, certifies the projects. The carbon offset have

³¹ International Carbon Action Partnership (ICAP), *Emission Trading Worldwide: Status Report 2020*, Berlin: ICAP, 2020

³² The EU ETS covers the 27 member countries of the EU plus Iceland, Liechtenstein and Norway and UK. For more detail about the EU ETS see European Commission, *EU ETS Handbook*, European Union, 2015

³³ Regional Greenhouse Gas Initiative (RGGI) carbon market includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Virginia is expected to join.

³⁴ World Bank, *State and Trends of Carbon Pricing 2019*, World Bank, Washington, DC, June 2019

traded at values up to \$11, but averaged \$3 per tCO₂e.³⁵ Forest Trends' Ecosystem Marketplace (EM) has tracked transactions of voluntary carbon offsets since the early 2000s. Voluntary carbon offsets for 2018, representing emission reductions of 98.4 MtCO₂e and cumulatively the volume has now exceeded 1.2 GtCO₂e, have been transacted and tracked by EM.³⁶ Another carbon market that is developing is the Carbon Offsetting and Reduction Scheme for International Aviation (CORISA) run by International Civil Aviation Organization (ICAO).³⁷ This scheme is been developed given national ETS only cover domestic aviation.

In addition to government programs to put a price on carbon to induce GHG emission reductions, the use of regulations can affect economic activity to promote climate change mitigation. Land use regulation has a lengthy history in affecting forest and wetland conservation and agricultural practices. In the area of road transportation, motor vehicles have been subject to increasingly strict regulations initially targeted at reducing air pollutants (such as NO_x and SO_x), but more recently also targeting GHG emissions. These have resulted in more energy efficient vehicles and an accelerating trend towards hybrid and electric vehicles. Nevertheless, road transport remains an important source of GHG emissions (Figure 1 shows some 12% of global emissions) and also a growing source with road transport forming some 72% of transportation sector emissions in 2010 and growing rapidly.³⁸

Another important area that has emerged in recent decades is the green building movement supported by national and international Green Building Councils (GBC)³⁹ as well as often by national or local government legislation. These GBCs play important roles in rating and certifying buildings as “green”. One important element is that the building has a low carbon footprint. In the analysis of sources of GHGs, residential and commercial buildings are linked to 12% of total GHG emissions in the US in 2018⁴⁰ and globally 17.5% of total emissions in 2016 (see Figure 1.)⁴¹ Indirect emissions arising from electricity and other heating and cooling services supplied to buildings are the main source, but direct emissions from combustion in buildings is also important.

³⁵ Kelley Hamrick, *State of the Voluntary Carbon Markets*, International Civil Aviation Organization (ICAO), presentation February 7, 2018

³⁶ Forest Trends' Ecosystem Marketplace, *Financing Emissions Reductions for the Future: State of the Voluntary Carbon Markets 2019*, Washington DC: Forest Trends, 2019.

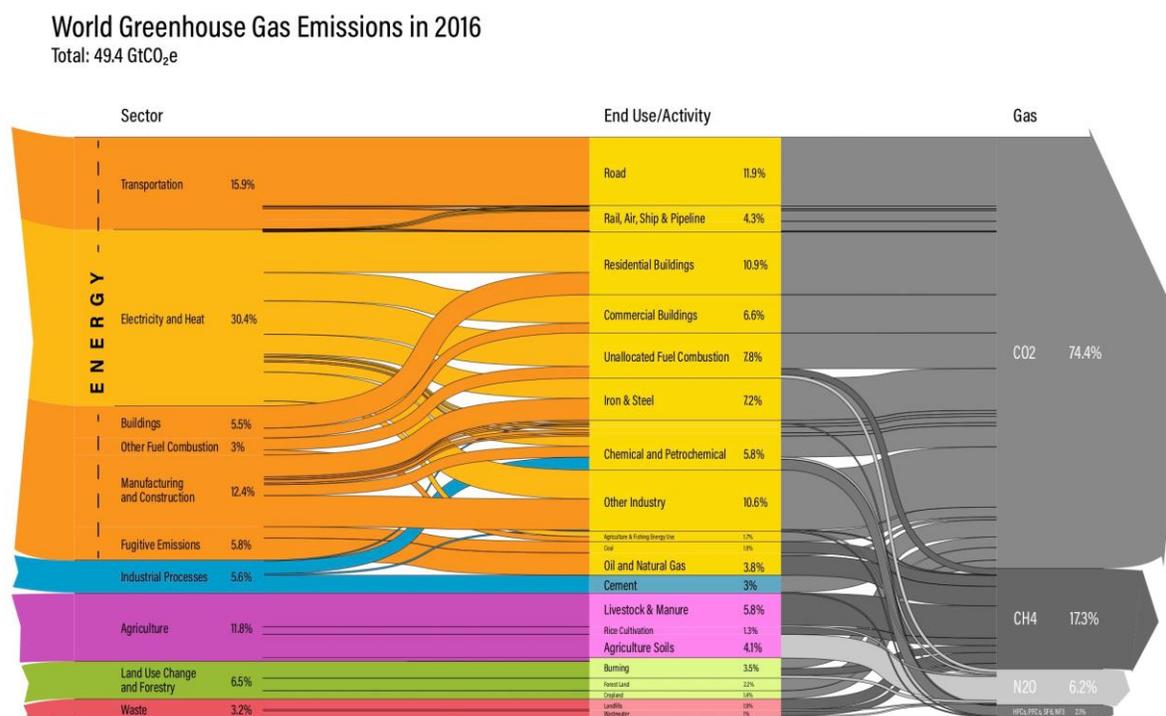
³⁷ Forest Trends' Ecosystem Marketplace, *CORSIA and the Voluntary Carbon Markets*, Fact Sheet

³⁸ See Figure 8.1 Direct GHG emissions of the transport sector. IPCC, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014

³⁹ The US Green Building Council (USGBC) was the first to be established in 1993. The World Green Building Council (WGBGC) was set up in 1999. Currently there are GBCs in 70 countries. See <https://www.worldgbc.org/about-green-building>.

⁴⁰ Environmental Protection Agency, *Sources of Greenhouse Gas Emissions*, 2018, <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>

⁴¹ World Resource Institute (WRI), Greenhouse gas emissions on Climate Watch, 2016. Available at: <https://www.climatewatchdata.org>

Figure 1. World Greenhouse Gas Emissions by Sector, End Use and Type of Gas in 2016

Source: Greenhouse gas emissions on Climate Watch. Available at: <https://www.climatewatchdata.org>

WORLD RESOURCES INSTITUTE

Source: World Resource Institute, <https://www.wri.org/resources/data-visualizations/world-greenhouse-gas-emissions-2016>

Overall, the GHG emission reduction measures outlined above largely target the private sector, particularly commercial businesses, through the imposition of prices on GHG emissions. No doubt, the effectiveness of these programs in inducing emission reductions in the future will require higher coverage of GHG emissions and higher carbon prices. This leaves the issue the role of the public sector in climate-change mitigation. Is it affected by the carbon market and regulatory programs outlined above? Does it have other roles to play in climate-change mitigation?

Aside from the direct role of the public sector in developing and implementing policies and programs for GHG emission reduction, the public sector typically is required to comply with the same regulatory frameworks as the private sector for its activities subject to construction, land use and other environmental protection regulations. In the area of carbon pricing, the main commercial players directly involving the public sector are the state owned enterprises (SOEs) and the public-private partnerships (PPPs). These can be major players in the GHG emitting sectors and activities. As is clear from the analysis of sources of GHG emissions, such as illustrated in Figure 1, transportation and fossil fuel-based electricity production are major sources of global emissions. In many countries, SOEs and PPPs are major players in electricity supply and public transportation. There is no systematic data available about the extent of coverage of these entities by the carbon markets and carbon taxes. Nevertheless, the government

should be playing significant roles in the preparation and implementation of all major investments by SOEs and PPPs through its PIM systems as discussed in sections below. Importantly, the government should be taking a broader economic perspective of the benefit and costs of investment projects than would be the case of the SOEs or PPPs themselves operating within their corporate financial constraints. Moreover, where the external benefits of a choice of technology or source of energy generate significant benefits, but leave the corporate entity facing financial losses, for example, the government may be in a position to provide budgetary support or arrange financing that makes the environmentally attractive project attractive.

In the case of all government sector projects that are not commercially viable and depend upon budget revenue support, clearly the government is directly involved in the project design and decision-making that can involve project choices that may have different GHG emission impacts. These projects include infrastructure and facility construction. As already noted, buildings are directly and indirectly linked to a major source of GHG emissions so that the PIM system needs to take into account the benefits of green buildings. Another consideration is the indirect impact of different building construction materials on GHG emissions. Cement, for example, has been identified as a major contributor to GHG emissions, forming at least 3% of total global emissions and in some country estimates as high as 8% of total emissions.

In the sections below, the integration of climate-change mitigation into the sector strategies, plans and the design and choice of projects are highlighted and discussed.

1.5. Outline of framework

Chapter 2 introduces a climate-smart public investment management framework. It first provides an overview of existing PIM diagnostic frameworks and tools. It then presents three tiers of the framework to assist countries to strengthen their PIM systems in the face of climate-related disasters and the ongoing need for climate-change mitigation. Tier 1 provides a high-level PEFA-style diagnostic tool to assess the climate-preparedness of the PIM system of a country. Tier 2 provides the changes or additions a country needs to make to its PIM system to (i) allow it to enhance its ability to improve its resilience to climate-related disasters through adaptive investments and (ii) account for changes in the climate impacts or mitigation of its investments. Tier 3 drills down into the detailed methods of enhancing project design and appraisal to evaluate the real options that are available in climate vulnerable projects to reduce the future costs of climate-related disasters to projects. The remaining sections of the chapter cover the issues involved in including the valuation of the impacts of projects on greenhouse gas emissions, and the need to strengthen institutional capacities to support cost-benefit analysis of projects and the overall PIM system of a country.

Chapter 3 provides a toolkit of twelve key tasks ministries responsible for finance and planning to direct and coordinate the efforts of governments to make their PIM systems sensitive to climate-change issues.

Chapter 4 reviews some financial and budgeting issues related to climate-impacted public investment. First, it provides a review of the available insurance facilities and new parametric

insurance facilities to insure against specific weather-related disasters. Second, it describes the rapidly emerging roles of climate finance and green bonds in financing climate-change mitigation and adaptation efforts. Third, it outlines necessary changes in budget allocations to finance (i) disaster risk insurance, (ii) adaptations to investments in infrastructure and facilities to enhance resilience or enhance GHG emission reductions, (iii) disaster management, and (iv) adequate operating and maintenance expenditures to improve service delivery and sustain the infrastructure and facilities.

2. Climate-Smart Public Investment Management Framework

2.1. Introduction

There has been a longstanding need to integrate climate-change adaptation and mitigation into the public investment management (PIM) systems. The urgency of insuring that PIM systems can integrate the growing vulnerability of economies to climate-change-related hazards is becoming increasingly evident. Climate-change-related impacts arise from cyclones or hurricanes (with higher than expected frequency and intensity of rain and winds), floods, landslides and droughts. These extreme weather events are increasingly causing disproportionate damage to public sector assets such as roads and bridges, water and sanitation and electricity generation systems, health and school facilities. In addition, the impacts are felt in housing units and commercial assets resulting in negative impacts on the population as well as costs and reductions in government service provision. There are also heavy impacts on people when damages occur to agriculture and other agriculture-based facilities, properties, and other sources of livelihood. It is clear that governments need to reform their PIM systems to both adapt projects to reduce the costs of climate-related damages as well as cut possible negative impacts of public sector projects on the climate.

This section introduces and elaborates the analytical frameworks and tools for mainstreaming climate screening and climate-sensitive project design, appraisal, budgeting and implementation in the Public Investment Management (PIM) framework. Three tiers of diagnostic and analytical tools are presented to test how climate smart a PIM system currently actually is and how to make a PIM system more climate smart. First, a review of available PIM diagnostic tools is provided along with annexes giving summaries of these tools. Second, the report develops and presents a *first tier* high-level screening diagnostic tool to assess the degree of preparedness of country PIM systems to manage climate-change impacts of projects and to adapt projects to strengthen the climate resilience of an economy. Is a PIM system climate sensitive or climate blind? Third, a *second tier* provides guidance on ways to mainstream climate resilience and adaptation in the public investment program. It identifies and develops climate-sensitive functions within the PIM system to inform the public investment pipeline to improve project selection and allocative efficiency. Fourth, a *third tier* presents at a more detailed level how to elaborate project design and appraisal to deal with climate-change impacts and project adaptation.

2.2. Overview of PIM diagnostic frameworks and tools

2.2.1. Essential PIM functions and PIM index

Public investment management (PIM) involves a complex series of stages involved in identifying, planning, designing, preparing, appraising, selecting, budgeting and implementing projects and programs in the public sector. Box 2.1 expresses these stages

in two ways. PIM has been characterized as being composed of eight essential functions that need to occur in the public sector but may be organized or arranged somewhat differently in different governments.⁴² Alternatively, PIM can be seen as in terms of the project cycle or the series of stages involved as a project moves from being identified to being implemented and evaluated as an operating project. These functions or stages of PIM are located in both the central and service delivery agencies of government depending upon the degree of delegation of functions in a government, but typically the key functions of guidelines, screening, budget approvals and oversight over methods, quality of appraisal and implementation performance are located in the central agencies responsible for finance, budget and economic planning. Service delivery agencies are typically delegated functions of project identification, design and appraisal and management of implementation. External review of appraisals and ex post evaluation of projects and programs could be delegated to separate entities under a central agency. Depending on the structure of government, subnational governments (SNGs), sector ministries, state owned enterprises (SOEs), public authorities, regulated corporations (such as utilities), and public-private partnerships (PPPs) can be allocated PIM functions with more or less control and oversight by the central agencies of government. Annex 2 elaborates on the essential or “must have” functions.

Box 2.1 Essential PIM functions and stages of project cycle	
Essential PIM functions	Stages of project cycle
<ol style="list-style-type: none"> 1. Investment guidance & preliminary screening 2. Formal project appraisal 3. Independent review of appraisal 4. Project selection and budgeting 5. Project implementation 6. Project adjustment 7. Facility operation 8. Project evaluation 	<ol style="list-style-type: none"> 1. Identification of projects & programs 2. Design, appraisal, and screening of projects & programs with stages <ol style="list-style-type: none"> 1. Prefeasibility 2. Feasibility 3. Detailed blue print 3. Independent review of the appraisal 4. Budget authorization of services and appropriation of funding 5. Project implementation: procurement, contracting, adjustment and monitoring <ol style="list-style-type: none"> 1. Construction 2. Operation 3. Rehabilitation/expansion/termination 6. <i>Ex post</i> program or project evaluation

⁴² Rajaram, Anand, Tuan Minh Le, and Nataliya Biletska (2008), 'Framework for Reviewing Public Investment Efficiency', (Washington, DC: Public Sector Group). Rajaram, A, Le, T, Biletska, N, and J. Brumby (2010), *A Diagnostic Framework for Assessing Public Investment Management*, Policy Research Working Paper 5397, World Bank, Washington DC, 2010.

A high-level diagnostic tool was developed known as the Public Investment Management Index (PIMI) to gain an initial assessment of the state of the PIM system in a country.⁴³ As shown in Box 2.2, PIMI is composed of four components and 17 dimensions. Two of the components, (1) Strategic Guidance and Project Appraisal and (2) Project Selection and Budgeting, cover the project preparation functions, and the other two components, (3) Project Implementation and (4) Project Evaluation and Audit. PIMI was applied and

Box 2.2 Public Investment Management Index: Components and Dimensions	
1. Strategic Guidance and Project Appraisal	
	1. Nature of strategic guidance and sector strategies 2. Transparency of appraisal standards 3. Observed conduct of ex ante appraisals 4. Independent review of appraisals conducted
2. Project Selection and Budgeting	
	5. Medium term planning and its integration to the budget 6. Inclusion in budget (or similar) for donor funded projects 7. Budget integration of recurrent & investment expenditures 8. Level of scrutiny & funding by legislature, including its committees 9. Public access to key fiscal information
3. Project Implementation	
	10. Degree of open competition for award of contracts 11. Nature of complaints mechanism relating to procurement 12. Funding flows during budget execution 13. Effectiveness of internal controls, such as commitment controls 14. Effectiveness of internal audit system
4. Project Evaluation and Audit	
	15. Degree of ex-post evaluations 16. Degree that external audits are timely and scrutinized by the legislature 17. Degree of asset register and/or asset value maintenance

⁴³ Dabla-Norris, Era, Jim Brumby, Annette Kyobe, Zac Mills, and Chris Papageorgiou (2011), “Investing in Public Investment: An Index of Public Investment Efficiency,” IMF Working Paper WP/11/37 (February 2011)

estimated for 71 low and middle-income countries by 2011. Further elaboration of the PIM diagnostic framework, including country studies, was presented in a major study, *The Power of Public Investment Management: Transforming Resources into Assets for Growth*.⁴⁴

The sections below elaborate on this core framework of PIM functions to identify how and where issues of climate-change adaptation and mitigation should enter the PIM system in order to make public investment more climate resilient, contribute to GHG emission reduction strategies and improve the economic performance of an economy despite the prospects of worsening climate related hazards.

2.2.2. PEFA-style PIMI

To allow a more detailed and structured drill-down diagnosis of the PIM process in a country, the PIMI was elaborated in 2014⁴⁵ using the diagnostic structure and methods of Public Expenditure and Financial Accountability (PEFA).⁴⁶ PEFA, which was initiated in 2005 and revised in 2016, has been widely applied across national and subnational governments to diagnose the budget preparation and implementation of financial management systems. PEFA is organized around 7 pillars, 31 indicators and 94 dimensions as summarized in Annex 3. The PEFA-style PIMI restructures PEFA to cover the eight essential functions of the PIM system discussed above by retaining the indicators that deal with PIM and adding detailed indicators and related dimensions to cover all eight of the essential PIM functions. This removed the gaps in the high-level PIMI relating to project adjustment and service delivery, but left a high concentration on project selection and budgeting and on project implementation given PEFA focuses on budget cycle and not on the longer project cycle. It also introduced quantitative performance criteria. Annex 4 shows how the PEFA-style PIMI covers the eight core PIM functions using 23 indicators with 73 dimensions. It also provides figures that show the project cycle stages organized into the two pipelines of projects under preparation and projects under implementation and how these project pipelines interact with the national and sector planning, regulatory review, independent review, budgeting, funding, procurement, implementation and asset management, completion review, and monitoring and evaluation functions. These functions are grouped under the eight essential PIM functions already discussed above.

⁴⁴ Rajaram, Anand, Kai Kaiser, Tuan Minh Le, Jay-Hyung Kim, and Jonas Frank (2014), *The Power of Public Investment Management: Transforming Resources into Assets for Growth*, Directions in Development Series, Public Sector Governance, World Bank Group (2014)

⁴⁵ Graham Glenday and G.P. Shukla, "Proposals to strengthen the PIM component of the PEFA framework and indicators," Report prepared for Public Sector & Governance, PREM, World Bank, October 2014

⁴⁶ <https://www.pefa.org>

The more detailed PIM diagnostic of the PEFA-style PIMI provides a good starting point for considering how to assess whether a PIM system is climate sensitive and how to adjust the PIM system to include key climate-change features.

2.2.3. PIMA

In 2015, the IMF introduced the Public Investment Management Assessment (PIMA) to provide a tool to evaluate the design, effectiveness and reform priorities of the infrastructure governance of a country.⁴⁷ As laid out in Box 2.3, PIMA covered three phases of planning, allocation and implementation of public sector investments that were evaluated in terms of 15 indicators of the institutions governing public investment. Like PIMI, PIMA is a more high level assessment tool that focuses more on the higher level government fiscal management arrangements in which public investment management is embedded rather than the drill-down details of the PIM system functions.

PIMAs have been conducted in some 30 countries since 2015. Usefully, these assessments do help reveal weakness in the institutions governing public investment. On average, based on the countries assessed, the four weakest institutions are Project Appraisal, Project Selection, Monitoring of Assets, and Project Management, all basic PIM functions.

It was recognized that the 2015 PIMA was not consistent with the basic framework of the eight essential functions of a PIM system. In 2018, a revised version of the PIMA was introduced (as shown in Box 2.3) that makes the PIMA more consistent with the eight essential function framework by including more PIM specific functions in the assessment.

⁴⁷ IMF, “Public Investment Management Assessment—Review And Update,” Board Report, April 25, 2018

Box 2.3 2015 Public Investment Management Assessment (PIMA) Framework: Phases and Institutions		
Phases	2015 Institutions	2018 Institutions
I. Planning		
	1. Fiscal principles or rules 2. National and Sectoral Planning 3. Central-Local Coordination 4. PPPs 5. Regulation of Infrastructure Companies	1. Fiscal principles or rules 2. National and Sectoral Planning 3. Coordination between Entities 4. Project Appraisal 5. Alternative Infrastructure Financing
II. Allocation		
	6. Multiyear Budgeting 7. Budget Comprehensiveness 8. Budget Unity 9. Project Appraisal 10. Project Selection	6. Multiyear Budgeting 7. Budget Comprehensiveness and Unity 8. Budgeting for Investment 9. Maintenance Funding 10. Project Selection
III. Implementation		
	11. Protection of Investment 12. Availability of Funding 13. Transparency of Budget Execution 14. Management of Project Implementation 15. Monitoring of Public Assets	11. Procurement 12. Availability of Funding 13. Portfolio Management and Oversight 14. Management of Project Implementation 15. Monitoring of Public Assets
Cross-cutting Issues (qualitative analysis)		
		IT support Legal framework Staff capacity with clear roles, and responsibilities

2.3. ***Tier 1: Assessing climate-preparedness of PIM system: a high-level diagnostic tool***

This section presents a first tier high-level screening diagnostic tool to assess the degree of preparedness of country PIM systems to manage climate-change impacts of projects and to adapt projects to strengthen the climate resilience of an economy. It asks the basic question of whether a PIM system is climate sensitive or climate blind? This ***Tier 1*** diagnostic should give an initial indication of whether a country needs to reform its PIM system or not to assure its inclusion of climate-change impacts and resilience enhancement.

Table 1 presents a PEFA-style diagnostic tool to assess whether a PIM system is climate-change sensitive or not. It is composed of ten indicators and the question that needs to be answered to score the indicator from A through D as per the PEFA scoring system. The essential PIM function or functions affected by the indicator are noted. Illustrative scoring for the first indicator is provided. Further details and discussion of the indicators and related questions are provided in the sections below.

Six of the ten indicators are highlighted in Table 1. These can be considered more core or “must have” capabilities or functions for a PIM system to be climate-change sensitive. The other indicators are more enabling or derivative functions. Note that in section 2.4 the logical sequence of dealing with climate change is elaborated in discussing disaster risk screening tools. The nature of hazards, exceedance, vulnerability, damages and economic losses are also elaborated in Chapter 1 and in Section 2.5 and Annex 6 that further elaborate climate-informed project appraisal. The integration of climate mitigation strategies into the government economic strategies and plans is elaborated Section 2.4.2 and 2.6 below. An important point to note here, however, is that eight of these ten indicators to assess the climate sensitivity of a PIM system focus on the first two essential PIM functions of investment guidance and project screening, and formal project appraisal. Climate-change considerations have to enter the PIM system at the early front-end stages of project preparation.

This ***Tier 1*** diagnostic tool should be able to be completed by senior officials of ministries of finance and planning in a country based on their knowledge of the PIM system. It should provide guidance for institutional strengthening required in a country where scores are low (Cs and Ds). Where countries have low scores for the indicators under this diagnostic tool and also have high vulnerability to climate-related disasters as indicated by its poor scores on

Table 1. A diagnostic tool to assess the climate-preparedness of a PIM system

Core function	Indicator #	Indicator	Question	Score			
				A	B	C	D
Cross cutting	1	Legal, regulatory and/or guidance frameworks	Does the government have an explicit framework expressed in guidance documents and/or regulations and/or laws expressing the climate change mitigation goals and strategies and/or climate adaptation requirements for programs and projects? Does this framework apply at all levels of government or only at the central or subnational levels? Does this framework also apply to SOEs and PPPs?	Government has general frameworks guiding climate mitigation goals, strategies, impacts and adaptation of investments at all levels of government and including SOEs and PPPs	Government has incomplete frameworks guiding climate mitigation goals, strategies, impacts and/or adaptation of investments at central or subnational levels of government. SOEs and PPPs are partially covered.	Government has limited frameworks guiding climate mitigation goals, strategies, impacts and/or adaptation of investments at central or subnational levels of government. SOEs and PPPs are not covered.	Government has no explicit guidance on making public investments climate sensitive
1	2	Hazard and exceedance information	Does government collect or have access to comprehensive range of natural hazard data by type, timing and location? Has the government used this data to estimate the frequency of natural hazards of various strengths linked to disasters?	Government collects and has access to adequate meteorological and other data for natural hazards. Government has developed models and makes predictions of extreme natural hazards for all vulnerable sectors and locations .	Government collects and has access to adequate meteorological and other data for most natural hazards. Government has started process of developing models and making predictions of extreme natural hazards for some vulnerable sectors and locations .	Government has weak collection, but has access to meteorological and other data for some natural hazards. Government has developed models and makes predictions of extreme natural hazards for some vulnerable sectors and locations .	Government has access to weak meteorological and other data given the inadequate monitoring capacity in the region. Government makes limited or no explicit use of available data in predictions of extreme natural hazards .
1	3	Vulnerability assessment capacity	Does government have the capacity and also effectively employ its capacity to use the hazard exceedance information to estimate infrastructure damages and economic losses for projects in vulnerable sectors and location based on historical data and future projections of hazards and their loss impacts.	Government has adequate capacity and effectively uses it to develop loss functions for all vulnerable projects	Government has limited capacity and effectively uses it to develop loss functions for some vulnerable projects	Government has limited capacity and is planning to develop loss functions for vulnerable projects	Government has no or minimal capacity and does not develop loss functions for vulnerable projects
1	4	Climate sensitive planning process and sector priorities	Does the government use the vulnerability assessments by sector and location to identify high vulnerability situations that put at risk the expected ability to achieve its national and sectoral priorities? Does the government require consideration of adaptations to the climate-related risk affected investments to reduce the potential losses? Does the government express its national climate change mitigation goals in terms of sectoral mitigation goals? Are programs and projects identified within the sectors that could contribute to achieving the mitigation goals?	Government routinely conducts and updates vulnerability assessments by sector and location in order to (i) assess the potential negative impacts on achieving its national and sector priorities and (ii) requires consideration of adaptations to investments to mitigate climate related risks. Government disaggregates national climate mitigation goals by sector, programs and/or projects.	Government occasionally conducts vulnerability assessments by sector and location in order to (i) assess the potential negative impacts on achieving its national and sector priorities and (ii) occasionally requires consideration of adaptations to investments to mitigate climate related risks. Government disaggregates national climate mitigation goals by sector.	Government is planning to or has conducted a vulnerability assessments by sector and location in order to (i) assess the potential negative impacts on achieving its national and sector priorities and (ii) has plans in place to require consideration of adaptations to investments to mitigate climate related risks. Government does not disaggregates national climate mitigation goals by sector.	Government has not conducted vulnerability assessments by sector and location in order to (i) assess the potential negative impacts on achieving its national and sector priorities and (ii) does not require consideration of adaptations to investments to mitigate climate related risks. Government does not have explicit national climate change mitigation goals.
1 and 2	5	Assessment of climate change mitigation impacts of projects	Does the government require for large or new projects the estimation and valuation of the incremental climate change mitigation impacts (changes in green house gas emissions from direct and indirect emissions of project) either as part of the environmental impact assessment of projects or under a separate regulation or directive?	The government has strong regulations or directives and routinely requires that all large or new projects estimate and value the incremental climate change impacts of the project as part of the project appraisal process	The government has weak regulations or directives and only occasionally requires that some large or new projects estimate and value the climate change impacts of the project as part of the project appraisal process	The government has weak regulations or directives and only required few large or new projects estimate and value the climate change impacts of the project as part of the project appraisal process	The government has no regulations or directives and does not require that large or new projects estimate and value the climate change impacts of the project as part of the project appraisal process
1 and 2	6	Climate sensitive construction regulations	Has the government introduced construction regulations to require cost-effective adjustments to infrastructure by location to make them more resilient to estimated hazards and vulnerability of sectors and locations and introduced land use regulations that aim to enhance climate change mitigation	Government has introduced wide ranging construction regulations to adapt new or replacement infrastructure and properties to mitigate estimated damage and losses from climate-related extreme events based on past experience and risk analysis. It has also introduced extensive land use regulations aimed at climate change mitigation.	Government has introduced some construction regulations to adapt new or replacement infrastructure and properties to mitigate estimated damage and losses from climate-related extreme events based on past experience and risk analysis. It has also introduced some land use regulations aimed at climate change mitigation.	Government has introduced few construction regulations to adapt new or replacement infrastructure and properties but has not used past experience to estimate damage and losses from climate-related extreme events	Government has introduced no construction regulations to adapt new or replacement infrastructure and properties to expected climate related damage

Table 1. A diagnostic tool to assess the climate-preparedness of a PIM system (contd.)

Core function	Indicator #	Indicator	Question	Score			
				A	B	C	D
1 and 2	7	Project climate change adaption and mitigation screening	Are new and replacement projects screened for inclusion of the assessment of the climate change-related impacts and for consideration of climate change adaptations to the project design?	New and replacement projects are routinely screened for inclusion of the assessment of both the climate change-related impacts of the project and for consideration of adaptations to the project design	New and replacement projects are occasionally screened for inclusion of the assessment of both the climate change-related impacts of the project and for consideration of adaptations to the project design	New and replacement projects are occasionally screened for inclusion of the assessment of either the climate change-related impacts of the project or for consideration of adaptations to the project design	New and replacement projects are screened for inclusion of the assessment of neither the climate change-related impacts of the project nor for consideration of adaptations to the project design
2	8	Project appraisal guidelines	Are there required project appraisal guidelines that specify (i) the requirement and methods to conduct the evaluation of climate change impacts and (ii) require the consideration of and provide evaluation methods for real options or adaptations in project design to mitigate the known vulnerabilities of a project?	Project appraisal guidelines require (i) the conduct and provide methods of evaluation of climate change impacts and (ii) the consideration of and provide evaluation methods for real options or adaptations in project design to mitigate the known vulnerabilities of a project	Project appraisal guidelines exist and require (i) the conduct but may not provide methods of evaluation of climate change impacts and (ii) the consideration of but may not provide evaluation methods for real options or adaptations in project design to mitigate the known vulnerabilities of a project	Project appraisal guidelines exist only require either (i) the conduct and may not provide methods of evaluation of climate change impacts or (ii) the consideration of and may not provide evaluation methods for real options or adaptations in project design to mitigate the known vulnerabilities of a project	Project appraisal guidelines do exist or do not require (i) the conduct and provide methods of evaluation of climate change impacts and (ii) the consideration of and provide evaluation methods for real options or adaptations in project design to mitigate the known vulnerabilities of a project
4	9	Capital and O&M budget allocations	Does the government capital budget include procedures for allocating and providing for the added capital expenditures that may be required to enhance (i) the resilience of the project to reduce net losses and/or (ii) the climate change mitigation impacts of project? Does the budget make adequate provision for O&M to ensure the sustained resilience of infrastructure, transportation and utility services? Does the government buy insurance policies or set up reserve funds to cover specific natural disasters?	The government (a) routinely adjusts capital budget allocations for the additional expenditures required by (i) project adaptations with estimated savings from adaptations to reduce climate-related losses and (ii) provide for projects with positive net climate change impacts; (b) has a consistent track record of adequate O&M budget allocations especially to climate-sensitive infrastructure and services; and (c) makes use of insurance markets and reserve fund allocations to offset climate related disasters	The government (a) occasionally adjusts capital budget allocations for the additional expenditures required by (i) project adaptations with estimated savings from adaptations to reduce climate-related losses and (ii) provide for projects with positive net climate change impacts; (b) has track record of adequate O&M budget allocations in most years, especially to climate-sensitive infrastructure and services; and (c) occasionally makes use of insurance markets and has limited reserve fund allocations to offset climate related disasters	The government (a) has weak or seldom used procedures to adjust capital budget allocations for the additional expenditures required by (i) project adaptations with estimated savings from adaptations to reduce climate-related losses and (ii) provide for projects with positive net climate change impacts; (b) has a mixed track record of adequate O&M budget allocations to all types of infrastructure and services; and (c) makes limited use of insurance markets and has inadequate reserve fund allocations that are not nor targeted at climate-related disasters.	The government (a) has no procedures to adjust capital budget allocations for the additional expenditures required by (i) project adaptations with estimated savings from adaptations to reduce climate-related losses and (ii) provide for projects with positive net climate change impacts; (b) has a poor track record of adequate O&M budget allocations to all types of infrastructure and services; and (c) makes limited use of insurance markets and may have reserve fund allocations, but these are neither well managed nor targeted at climate-related disasters.
7 and 8	10	Monitoring and evaluation	Does the government and its agencies undertake monitoring of (1) the climate change impacts of projects and (2) the damage and losses incurred caused by natural hazards over the project life? Do project completion reports include checks of the inclusion of any climate change features included in the project design? Do ex post project evaluation require the inclusion of actual climate change impacts and the effects of the use of any real options built into the project to enhance its climate resilience?	Government and its agencies (i) routinely require measurement of climate impacts (such as GHG emissions) of projects where feasible, (ii) measure and document damage and losses to projects caused by natural hazards, (iii) require project completion reports to include verification and assessment of climate-change related mitigation measures and adaptations included in the project design, and (iv) require ex post project evaluations to include climate-related impacts and assessments of any savings caused by inclusion of climate-related adaptations to projects	Government and its agencies conduct three of the four specified monitoring and evaluation activities	Government and its agencies conduct two of the four specified monitoring and evaluation activities	Government and its agencies conduct one or none of the four specified monitoring and evaluation activities

the Global Climate Risk Index⁴⁸ or on the ND-GAIN Country Index,⁴⁹ then this is a clear indicator of the urgency that there is a critical need to strengthen its PIM system and make it more climate sensitive.

2.4. *Tier 2: Mainstreaming Climate-Change Mitigation, Resilience and Adaptation in the Public Investment Program*

This section provides guidance on ways to mainstream climate-change mitigation, resilience and adaptation in the public investment program. It identifies and develops climate-sensitive functions within the PIM system to inform the public investment pipeline to improve project selection and allocative efficiency. Accordingly, it develops *Tier 2* of the framework that entails a climate-screening framework at the project identification and concept development stage to inform the project prioritization as well as the evaluation and selection of projects entering the Public Investment Program and the Budget. It also discusses the WB's Climate and Disaster Risk Screening Tools and related tools that serve to identify risks and options using climate models.

In any PIM system, the starting point is the development of project ideas and designs based on an interplay with the national and sector planning process which should be identifying key public sector areas of undersupply of services in energy, water, transportation, health, education, etc. sectors that need to be corrected to support the national goals for growth and inclusive development of the economy. It is clearly part of this key process of identifying designing and screening projects that support the national and sector goals that climate-related issues need to start entering the PIM processes. Climate sensitivity has to recognize both the **climate mitigation impacts of projects** and the **adaptation of projects** to minimize the economic costs of expected and possibly worsening damage from natural hazards. Each of these two major considerations requires the PIM system to be climate informed. In terms of the logical sequencing of information gathering and analysis the demand of climate-change adaptation generally precede those of dealing with the climate impacts of projects and accordingly climate change adaptation will be dealt with first. It is also recognised, however, that the screening and selection of projects should be advised by climate-change mitigation strategies and plans that should be part of the national and sector strategies and plans.

⁴⁸ GERMANWATCH, *Global Climate Risk Index 2019 : Who suffers Most from Extreme Weather Events? Weather-related Loss Events in 2017 and 1998 to 2017*, GERMANWATCH, Bonn, 27 November 2018, <https://germanwatch.org/en/cri>

⁴⁹ Notre Dame Global Adaption Initiative, *ND-GAIN Country Index*, University of Notre Dame, <https://gain.nd.edu/our-work/country-index/rankings/>

2.4.1 Climate-change adaptation

The efficient adaptation of projects to climate change requires the understanding of the relationship of the strength and frequency of natural hazards to the damage and economic losses that these hazards cause. This requires the historical analysis of past damage and economic losses to sectors and locations in a country arising from natural hazards. Basic questions about the strength and frequency of the natural hazards and the extent of the damage and economic losses as hazard strengths vary to date need to be understood. Going forward, predictions need to be made as to whether the strength and frequency of specific natural hazards will change over time, in general, and more specifically, in the context of planning investments in a specific sector and location so that adaptations can be designed into projects that improve the expected net gains from projects. The mechanisms for altering investments can either be through construction regulations or through project-specific design changes. Using construction regulations is appropriate where the hazard is expected to occur relatively frequently and can be applied to a wide range of investment types in a specific sector and location. For example, minimum road drainage standards may be required where significant rain storms occur fairly regularly such that, for example, storms that occur at least once every five years can be handled. Where more extreme, but infrequent storms occur, more project specific plans may be required to minimize the damage and losses to particularly vulnerable road segments and/or provide alternative transportation routes or modalities while the vulnerable road segments are being repaired after such a storm.

The challenge for planning and investment is to develop (i) an understanding of the sources, types and sizes of damage and economic losses, (ii) how these relate to the size or strength of different natural hazards, and then (iii) how to analyze the historical record and to use models to predict the frequency of different natural hazards of different strengths. The third function concerning the monitoring and modeling of meteorological and other natural phenomena (sea levels and temperatures, wind and rain storms, glacier sizes and movements, wildfires, forest coverage, etc) generally occurs outside of the economic planning and financing central agencies. Clearly this poses a challenge to develop the channels by which this information on natural hazards flows into the government planning process and can help guide investment design, selection and budgeting. In addition, as with all information it is critical to get the most valuable information that will improve decision making to avoid and reduce the net losses from natural disasters. This information channelling should be guided by the understanding of the sizes and types of losses being experienced in a country. Where major hazards are occurring, but only in isolated parts of an economy or where the infrastructure has already been made resilient to the typical strengths of the hazards, then the flow of information is less important to the investment preparation functions than where significant damage and economic losses have been caused in the past and are also expected to be caused in the future again and with possibly greater severity.

Figure 2 gives an outline of the relationships between the actual causes of damage and losses so that the causal chain can be traced to the larger and more serious damages and losses being suffered in an economy from natural disasters. Figure 2 includes geophysical natural disasters (earthquakes and volcanoes) in addition to climate-related disasters as these can have overlapping impacts on the economy especially where they result in tsunamis. The motivation here is that a government should have records of the damage caused by natural disasters (flooding, landslides, high winds, wild fires, drought, etc) and given that many of these can be caused by multiple hazards, the source of the damage needs to be traced back to the types of hazard. Clearly the major focus should be on the hazards causing the largest damage in terms of loss of assets and the largest economic loss where the net benefits that would otherwise have been derived from these assets are forgone. Figure 2 goes on to note some of the typical adaptations that can be taken to reduce the economic losses in the future.

Where an economy has already implemented many of the adaptation measures in the past it will be more resilient to natural disasters and should have experienced lower losses. Figure 2 notes that the size of the damage and economic loss depends upon the sensitivity of the sector investments and location to the hazard that can also be moderated by the resilience built into the existing infrastructure and its management. Effective disaster warning and management systems can ameliorate the impacts of disasters, for example. This is why the important starting point should be identifying where large damages are actually occurring by sector and location and then mapping backwards to identifying the types of hazards to which the economy is still vulnerable. This should establish an agenda to determine whether the necessary data and models are available to analyze and forecast the expected size and frequency of the natural hazards, and then go on to estimate the expected damage and economic losses in key sectors and locations in the country.

What is the state of information about natural hazards, their frequency and the damages and population numbers affected by them? To establish a context for designing a framework for climate-sensitive PIM, it is useful to review some of the most comprehensive information available on natural disasters, their occurrence and effects on population numbers and the value of damage caused. The Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain (UCL) has aggregated natural disaster database known as the Emergency Events Database (EM-DAT), which includes some 22,000 natural disasters worldwide since 1900. Table 2 below extracted data on disasters by decade since 1960 to assess the occurrence, number of persons affected and US dollar value of the damages (in total and by event) by subtype of natural disaster. It also includes indicators of the percentages of disasters that occurred where information on the affected persons and damages is actually available. Table 2 also aggregates the disaster subtypes in line with Figure 2 so that the common sources of damage and economic loss, namely, water (or flooding), earthquakes, wind, fire, extreme temperatures and drought, can be lined up with their damages in aggregate and per event.

The highest costs of damage per occurrence have typically come from earthquakes (a geophysical disaster), tsunamis and tropical cyclones (a tropical storm as a meteorological disaster). The highest number of affected persons typically come from droughts, riverine floods and tropical cyclones. A review of the changes in disasters over the past six decades show that the number of occurrences has increased by a factor of six between the 1960s and post 2000. Even after adjusting the damage costs to constant US\$, the total reported damage cost per decade increases by a factor of twelve and the cost per occurrence increases by a factor of nearly four. Some changes in the composition of damage has also emerged over the decades. Geophysical damage has grown in absolute terms, but has declined in relative importance. Tropical storms have remained more constant as share of the total classified costs at around 30% on average. There has been a significant growth in other water related damage including tsunamis, coastal flooding and riverine flooding. In the last decade hazards causing water-induced damage caused about 83% of the damage in the classified cases, and when all climate related hazards are included the share rises to 91%.

The data in Table 2 also reveals some fundamental problems in the measuring the impacts of natural hazards. While the share of unclassified disasters drops from over 30% of occurrences in the early decades to about 11% since 2000, the share of disaster occurrences where the number of affected people and/or the damage costs have not been recorded and reported remains high. The number of affected persons is known for over 50% of all the occurrences and climate related disasters in all the decades. The damages, however, are assessed for only around 20 to 30% of climate related disasters. This indicates a major gap in the estimation of the total natural disaster damages and a major problem for countries to develop economic strategies and plans, and design investments in climate-sensitive sectors and locations.

Given this brief review of natural disasters and the related damages, the task is now of how to integrate the identification of expected extreme hazards that may impact proposed projects into the PIM framework so that efficient climate-sensitive projects are prepared and implemented.

Figure 2. Types of natural hazard, sources and types of damage and loss, vulnerability and potential adaptations

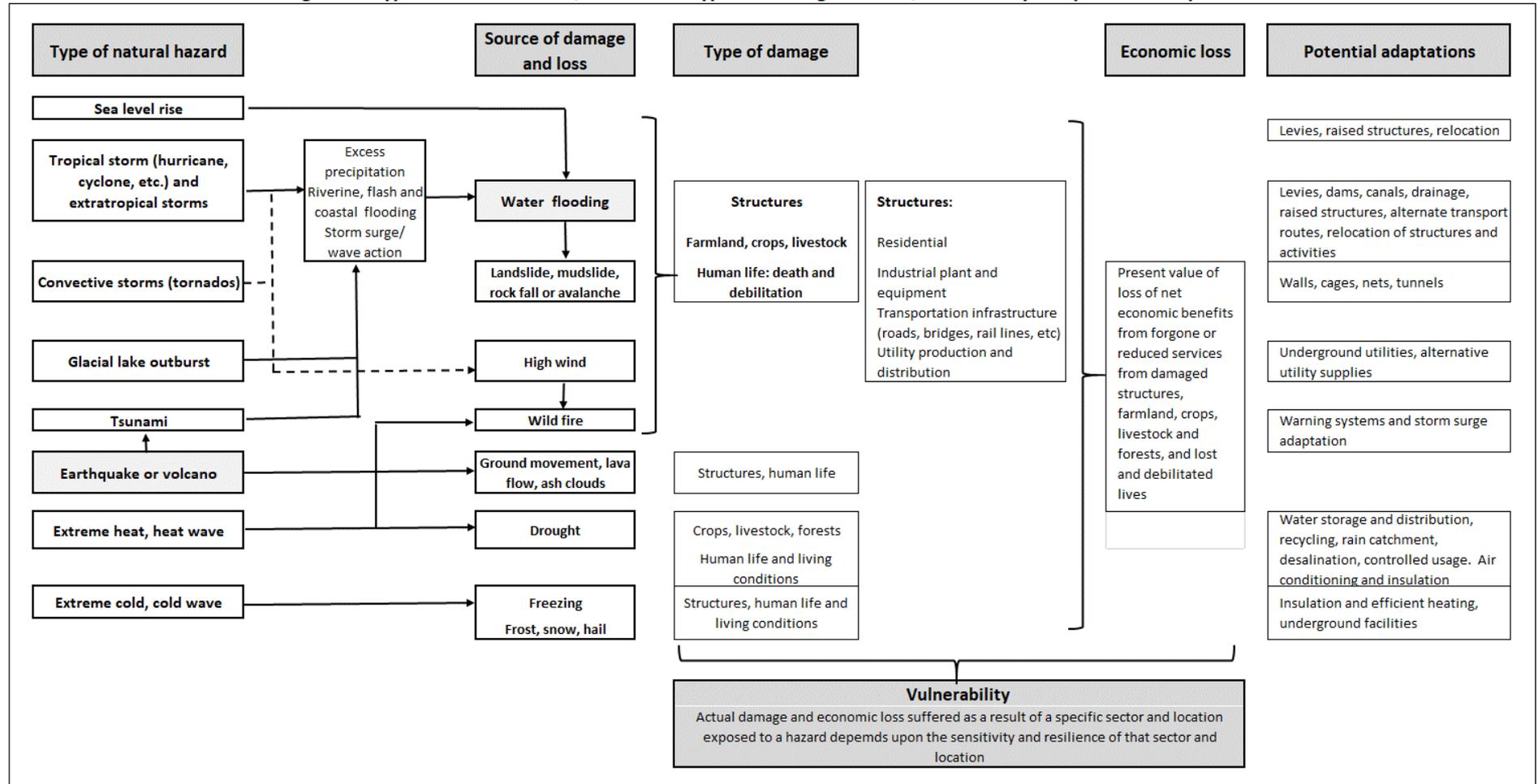


Table 2: Worldwide occurrence of natural disasters by decade since 1960: affected persons and damage by disaster type

Disaster type ^a	Time period	Occurrences	% reporting affected persons	Affected persons (millions)	% reporting damages	Damages (millions current US\$)	Damages (millions US\$) per reported occurrence
	1960s						
Biological		35	83%	0.478	3%	0.0	0.0
Geophysical		80	74%	4.404	56%	3,745.2	83.2
Fire		9	22%	0.005	33%	70.5	23.5
Heat & Drought		54	61%	117.900	35%	1,006.3	53.0
Cold		3	0%	0.000	0%	0.0	
Tropical storm		150	43%	24.950	43%	6,179.9	95.1
Coastal flood & tsunami		7	43%	0.037	43%	940.1	313.4
Other storms and flooding		34	65%	8.872	71%	1,564.8	65.2
Landslides etc		21	24%	4.002	10%	200.0	100.0
Water damage hazards		212	44%	37.861	44%	8,884.7	94.5
Climate related hazards		278	46%	155.765	42%	9,961.6	85.9
Classified		393	55%	160.648	41%	13,706.8	84.6
Unclassified		191	45%	38.797	38%	4,738.9	65.8
Grand Total		584	52%	199.445	40%	18,445.7	78.8
	1970s						
Biological		61	64%	2.239	0%	0.0	0.0
Geophysical		121	59%	17.106	36%	16,941.8	385.0
Fire		26	12%	0.042	15%	139.9	35.0
Heat & Drought		74	51%	263.707	26%	6,095.7	320.8
Cold		6	17%	0.001	67%	3,580.0	895.0
Tropical storm		185	44%	51.899	32%	13,199.1	223.7
Coastal flood & tsunami		4	50%	0.000	25%	1.0	1.0
Other storms and flooding		53	58%	10.272	34%	3,213.5	178.5
Landslides etc.		51	33%	0.098	6%	124.2	41.4
Water damage hazards		293	45%	62.269	28%	16,537.8	204.2
Climate related hazards		399	43%	326.019	27%	26,353.3	244.0
Classified		581	49%	345.364	26%	43,295.1	284.8
Unclassified		323	51%	209.246	33%	10,551.5	100.5
Grand Total		904	50%	554.610	28%	53,846.6	209.5
	1980s						
Biological		152	49%	1.035	0%	0.0	0.0
Geophysical		227	66%	33.638	26%	64,146.7	1,069.1
Fire		60	37%	0.316	18%	5,281.0	480.1
Heat & Drought		141	51%	593.549	13%	19,377.2	1076.5
Cold		23	17%	0.037	9%	144.6	72.3
Tropical storm		306	48%	108.842	38%	31,695.8	273.2
Coastal flood & tsunami		6	67%	0.005	50%	474.1	158.0
Other storms and flooding		254	58%	124.667	29%	17,693.6	242.4
Landslides etc.		113	40%	3.524	5%	1,033.9	172.3
Water damage hazards		679	51%	237.038	29%	50,897.5	257.1
Climate related hazards		903	49%	830.941	25%	75,700.3	330.6
Classified		1,282	52%	865.614	23%	139,847.0	483.9
Unclassified		543	42%	376.959	23%	44,327.3	360.4
Grand Total		1,825	49%	1,242.573	23%	184,174.2	447.0

Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

Table 2: Worldwide occurrence of natural disasters by decade since 1960: affected persons and damage by disaster type, continued

Disaster type ^a	Time period	Occurrences	% reporting affected persons	Affected persons (millions)	% reporting damages	Damages (millions current US\$)	Damages (millions US\$) per reported occurrence
	1990s						
Biological		346	72%	11.428	0%	3.5	3.5
Geophysical		315	59%	26.646	28%	195,107.0	2,242.6
Fire		103	46%	3.377	33%	19,133.2	562.7
Heat & Drought		169	57%	314.515	36%	45,255.2	754.3
Cold		60	27%	2.533	22%	5,231.6	402.4
Tropical storm		422	46%	176.133	44%	148,921.6	796.4
Coastal flood & tsunami		38	66%	10.641	29%	2,594.4	235.9
Other storms and flooding		782	55%	1,181.183	38%	205,569.0	687.5
Landslides etc.		154	53%	2.041	16%	3,164.7	131.9
Water damage hazards		1,396	53%	1,369.997	37%	360,249.7	691.5
Climate related hazards		1,728	52%	1,690.422	36%	429,869.7	684.5
Classified		2,389	56%	1,728.496	30%	624,980.2	872.9
Unclassified		583	48%	294.887	26%	74,559.6	493.8
Grand Total		2,972	54%	2,023.383	29%	699,539.8	806.9
	2000s						
Biological		537	71%	4.762	0%	120.0	120.0
Geophysical		328	59%	81.134	23%	163,464.6	2,209.0
Fire		136	45%	2.080	25%	20,426.5	600.8
Heat & Drought		257	55%	755.629	22%	36,376.6	649.6
Cold		140	31%	85.392	9%	24,627.4	2,052.3
Tropical storm		581	41%	256.890	35%	406,080.0	1,971.3
Coastal flood & tsunami		60	77%	13.069	45%	19,249.0	712.9
Other storms and flooding		1,755	53%	1,041.461	21%	194,121.9	539.2
Landslides etc.		193	53%	1.561	10%	844.7	42.2
Water damage hazards		2,589	51%	1,312.982	24%	620,295.6	1,011.9
Climate related hazards		3,122	50%	2,156.083	23%	701,726.0	981.4
Classified		3,987	53%	2,241.980	20%	865,310.6	1,095.3
Unclassified		492	52%	40.947	15%	27,122.2	371.5
Grand Total		4,479	53%	2,282.927	19%	892,432.8	1,034.1
	2010-18						
Biological		216	87%	3.326	0%	0.0	0.0
Geophysical		254	59%	32.961	28%	118,465.9	1,645.4
Fire		65	68%	0.997	42%	47,757.2	1,768.8
Heat & Drought		187	61%	622.911	27%	83,566.9	1,671.3
Cold		144	35%	10.581	8%	6,654.9	554.6
Tropical storm		515	40%	163.670	30%	493,195.1	3,223.5
Coastal flood & tsunami		11	100%	4.148	55%	245,702.0	40,950.3
Other storms and flooding		1,385	51%	639.067	24%	451,060.2	1,371.0
Landslides etc.		160	56%	3.047	13%	3,316.4	157.9
Water damage hazards		2,071	49%	809.932	25%	1,193,273.7	2,344.3
Climate related hazards		2,467	50%	1,444.420	24%	1,331,252.8	2,226.2
Classified		2,937	53%	1,480.706	23%	1,449,718.7	2,163.8
Unclassified		348	56%	150.777	18%	98,235.8	1,559.3
Grand Total		3,285	53%	1,631.483	22%	1,547,954.5	2,111.8

Source: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

a. Disaster types are composed of disaster subtypes as follows:

Biological = Bacterial disease + Grasshopper + Locust + Parasitic disease + Viral disease

Geophysical = Ash fall + Ground movement + Landslide + Lava flow + Subsidence

Fire = Forest fire + Land fire (Brush, Bush, Pasture)

Heat & Drought = Drought + Heat wave

Cold = Cold wave + Severe winter conditions

Tropical storm = Tropical cyclone + Extra-tropical storm

Coastal flood & tsunami = Coastal flood + Tsunami

Other storms and flooding = Convective storm + Flash flood + Riverine flood

Landslides etc. = Avalanche + Landslide + Mudslide + Rockfall

The challenge in making PIM climate sensitive is to recognize that the functions of:

- i. building data bases of the historical occurrence of natural hazards and predicting the strength and frequency of hazards going forward,
- ii. documenting and analyzing the damage and economic losses caused by past hazard disasters by sector and location and predicting the potential damage and economic losses by sector and location over time,
- iii. establishing climate-sensitive construction regulations by sector and location,
- iv. screening projects for natural hazard vulnerability,
- v. developing climate-sensitive project designs for vulnerable projects and appraising these projects,
- vi. selecting and financing projects, including the possible added climate adaptation costs and sustaining appropriate levels of operations and maintenance financing, and
- vii. monitoring and evaluating project performance, particularly for climate-related impacts and valuation of disasters (to feedback into the disaster damage prediction in “ii” above)

need to be allocated to specific government agencies as well as coordinated and managed by sector and central ministries. The coordination and aggregation function demands active involvement and direction from the central planning and finance agencies. Many natural hazards, especially storms and flooding, are regional and multi-sectoral in their impacts so that the documenting of damage and economic loss (function “ii.” above) has to aggregate the combined impacts across sectors in a region. By contrast, hazard monitoring, documentation, databases, analysis, modelling and forecasts (function “i.” above) tend to be concentrated in specific specialized agencies often under a ministry responsible for the environment. A core issue then is the coordination of these specialized agencies outputs with the work of the agencies regulating and developing the sectors and regions (functions “iii., v. and vii.” above). The functions of screening, selecting and financing are all functions that require the direction and oversight of and/or direct involvement of central agencies responsible for planning and finance. A well-functioning PIM system requires clear allocations of responsibility and channels through which projects flow in their preparation and implementation. Note that this demands a disaggregated approach to the design of the PIM processes to handle the flow of public investments rather than an aggregate assessment of a country’s overall risk vulnerability and resilience.

Screening projects for their vulnerability to hazards should be part of the overall screening of projects that are selected to move forward to the feasibility, selection and budgeting stages of project preparation. See Figure 3 below. Here the focus is on vulnerability to natural hazards, especially climate or weather-induced hazards. Climate-sensitive screening of projects requires that projects both identify the exposure to natural hazards and provide some level of assessment of vulnerability to risks. To be clear, however, climate-sensitive

screening is more to indicate whether a project has some climate-sensitive features that need to be addressed rather than an issue of rejection or acceptance. Projects entering further appraisal should meet broader criteria of consistency with strategic development goals that in turn should be addressing service delivery shortages, growth promotion and distributional goals. Climate and other environmental features typically would be additional considerations in the project preparation, but in some cases where frequent extreme weather hazards are prevailing, climate adaptation of some project types may become a core issue.

Identification of natural hazards requires the accumulation of meteorological, geological and other data to analyze and develop forecasting models of the probabilities of extreme natural hazard events that can lead to significant damage and economic losses as illustrated in Figure 2. Historical climate data for temperature and precipitation has been collected for more than 100 years and the density of earth-based weather stations has been increasing and since the 1980s been supplemented by data from satellite-based platforms. This has allowed the development of sophisticated weather models used for forecasting climate events for most regions of the world. These data and models have allowed access to climate event data provided by a number of major international and national agencies. The World Bank *Climate Change Knowledge Portal*⁵⁰ gives access to its aggregated knowledge on climate data and events as well cross references the major sources of climate data.⁵¹ These include the UN Intergovernmental Panel on Climate Change (IPCC)⁵² and the US Department of Commerce National Oceanic and Atmospheric Administration (NOAA)⁵³ weather, climate and related services. Other sources of global climate data include UK MET Office,⁵⁴ Max Planck Institute of Meteorology⁵⁵ and the Climate and Environmental Retrieval and Archive (CERA) database of the German Climate Computing Center (Deutsches Klimarechenzentrum, DKRZ).

The reliability of predictions of weather phenomena for a location depends upon the density of weather data collected in the region and the length of the time series of data available (30 years of data or more is desirable.) In countries with relatively few weather stations, interpolations are typically made from information and modelling for the surrounding region as developed by major national weather monitoring and modelling services in many of the larger economies.⁵⁶ This means that for many smaller developing economies without strong domestic weather monitoring and modelling capacity, they still have access to adequate weather data and forecasts. There are still regions of the world, however, where the number and density of earth-based weather stations are low and the time series of data relatively short such that weather forecasts tend to have much larger variances. Hence, predictions of

⁵⁰ <http://sdwebx.worldbank.org/climateportal/index.cfm>

⁵¹ The METADATA of the Climate Change Knowledge Portal is available at https://climateknowledgeportal.worldbank.org/themes/custom/wb_cckp/resources/data/Metadata.pdf

⁵² <https://www.ipcc.ch/>

⁵³ <https://www.noaa.gov>

⁵⁴ <https://www.metoffice.gov.uk/>

⁵⁵ <https://www.mpimet.mpg.de/en/home.html>

⁵⁶ For example, the Climate Change Knowledge Portal uses data from over 20 meteorological modelling centers around the world as listed in Table 1 of the *METADATA of the Climate Change Knowledge Portal*, op cit.

extreme weather conditions (floods, droughts, etc) for specific locations become more unreliable which raises challenges for disaster management and planning. One such area is central Africa where the problem is exacerbated by it being in the tropics where weather phenomena are more sensitive to relatively small temperature changes.⁵⁷ For countries, within such a region, investment in weather stations by the national governments with possible support from international aid agencies and financial institutions would appear to be a priority to allow for improved climate-sensitive PIM.

While the forecasting of climate, weather and other natural events, which could potentially result in disaster and damage, is difficult, the availability of data internationally is improving. The challenge, however, comes in linking natural disaster data to the actual historical and projected potential disaster information by country, location and sector. Some of the data on disaster impacts becomes available through international organizations given that many natural disasters tend to overwhelm the capacity of the local and possibly the national governments such that international assistance is called upon to assist with the recovery, and accordingly, information on the extent of disasters becomes available. For example, the Emergency Events Database (EM-DAT)⁵⁸ has been recoding data on disasters by country and type going back to 1900. The size of a disaster is measured in terms of the number of persons affected (which includes the number of persons killed, injured, missing, made homeless, or otherwise requiring emergency basic needs assistance) and the current US dollar value of damage to property, infrastructure, crops and livestock. The availability of this data, however, varies according to the capacity of the countries involved to collect and collate it. The EM-DAT for natural disasters since 2000 shows in Table 3 that while the data for persons affected is available in about 90% of all the disaster occurrences in countries in all regions, the availability of damage estimates varies significantly across regional country groups. Damage estimates are available in 98% of the occurrences in Australia and New Zealand, but only 12% of the occurrences in Sub-Saharan Africa. Moreover, damage estimates are available in less than 50% of the countries in Latin America and the Caribbean and South Asia. This indicates a significant lack of capacity in many developing and emerging economies to capture information on the damage estimates which would need to be collected by a combination of disaster recovery and management agencies as well as local governments and sector agencies (typically those responsible for transportation and agriculture.) This lack of capacity and information clearly limits the precision of any vulnerability screening that can be readily achieved. It is also likely to be compounded by the lower resilience of the the developing country to a natural hazard. For example, the same storm may do minimal damage to a road that has a hard surface, well constructed foundation and drainage compared to a gravel road with poor drainage. Similarly, a snow storm in a location with strong snow removal and clearance capacity will cause less economic loss than the same storm in a location with weak capacity. This changes how hazard information should be reported and linked to damage estimates and economic

⁵⁷ Future Climate for Africa, *Africa's Climate: Helping decision-makers make sense of climate information*, Reported funded by UK DFID and NARC, November 2016, <https://futureclimateafrica.org/>

⁵⁸ https://www.emdat.be/emdat_db/

loss estimates in the two cases. The greater resilience could come about by infrastructure being implemented subject to stricter design regulations appropriate to dealing with expected hazards and/or the capabilities of the institutions to predict, warn and respond effectively to hazards to reduce impact costs.

Table 3. Shares of natural disasters occurring during 2000-18 in selected regions with countries reporting total persons affected by or damages caused by natural disasters

Region	Total occurrences of natural disasters during 2000-18	Share of natural disaster occurrences with estimates of	
		Total persons affected	Damages
Australia and New Zealand	1,016	98%	98%
North America	626	88%	80%
E and SE Asia	1,714	96%	70%
Caribbean	264	86%	43%
Latin America	632	90%	33%
South Asia	836	86%	36%
Sub Saharan Africa	1,473	94%	12%
World	7,764	87%	44%

Source: Authors calculations based on EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

Another source of vulnerability or resilience of projects arises from their operation and maintenance (O&M) funding. Where facilities receive inadequate O&M funding, then the facility can be more vulnerable to extreme natural hazards. For example, failure to maintain drainage facilities or retention walls of a road can put it at greater risk of damage in an extreme storm. Underfunding of O&M of existing public assets lowers their resilience to hazards. Similarly, going forward, under funding the provisions for O&M of new projects raises their vulnerability.

The core concern is the occurrence of extreme natural hazards that can lead to significant damage and economic loss. This requires estimating the threshold strength for a hazard in a location that will cause significant damage, and then estimating the probabilities of hazards above the threshold occurring. This is the “exceedance” probability distribution that then needs to be linked to damage and loss estimates. This capability is covered in more detail in the next section on climate-sensitive cost-benefit analysis techniques. At the point of initial project identification, design and screening, the estimation of the expected costs may not

have been made yet, but there is a need to identify the project as vulnerable to one or more natural hazards so that further project preparation, design and appraisal will take these into account.

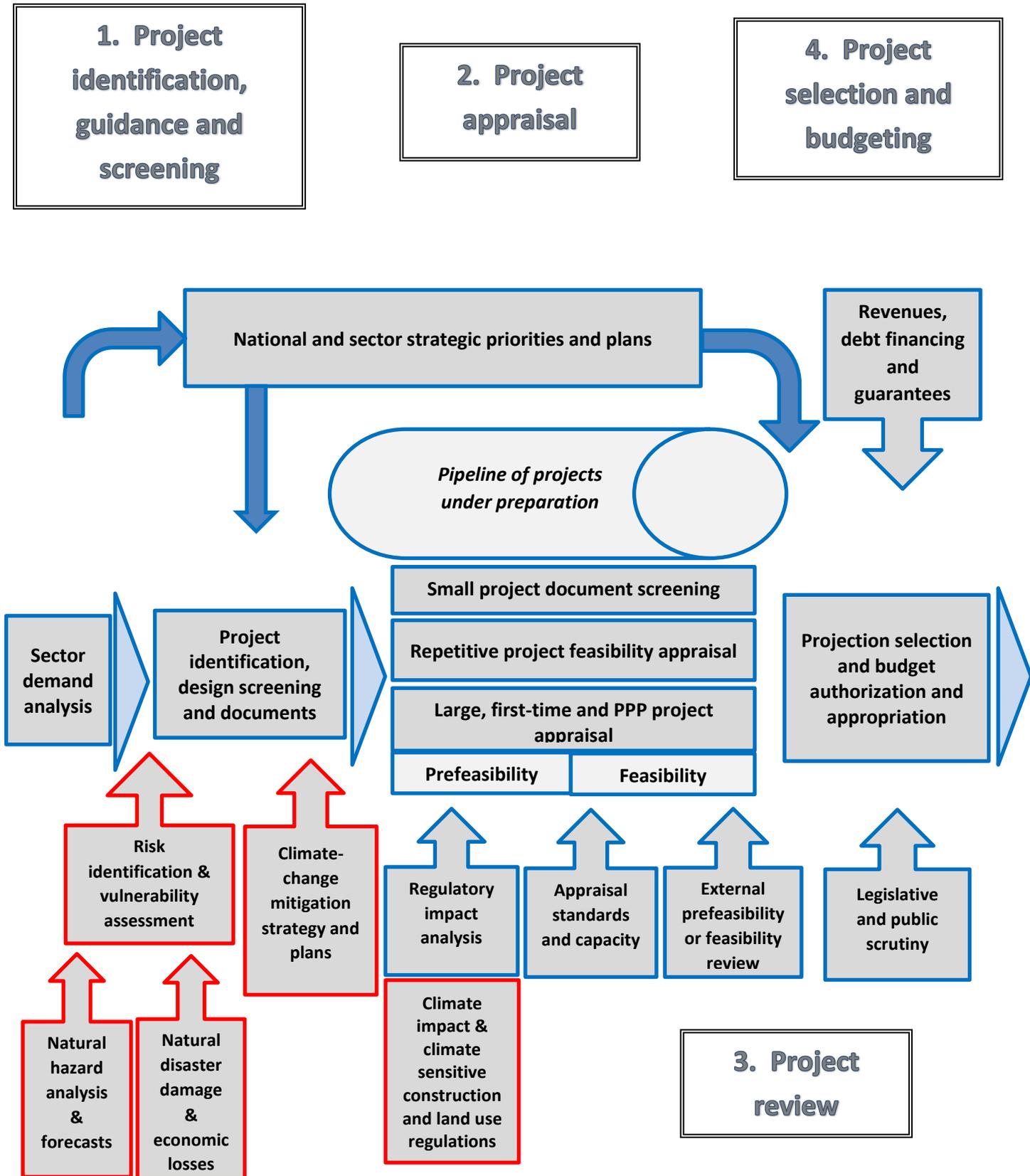
Climate-sensitive screening should serve the following functions as illustrated in Figure 3 (adapted from Annex 4):

1. Need for climate-change mitigation (or GHG emissions reduction) strategy and plans to be developed as part of national and sector strategies as plans that then advise the selection of projects.
2. Risk identification and vulnerability assessment to advise any project adaptation
3. Land use and construction regulation compliance assessment.
4. Need for climate impact (or incremental changes in GHG emissions) assessment as part of its environmental impact assessment or a separate assessment.

First, the development of climate-change mitigation strategies and plans should be integrated into the national and sector strategies and plans of a government. The goals for GHG emission reductions over some time horizon should be expressed in terms of contributions by sectors (especially energy, transportation, agriculture and forestry) depending on the current and expected main sources and sinks of GHG emissions. Importantly, the plans and projects of SOEs (especially where SOEs are major players in the energy and transportation sectors) should be integrated or coordinated and reviewed by the central government agencies.⁵⁹ Specific sector strategies and plans have to be developed that include the emission reduction contributions coming from specific plans such as changes in efficiency and fuel use in energy production and transportation. As noted in Section 1.4 above, a suite of methods have been developed under the GHG Protocols to account for the GHG inventories at the national, subnational and entity levels as well as incremental changes in GHG emissions arising from policies, programs and projects. These capabilities should be employed in developing the climate-change mitigation strategies and plans that advise the screening and selection of new projects entering the project preparation pipeline. Caution has to be taken, however, with using strategies plans as a strict screening device if these strategies themselves are not based on economic evaluations of prior projects that support the strategy and plans or the strategy and plans have not undergone some level of ex ante economic valuation. Where these strategies and plans are untested or unappraised, then the appraisal process itself has to consider and appraise the range of options that meet the excess market demand (different generation plant types for electricity supply, for example) to test which generates the highest net benefits including the valuation of net GHG emissions arising from the project alternatives.

⁵⁹ For a discussion of the relationship of SOE PIM to the broader government PIM system, see Glenday, Graham, *Diagnostic Assessment of Public Investment Management for State Owned Enterprises and Non-Profit Government Entities*, report prepared for the World Bank, January 2020.

Figure 3. Project Cycle: Project Implementation Functions with climate-sensitive screening, regulation and impact appraisal



Second, the natural hazards (and, more generally, other risks) should be identified and the vulnerability of the project assessed in order to consider the need to include adaptations to the project that should be evaluated as part of the project appraisal. The details of such appraisal is provided in the **Tier 3** below. In some extreme cases, the vulnerability may be already estimated for a project in terms of expected damage or economic loss. If it is found to be so severe that it is expected to exceed the present value of the project net benefits, then the project should be rejected. This requires, however, that the project appraisal is already at an advanced enough stage and the expected damages or economic losses have already been well estimated based on past experience using the exceedence function for the hazard type and location. This raises the issue of the level of climate-sensitive screening that is feasible. Data collection, analysis and decision making are all costly exercises so that an efficient level of effort has to be applied in project screening and appraisal.⁶⁰

Third, whether a project is compliant with land use and/or construction regulations needs to be noted early in the project screening as this is likely to affect the vulnerability of the project to natural hazards or whether the project needs to be compliant with green building or climate-change mitigation land use requirements. In locations or situations that are known to be sensitive to natural hazards (such earthquakes, flooding, landslides, mudslides, etc) construction regulations are often adjusted such that infrastructure and buildings are more resilient to expected natural hazards.⁶¹ Where projects are compliant in their designs with such regulations, then the threshold for vulnerability of the project will be higher and possibly remove the need for a vulnerability assessment, and moreover, the need to consider any added adaptations to expected extreme natural hazards. Where projects are not compliant with climate-sensitive construction codes in situations and locations that are vulnerable to natural hazards, then they should be rejected until their designs are made compliant.

Fourth, climate impact (or incremental changes in GHG emissions) assessment should be conducted part of its environmental impact assessment or as a separate stand alone assessment. This impact on GHG emissions becomes the critical input in the economic appraisal of the project that is discussed further below and in **Tier 3**.

It is often the case that governments will develop different channels to screen and appraise projects before selection and budgeting. The level of effort in all project preparation functions can be channelled as illustrated in Figure 3 based on whether the project is (i) a small project (below \$5 million, say), (ii) medium sized or a repetitive project with similar

⁶⁰ See Graham Glenday, Kai Kaiser, and Tuan Minh Le “Approaches to Better Project Appraisal” Chapter 4 in Rajaram, Anand; Minh Le, Tuan; Kaiser, Kai; Kim, Jay-Hyung; Frank, Jonas, *The Power of Public Investment Management: Transforming Resources into Assets for Growth*, Directions in development; Public sector governance. Washington, DC; World Bank Group (Sept 2014)

⁶¹ Ideally, as with any regulation, climate-sensitive construction codes should be subjected to cost-benefit analysis to ensure that the costs of compliance are expected to result in cost savings when exposed to a natural hazard.

project having been previously analyzed, or (iii) a first time, complex or large project (above \$50 million, say.)

In the case of small repeat projects, screening and selection will be based on the projects consistency with sustaining the existing productive capacity or service delivery levels and/or meeting development priorities to expand service delivery as well as meeting regulatory requirements and technical, managerial and financial feasibility criteria.

Repetitive projects are often small or mid-sized where the financial and economic characteristics are well known such that satisfying a minimum service scale and demand levels or cost-effectiveness criteria become sufficient levels of appraisal.

Finally, first time and large, complex projects often need to be subjected to full cost-benefit analysis, including financial, economic, distributional and risk appraisal. Typically, major projects vulnerable to natural hazards fall in this last category. The outline of a full appraisal is covered below in **Tier 3**. This may include the consideration of project design changes that better adapt it to deal with expected extreme natural hazards.

The level of effort applied to risk identification and vulnerability assessment would follow the channels through which projects are being processed. The screening function would also be affected by the capacity factors already discussed above: (a) the ability to identify and quantify the strength of expected extreme natural hazards, (b) the existing natural hazard-sensitive construction regulations and disaster management capabilities, and (c) the ability to quantify the exceedence probabilities for natural hazards into expected damages and economic losses by sector and location. Clearly, these capabilities are dynamic in any government based on the development, implementation and learning from natural hazard monitoring and modelling and natural disaster monitoring, measurement and management. In response to this range of capabilities by country and sector, the World Bank has developed a range of **Climate and Disaster Risk Screening Tools** which are discussed in Annex 5.2 and are also available online.⁶² These are developed at a generic level to assist developing countries and to suit most sectors. Some tools have been developed to a more sophisticated level as may apply to major transportation projects.⁶³ In general, however, a generic “traffic signal” type rating guide could be used to rate the preliminary risk of hazards to specific sectors. For example, the guide could provide the following rating categories for a sector and/or region⁶⁴:

⁶² <https://climatescreeningtools.worldbank.org/>

⁶³ Jane Olga Ebinger and Nancy Vandycke, *Moving Towards Climate Resilient Transport: The World Bank's Experience from Building Adaptation into Programs*, Transport & ICT Global Practice, World Bank, 2015

⁶⁴ These sector risk ratings for a hazard are available at <https://climatescreeningtools.worldbank.org/content/risk-rating-popup>

Insufficient Understanding	Greater familiarity with the sector and/or hazards is needed. This rating should be revised once there is sufficient understanding
No risk	The hazard does not pose a risk to the sector and/or region and will not affect the achievement of development goals and priorities.
Low Risk	The hazard could have a modest negative effect on the sector, but the country and/or sector has sufficient institutional capacity to respond to the hazard.
Moderate risk	The hazard could have a considerable negative effect on the sector, and institutional capacity to respond to the hazard might not be sufficient; this risk has the potential to affect the ability of the country to meet its development objectives.
High risk	The hazard is likely to have a considerable negative effect on the sector, and institutional capacity to respond to the hazard will not lessen the impact; this risk will likely affect the country's achievement of development goals and priorities.

Ideally, the risk categories should be based on more refined quantitative criteria that would require some action in the project preparation process – reject, redesign, re-evaluate, etc. Generally, the no or low risk cases could be ignored for the small, medium and repetitive projects, and result in some reduction in the expected net benefits in the case of large projects being subjected to full cost-benefit analysis. The moderate and high risk cases in the case of large projects would be handled by *Tier 3* where adaptive measures could be considered to lower the expected losses.

The case of the small, medium and repetitive projects poses some challenges. Projects in these channels are not typically subjected to cost-benefit analysis, and while the project capital and operating and maintenance costs should be available, the estimates of the economic benefits may not be available. This means that it is not possible to assess the reduction in the net benefits that exposure to the hazards are expected to cause and whether this would result in the project rejection or reconsideration after being redesigned. Alternative criteria for screening projects for rejection or redesign based on hazard vulnerability would be to assess (i) the expected numbers of people that would be affected in terms of deaths, injuries, home damage or livelihood damage, and (ii) the expected value of the damage to the project assets (infrastructure, buildings and inventories.) Where the number of people affected and/or share of project asset damage is high, then this should trigger the need to consider adaptive designs and improved project management (including disaster management) or project rejection if these persons affected and/or damage costs remain unacceptably high.

2.4.2 Climate-change impacts

The other major climate consideration in project preparation and appraisal is the climate-change impacts (positive or negative) of the project. The core issue here is the impact of the project on green house gas (GHG) emissions. This may be either a direct impact through

GHG reduction through, for example, expanded green power supply in place of fossil fuel-based power or an indirect impact through changes in forest coverage or management that impact the carbon sequestration capacity of the country and possibly the local climate. The climate-change impacts of changing the level of CO₂ and other GHG emissions have both domestic and international economic values that should be taken into account in economic cost-benefit analysis of a project.^{65, 66} The changes in carbon emissions can have significant effects on the economic net benefits of power generation plants and transportation projects. The issue of how to account for the national and international impacts of changes in carbon emissions is discussed further under *Tier 3* below.

Here the concern is more focused on the need to plan how the climate-change impact valuation enters into the PIM process. First, as noted above climate-change mitigation should be integrated into the sector strategies and plans of governments that should help screen and select projects entering the appraisal pipeline. This screening for projects with expected positive climate-change impacts is especially important for smaller projects that do **not** get subjected to full appraisal which evaluates the GHG emission impacts of the project. GHG Protocols have been developed that governments can use to help set and manage mitigation goals.⁶⁷

Second, in many countries large projects or projects that are expected to impact environmentally sensitive areas such as forests, wetlands, coastal zones, etc are required to undergo some level of environmental impact assessment to identify the vulnerabilities and possible adaptations required to the project to minimize the environmental impacts. These could include changes in the ability of the land to act as net GHG sink. In addition, projects that have incremental impacts on net GHG emissions either directly through changes in fuel types used or significant efficiency gains or indirectly through upstream or downstream impacts on emissions need to estimate the time profile of these net changes in emissions. In many countries an environmental impact assessment is required for major projects or projects affecting environmentally sensitive locations. These environmental impact assessments (EIA) are typically conducted as an early input into the appraisal of the project. See Figure 3 above. The assessment of the climate impacts of the project should be part of that EIA process. Clearly, where a country has no EIA process or they currently do not cover climate impacts adequately, special regulations or directives are needed to have climate impacts routinely assessed as part of project screening, appraisal and approval. This should be especially important in countries that are vulnerable to climate-related disasters.

⁶⁵ Current estimates in the US of the economic costs of an added ton of CO₂ emission are \$42 per ton. National Academies of Sciences, Engineering, and Medicine 2017. *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/24651>

⁶⁶ The value of carbon traded on the EU ETS as of March 2019 is US\$25 per tonne.

⁶⁷ GHG Protocol, *Mitigation Goal Standard: An accounting and reporting standard for national and subnational greenhouse gas reduction goals*, WRI et al; GHG Protocol, *Policy and Action Standard: An accounting and reporting standard for estimating the greenhouse gas effects of policies and actions*, WRI et al

Third, in the conduct of full project appraisal where the external benefits of any GHG emission reductions are estimated, the capacity to estimate the additional contribution of the project to GHG emission reductions becomes a crucial input to the appraisal. It is important to have a cadre of officials trained with capacity in the methods of estimating additional reductions in GHG emissions. GHG Protocols have been developed that provide standards and guidelines for policies and projects⁶⁸ and for standalone corporations⁶⁹ (such as can occur where a project is implemented as a Public Private Partnership.)

In Chapter 3, the general findings and recommendations of Chapter 2 are brought together to emphasize the need for the central agencies responsible for finance and economic planning to take an active role in ensuring that the various PIM functions that make the PIM climate sensitive are allocated to agencies or units, and guidance, support and oversight is provided.

2.5 Tier 3: Climate-Informed Project Appraisal and Design⁷⁰

This section presents the methodology to incorporate climate-change impacts into the economic analysis module of an integrated projects appraisal (or cost-benefit analysis (CBA)) that should be conducted for all new, large or complex projects as indicated in the previous section and illustrated in Figure 3. This includes how adaptations to the project are incorporated in the design and appraisal for decision-making purposes. These adaptations may arise from climate-impact related construction regulations for a sector and region or may be tailor made for a project given its vulnerability to expected climate-related disasters. The other key inclusion in the project appraisal or CBA function is the economic evaluation of the climate impacts expected to be caused by the project, which raise some demanding technical issues.

Annex 6 gives a more detailed description of climate-informed project appraisal methods. Here the essential components and steps are outlined.

For an infrastructure or facilities project that is potentially vulnerable to climate-related hazards (such as a bridge that could be damaged by riverine or coastal flooding), the project appraisal has to take into account the projected hazards that may damage the ability of the project to generate its expected services. Based on past records or expert opinions, the

⁶⁸ GHG Protocol, *Policy and Action Standard: An accounting and reporting standard for estimating the greenhouse gas effects of policies and actions*, WRI et al

⁶⁹ GHG Protocol, *A Corporate Accounting And Reporting Standard (Revised Edition)*, World Resources Institute (WRI) et al

⁷⁰ This section draws heavily on a World Bank report prepared by Fernando Fernholz and a team from Duke University, "Climate Sensitive Public Investment Appraisal: General Methodology and Applications, St. Lucia," Report prepared for the World Bank, June 2018

potential costs of damage need to be assessed along with the vulnerability of the project to suffering damage from different intensities of the hazard. In addition, the net economic losses that economy is expected to suffer if the infrastructure or facility services are lost until some future time that they can be restored have to be assessed. The overall economic loss of a disaster depend both on damages and the loss of services, or the cost of replacing or repairing the infrastructure and the value of the lost services. It is clear that the economic loss will vary with the intensity of the hazard and the ability of the infrastructure to withstand the hazard and the government to reduce the hazard (for example, divert or dam up floodwaters) and the speed with which the government can restore the infrastructure services or provide alternatives. The expected economic loss depends on both the hazard analysis (past and projected hazard intensities) and the vulnerability analysis of the project (based on past experience and analysis.) This combination of data and modelling allows the simulation of the project and its risk analysis to be conducted to both assess the probability of economic losses from climate-related disasters and how best to adapt the project to efficiently reduce these losses. Box 2.4 provides an illustration of this hazard and vulnerability analysis for road systems or segments. Annex 6 provides a more detailed technical description.

A gradual buildup of quantitative methods of analysis (CBA and Risk Simulation) is required in government ministries responsible for planning and financing these projects at risk. This capability includes models of past events and the associated damages and an ability to formulate a forward-looking probability of future climate or other natural disaster events and future associated estimated damages. This deals with deep uncertainty, and the knowledge base and model formulation needs to be adaptive and flexible to obtain more robust results for decision making purposes. Clearly, these capabilities are dynamic in any government based on the development, implementation and learning from natural hazard monitoring and modelling and natural disaster monitoring, measurement and management.

The next step is to consider whether adaptations can be made to the new infrastructure investment (a road system, say) that will make it more resilient while also improving the expected net benefits gained out from the enhanced investment. The approach is known as real options analysis.

Box 2.4 Illustrative Example: Climate-change impacts on road systems (including individual infrastructure assets)

Hazards or risk sources can include flooding caused by rain, sea level rise and surges, and wind storms. Floods, for example, can inundate road platforms, softening their base and washing out entire segments during extreme events. Roads or highways surrounded by mountain slopes are vulnerable when heavy rains can cause landslides and erode the road platforms. There are similar effects to bridges. Floods can affect the foundations of a bridge or destroy the entire structure. In some cases and for some bridges, hurricane intensity winds can be physically destructive.

The impacts from climate change can be complex. A combination of factors needs to be assessed: weather events through probabilities of frequency and intensity (rain, winds, sea waves and surges), local conditions of topography, soil characteristics and soil-mechanics, as well as the norms and quality control that are used to design each piece (or asset) of the system. The expanded or smart design and decision-making process incorporates knowledge coming from disciplines of engineering, economics, weather science, geology, and institutional variables such as the PIM system itself as well as government policies.

Assessing Potential Damages to Infrastructure

A starting point is to assess potential climate risk-related damages to the road infrastructure assets by doing an inventory or an approximate calculation of the construction replacement costs by exact location. These potential damages need to be estimated initially with some approximations provided by local professionals.

An initial assessment of losses due to the inability of the infrastructure to deliver services is the basis for an empirical relationship to the assets or segment of a road system. In the case of the road, the inability to travel safely and within time dimensions that support the functioning of the economy (e.g. tourism, shipping goods) and other social services and access (such as visits to hospitals or attending schools)

A risk matrix is developed with the contributions of professionals and local experts providing inputs from their subjective understanding of the costs and time frames of construction. In addition, relevant information needs to be classified and recorded on the quality and maintenance status of protective investments such as slope coverage, retaining walls and drainage conditions with references to past records and maps, including the geological and geotechnical characteristics, topography, and soil conditions. The risk related information, if possible, should have some references to past records of catastrophic events such as heavy rain or wind, or water surges, and also from past events reconstruction costs and other relevant loss information, for example on days of disruption.

The information on past weather related events (rain, wind and water surges) is then incorporated into the qualitative and descriptive risk matrix, linking past events to recorded reconstruction costs (or the repair of damages).

Real Options Analysis

A climate-sensitive public investment appraisal method should consider questions such as: What are the additional measures and design features that need to be implemented to increase the resilience of a project? (In this case for a segment of a road and then the road system for a particular area of a country). For example, increasing the strength and depth of the supporting platform for a road segment that will potentially face flooding, or increasing the height of the road pavement, strengthening the foundations of a bridge to withstand flood pressures of different duration and intensity, or additional bridge structure reinforcements for increased resistance against different intensities of windstorms. The value of real options of enhancing a particular vulnerable bridge or road segment will be affected by the existence of alternative (but currently) less attractive routes that can be used in the case of damage to the bridge or road segment in question. If alternative routes do not exist, then a real option to consider is the development of alternatives instead of strengthening the vulnerable bridge or road.

The real options can include provisions in the design and construction, for adaptive reinforcement of structural elements in the future. What is the expected relationship between the additional climate-related resiliency investment costs in the near future and expected and estimated probabilities of loss savings due to increased resilience of the infrastructure assets?

Real options also include the pre-emptive measures taken ex-ante, which can allow decision makers more flexibility to adapt to changing future project conditions. Real options have an initial higher investment cost. This is the price for higher flexibility and the potential for higher net benefits under conditions of high uncertainty.

An example of the application of real options is the case of developing a flexible strategy to incorporate uncertainties of climate change for drainage system in West Garforth, England.⁷¹ “*‘Real options’ (RO) is a recognised procedure to handle uncertainties in infrastructure investments by providing managerial flexibility. A RO is ‘the right—but not the obligation’ to adjust the infrastructure system in ways likely to be more resilient, as needed to continue to function as expected in the face of change. As such, these options represent physical choices about the system that can provide the flexibility to deal with uncertainty. RO may be utilised even when modifying existing systems. When applied to the (re)design of infrastructure systems, RO analysis focuses on making changes to the system configuration in reaction to reductions in uncertainty through future learning. This is known as real ‘in’ options (RIO) analysis (de Neufville 2003).*” Using the Real in Option optimization author shows how to include future uncertainties to make water infrastructure more resilient in relation to flooding. Running possible scenarios and adaptations, the authors show the net savings that can be obtained in economic terms.

⁷¹Gersonius, B., Ashley, R., Pathirana, A., & Zevenbergen, C., “Climate change uncertainty: building flexibility into water and flood risk infrastructure,” *Climatic Change*, 116(2), 411-423, Jan 2013

Practical considerations

In more practical terms, a recommended course of action is to enhance appraisal methods to take deep uncertainty (caused by climate change) into consideration, embed guidance documents and practice, and strengthen the overall PIM system in the context of changing profiles for climate change that are anticipated now. These models and projections will be refined in the future as more and detailed information and methods become available. For effective public investment decision making (as a key component of any PIM system), the integrated and expanded appraisal methods, which include climate-change related analysis, need to be developed further and used. Financial and economic analysis based on climate-sensitive cost benefit methodologies can be used to estimate the potential damage to infrastructure that can result from weather-related events. Different scenarios can be constructed using probabilities from local and international historical weather records and data from previous major catastrophic climate related events in past years. These events would have affected the level of public services (losses) as well as operating condition and function of many public sector assets (damages) requiring additional funding for repairs and recovery. The need to fund emergency repairs and assistance severely distorts the allocation of budget resources, delays planned investment outlays and has an impact on the development and growth trajectory of the country. Several reports from donors and international lending agencies in past years point out the scale and cost of reconstruction efforts.⁷²

Project Level Impacts

At project level, the recommended applied methodology can be applied to essential infrastructure and public services that are expected to be affected by climate-related disasters. Projects and sub-projects can be identified where the resiliency related investment costs generate a large expected net present values, justifying the investment. This is consistent with several studies about the benefits of resiliency investments in the world. The problem, with an ex-post appraisal is that in the projects where sensible resilience related additional investments have been made, a high benefit to cost ratio, or a large net present value, will be obtained. But there might be some other investments, where the additional costs of resilience related investments did not result in ex-post net benefits as they were not yet affected, up to a certain year or the present, by a major climate-change related event.

Climate-Sensitive Appraisal Methods

Cost benefit analysis (CBA) should help guide governments to invest in projects and programs that are optimized in terms of net economic benefits (including their financial,

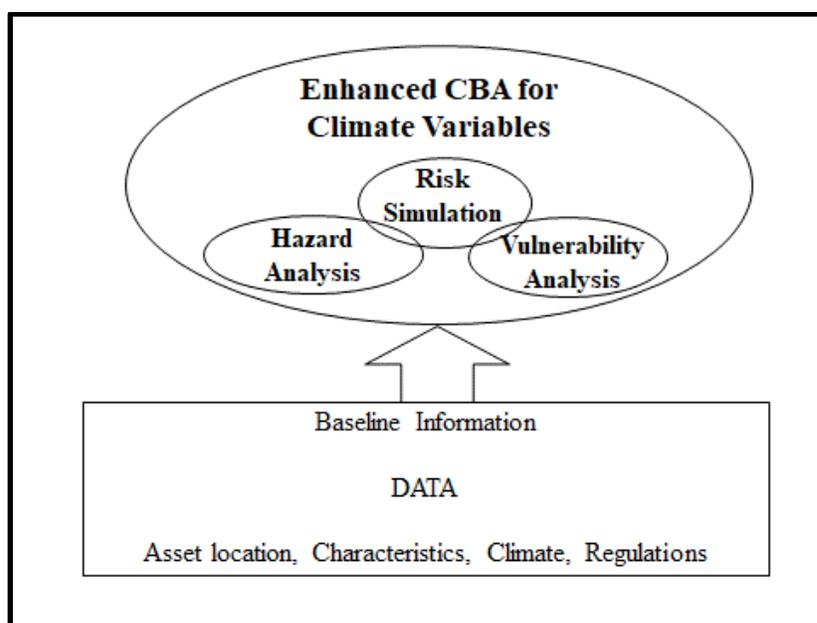
⁷² See References section for references relating to costs of reconstruction and adaptations to improve resilience

environmental and distributional impacts). For selection of projects, given limited budget resources, preference is for projects with comparatively higher net benefits. These should be selected, financed and implemented. This CBA approach needs to be expanded or enhanced, however, in the face of potential climate disasters. In the context of climate uncertainties, essential infrastructure in a country or locality that could be damaged by extreme weather should be identified. Next, potential climate scenarios and their impacts on projects should be developed. This hazard and vulnerability analysis should then inform the CBA and allow risk analysis and real options analysis to be conducted. Figure 4 shows the components of the enhanced CBA for climate-change considerations. This illustrates the need to bring together hazard analysis and vulnerability analysis to estimate the loss functions for hazard intensities that are needed to simulate and conduct risk analysis of projects subject to climate-related risks as discussed in Annex 6.

Essential Infrastructure

Government officials, in some cases with the help of consulting professionals, need to determine the essential infrastructure and services that it needs to provide at all times and in times of emergency. The focus is on essential infrastructure that can be threatened by natural disasters and which is critically needed in the aftermath, for the economy and society to function. An important consideration is the incremental investments (both new projects as well as enhancement to existing ones) needed if we take into consideration climate-change impacts and their economic implications.

Figure 4: Components of the Climate-Sensitive CBA



Source: *Authors*

Climate-smart construction regulation

Where countries, regions or localities experience repeated and relatively major climate disasters (such as from tropical cyclones or riverine floods that affect broad categories of infrastructure and buildings), the CBA of introducing preventative construction regulations or financial incentives (such as preventing construction in river or coastal flood plains or requiring protective features in construction designs) should reveal that the avoided disaster losses should exceed the added costs of complying with these climate-related regulations. Essentially these regulations can be viewed as real “options” (or requirements) in the designs of infrastructure and other property.

An example is found in the Florida housing norms. After hurricane Andrew, Florida adopted a new 2001 Florida Building Code (FBC), which became one of the strictest in the United States. Using 10 years of paid insured loss data, the authors⁷³ show that the FBC reduced windstorm losses by up to 72%, and use the results to conduct a CBA. The FBC passes the Benefit to Cost Ratio by a margin of \$6 in full reduced loss to \$1 of added cost, with a payback period of approximately 8 years.

2.6 Climate-change mitigation and impacts in economic appraisal

As already noted above, a key aspect of a climate-smart system is the inclusion of the evaluation of climate impacts of changing GHG emissions arising from a project. This may be either a direct impact through GHG reduction through, for example, expanded green power supply in place of fossil fuel-based power or an indirect impact through changes in forest coverage or management that impact the carbon sequestration capacity of the country or possibly the local climate. The climate-change impacts of changing the level of CO₂ and other GHG emissions (measured in tonnes of CO₂e) have both domestic and international economic values that should be taken into account in economic cost-benefit analysis of a project. The two most common methods of estimating the GHG emission externality are either by estimating the added economic costs of damage from added carbon dioxide emissions^{74,75} or by the value of carbon emission rights traded in an open market.⁷⁶ The challenge to CBA from an economic perspective is that GHG emission reduction is a global public good such that the benefits accrue nationally *and* to the rest of the world.

⁷³ Simmons, Czajkowski and Doneshow, “Economic Effectiveness of Implementing a Statewide Building Code: Florida,” *Land Economics*, May 2018

⁷⁴ Recent estimates in the US of the economic costs of an added ton of CO₂ emission are \$42 per ton. National Academies of Sciences, Engineering, and Medicine 2017. *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/24651>

⁷⁵ A recent High Level Commission recommended prices in the range \$40 to 80\$ per tCO₂e in 2020 and rising to \$50 to \$100 per tCO₂e by 2030. Carbon Pricing Leadership Coalition, *Report of the High-Level Commission on Carbon Prices*, May 29, 2017

⁷⁶ The value of carbon traded on the EU ETS whether taken as has averaged over €20 per ton of EU Emission Allowances (EUA in ton of CO₂ or CO₂e) or Carbon Futures Prices for most months since November 2018 and reached a high of over €29 in mid-2019, but has dropped again to about €20 in May 2020.

The basic approach in CBA is that the incremental costs and benefits are added up from the perspective of a particular group of persons affected by an investment, typically the parties sponsoring a project (such as private equity holders) or financing a project (such as the debt holders) or all parties that are nationals of a country. Economic analysis conducted by a national government typically adds up all the incremental costs and benefits experienced by its nationals of the country. An external benefit accruing to the rest of the world is typically not accounted for unless (a) the nationals regard this as a merit good that they are willing to pay for such as others in the rest of the world benefit from the reduced GHG emissions, and/or (b) the government (or some private nationals) are compensated by some party outside of the country for the undertaking the project because of its positive global climate impact. Such compensation could be paid either by a particular donor country or group of countries or paid out of a global fund set aside by donor countries for the purpose. To estimate the amount that nationals are willing to pay for a merit good provided to the rest of the world can be estimated by the contingent claims method, which is a common, but challenging valuation method used for valuing non-use environmental externalities. It is therefore possible to include in the national economic CBA the value of the reduced GHG emissions at least up to the sum of (i) the measured merit good value, (ii) the compensation received by the nation from the rest of the world, and (iii) the share of the global cost saving that would accrue to the country.⁷⁷

As noted in Section 1.4, the GHG emissions behavior of the private sector is influenced largely through a range of policies and programs such as those (a) aiming to put a price on GHG emissions through ETSs or carbon taxes, (b) directly regulate emissions and encourage fuel switching and technology changes (as is happening in the automobile markets, for example), (c) introduce green building codes or (d) regulate land use to protect and expand forests, wet lands, etc. Ideally, all these policies and programs should be subjected to *ex ante* and *ex post* CBA to ensure that they are economically attractive, including the valuation of their incremental or additional impacts on net GHG emission reductions.⁷⁸ Note where projects are subject to ETS and/or carbon taxes, all or some of the GHG emission externality may already be internalized in the accounting of emission costs. As will be noted in Box 2.6 below, some countries, particularly in Europe, are raising their traded carbon prices over time up to the estimated costs of economic damage caused by incremental GHG emissions.

In the public sector, projects may well also be affected by the same regulatory policies aimed at climate-change mitigation that affect the private sector. Governments are also major investors. They take investment decisions, however, based on the broader economic impacts of the investments that also include the externalities from the climate-change impacts. Hence, the

⁷⁷ Note that the share of the global cost saving would be significant for large economies (such as the USA, China, India or the EU) but negligible for small economies.

⁷⁸ The issue of mitigation programs, policies and projects causing or inducing **incremental** or **additional** GHG reductions compared to what would have happened in the absence of the program, policy or project is crucial to assessing their effectiveness in lowering GHG emissions and levels. “**Additionality**” is a major focus in the GHG Protocol for policies and projects (GHG Protocol, *Policy and Action Standard*) and for corporate entities (Chapter 11 of GHG Protocol, *A Corporate Accounting and Reporting Standard (Revised Edition)*).

public investment itself is a tool with climate-change mitigation potential as governments can financially support projects with significant green potential. This requires the project appraisal process to answer a series of questions: What is the net impact of the project on GHG emissions? What is the economic value of this externality, particularly if it is positive? Is it justifiable to account for the whole of the global external benefit as a national benefit, particularly if this benefit is (i) the deciding factor in the choice between projects and (ii) requires government support to make the project financially viable? To help answer these questions further, consideration is now given to the conduct of CBA and PIM in the context of projects supporting climate-change mitigation.

At the heart of economic decisions about public investments is the application of CBA. There are two basic types of project decision: (i) investing in the project or not, and (ii) deciding between competing alternative investments that deliver the same or similar services or benefits. The first case actually poses a challenge in that it requires estimating net impact or additionality of the project on GHG emissions. The problem is the alternative is “not doing the project” that releases the resources the project would have absorbed for use in alternative economic activities. (This is also the opportunity costs of doing the project.) On average, economic activities in an economy have positive GHG emissions so that the base line to judge emissions incrementality is what these other activities would have released. To date, this variable has not been estimated relative to the scale and type of project to allow this base line to be estimated.⁷⁹ Clearly, if the project provides a net GHG sink, such as a forestry or wetland improvement project, then the net positive impact on GHG emissions is underestimated. Taking the direct and indirect emissions impact of the project could be used as a conservative basis for estimating the positive global externality. By contrast, if the project is a net GHG source, then the net impact on total emissions is uncertain (is it above or below the national average?) and, unless the project is a major GHG emitter, such as a fossil-fuel based power plant, the GHG externality can possibly be omitted. For projects that are major GHG emitters, the direct and indirect emissions impact of the project could be used as a basis of estimating the negative GHG externality. In many countries these externalities may already be fully or partially internalized in the financial accounts through participation in ETSs and/or through carbon taxes.

Fortunately, most projects that are major players in climate-change mitigation programs can be appraised using the change in emissions between alternative projects so that the net emissions impact is knowable. One example, is the choice in electricity generation plants between fossil fuel-based plants and green power generation plants. Another is the design and climate-control technology choices in a green building. Assuming the project options are all economically attractive, if they produce the same or similar benefits, the choice can be made using cost-effectiveness analysis where the project with the lowest economic cost is chosen after penalizing the project with the cost of the net emissions it would create if selected.

⁷⁹ One rough approach could be to take the estimated CO₂ emissions as a share of GDP for a country to get an estimate of what the labor and capital used by the project would have produced in alternative activities.

In conducting appraisal of projects, governments have to handle two basic types of investment entering PIM systems: (i) budget supported projects, which include most types of infrastructure and facilities supporting public service delivery, and (ii) self-financing or commercial projects where the project may be financially self sustaining, which includes most SOEs and PPPs. In the first case of budget supported projects, the financial analysis largely focuses on the ability of the government to fund or finance the capital and current expenditures required over time. Most critically, however, the appraisal stage of the PIM system is required to check the economic attractiveness and the distributional effects of the project. The economic appraisal would need to estimate and value the net GHG emission impact of the project. This is most important where the project design could have different choices affecting how green the infrastructure or facility is expected to be in terms of building materials used (for example, concrete uses cement the manufacture of which is a major source of CO₂ emissions⁸⁰) or energy usage for heating or cooling the facility.

The second case of potentially self-financing commercial projects covers some of the important GHG emission sectors such as electric power generation, public transportation and waste management. Many of these projects are implemented by SOEs and PPPs. If competing projects are both financially and economically attractive, then the choice of the one generating the highest net economic benefits is straight forward. The choice becomes more difficult when the green project is financially more expensive and is not financially viable, but is economically more attractive because of the value of the net GHG emissions reduction. In such cases, the government has to arrange financial support to have the green project go ahead. How much of the global GHG reduction benefit that largely accrues to the rest of the world can a government, particularly in a developing and emerging economy, use to justify the amount of support. It is clear that in such situations, if financial support is available from the rest of the world, this can transfer more of the benefit to the country hosting the green project. The emergence of green finance and green bonds (see Section 4.2 below) can play a crucial role. Green finance is provided by the major international development banks, mainly as loans, but also as guarantees or grants, to assist with green investments including climate-change mitigation projects. Green bonds are issued by governments or corporations linked to the financing of green projects. The linkage of these types of finance to the implementation of a specific green project is crucial in treating these as incremental inflows of foreign exchange to the implementing country. In such cases, the net present value of the inflows less the repayment outflows becomes an added benefit to the country. Clearly, green-project-linked grants or low-interest rate loans would raise the benefits to the recipient country. Access to such incremental finance can then justify the country supporting the financially more expensive green project. An example of such a project choice is provided by the case of the Indonesian Government supporting the implementation of geothermal power plants in place of added use of financially cheaper coal-based power plants. See Box 2.5. Financing was provided from the Clean Technology Fund (a trust fund within the Climate Investment Fund) plus some grants to support technical assistance. This green financing allowed the choice in favor of the geothermal power development by allowing Indonesia to

⁸⁰ Estimates of the share of total GHG emissions arising from cement production range from 3% to 8%.

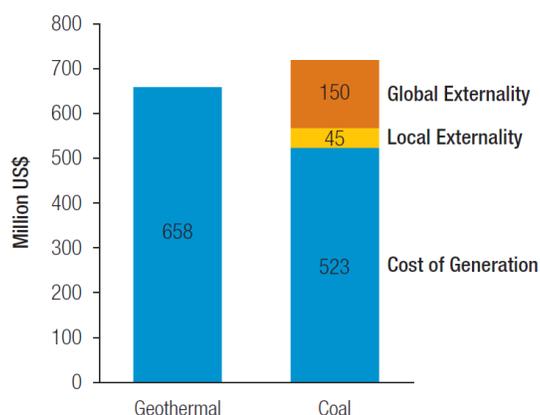
Box 2.5. Indonesia Renewable Geothermal Energy Case

In 2006, Indonesia had only exploited some 4% of its world-leading geothermal energy potential of between some 10 to 27 gigawatts of electric power. A full-integrated project appraisal or CBA (including financial, economic, distributive, and risk analyses) was conducted of two proposed 150 MW geothermal plants at Ulubelu and Lanhendong to be implemented by PERTAMINA GEOTHERMAL ENERGY instead of the equivalent power generation from coal-fired plants. Coal-based energy was financially the cheapest option at the time. In 2010, electricity in Indonesia was based 37% on coal, 35% on gas and 11% on diesel. The two geothermal plants were seen as the test cases for a potential major expansion of renewable green energy in Indonesia going forward.

The economic analysis conducted as part of the CBA revealed, as shown below, that coal generation would be US\$135 million less than the geothermal without consideration of the environmental benefits of geothermal energy. When the local pollution (nitrogen oxides, sulphur dioxide and total suspended particles) reductions were taken into account the cost difference was reduced by US\$45 to US\$90 million. If the global benefit of reduced GHGs (about 1.1 million tons of CO₂e per year) of \$150 million is included then this gap is exceeded.

The GHG reductions were valued at €14 or US\$20 per ton, which was the average of EU ETS Futures prices over 2009-10. These prices had averaged about €20 earlier, then dropped as low as €5 thereafter, but have risen again to average above €20 since late 2018. EU ETS carbon trading prices are expected to rise as GHG emission caps get tighter going forward as countries make efforts to meet their GHG emission reduction goals. In addition, estimates of the economic damage caused by rising GHG emissions are also generally higher than carbon emission trading prices. Hence, over a long-term horizon, this GHG global benefit appears to be reasonable and possibly conservative estimate.

The other issue concerns whether Indonesia should credit itself with the full amount of the global benefit most of which accrues to the rest of the world. In the case of this project, it received a long-term US\$125 million low-interest rate loan from the Clean Technology Fund, which was valued as a net benefit to Indonesia worth US\$86 million. In addition, the project attracted a US\$7 million grant for capacity building in the geothermal energy sector. These net inflows allow Indonesia to realize sufficient external benefits to capture enough of the global benefit to make the geothermal energy option more economically attractive than coal-based power.



Source: Jayawardena, Migara S., M. Baher El-Hifnawi, Gangadhar P. Shukla and Yan Li, *Scaling-Up Renewable Geothermal Energy in Indonesia: An Integrated Approach to Evaluating a Green Finance Investment*, Knowledge Series 015/13, World Bank, May 2014

Box 2.6 Selected country experience with valuation of GHG emissions for use in Cost-Benefit Analysis (CBA)

1. United States Federal Government

General guidelines for the analysis of Federal Government projects are provided in an Office of Management and Budget circular,^a but this does not provide specific details on economic valuation methods for GHG emissions. Following the issuance of a Presidential Executive Order on “Regulatory Planning and Review” in 2009,^b which required the assessment of the costs and benefits of regulations, a major coordinated interagency effort was undertaken to estimate the economic costs of GHG emissions. These estimates then were used across all agencies conducting CBA.^c Separate estimates were derived for carbon dioxide, methane and nitrous oxide, with the major focus on what is referred to as the social cost of carbon or SC-CO₂. Social cost estimates were made of the economic damage caused by CO₂ emission in a specific year over the long-term using a range of models and then reporting the costs in constant dollars for a specific year assuming different discount rates. For example, the central estimate as of 2016 of SC-CO₂ at a discount rate of 3% for 2020 emissions is US\$42 per metric ton in 2007 dollars.^d The SC-CO₂ estimates rise over time as future damages are expected to increase. Estimates for the social costs of methane (CH₄) and nitrous oxide (N₂O) were also made. For 2020, for the same cases as SC-CO₂, the SC-CH₄ is \$1,100 per metric ton and SC-N₂O is \$17,000 per metric ton.^e In parallel to the efforts to estimate the social costs of GHG emissions, the US Federal Government (as mandated by E.O. 13514 of 2009^f) worked with the GHG Protocol initiative to develop standards and guidelines for the accounting of GHG emission inventories by US public sector agencies.^g These standards are generally developed for use by government organizations at all levels of government.

^a. United States Government, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Circular A-94, Office of Management and Budget, Washington DC (1992)
http://www.whitehouse.gov/omb/circulars_a094/

^b. Executive Order 12866 of September 30, 1993, *Regulatory Planning and Review*, Federal Register, Vol. 58, No. 190, October 4, 1993, Presidential Documents

^c. EPA Fact Sheet, *Social Cost of Carbon*, December 2016.

^d. Interagency Working Group on Social Cost of Greenhouse Gases, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, United States Government, August 2016.

^e. Marten, Alex L. and Stephen C. Newbold, *Estimating the Social Cost of Non-CO₂ GHG Emissions: Methane and Nitrous Oxide*, Working Paper # 11-01, National Center for Environmental Economics, US EPA, January, 2011

^f. Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, October 5, 2009.

^g. GHG Protocol, *The Greenhouse Gas Protocol for the U.S. Public Sector: Interpreting the Corporate Standard for U.S. Public Sector Organizations*, WRI et al

2. United Kingdom

In the UK the Green Book provides guidance for the conduct of CBA of projects.^h It requires valuation of the GHG impacts of projects.ⁱ In addition to the Green Book, the government provides supplementary guidance and background documents on the valuation of GHG emissions.^j Projects in sectors that are covered by the EU ETS are required to use traded prices of CO₂e. This includes all power generation,

^h. HM Treasury, United Kingdom, *The Green Book: Central Government Guidance On Appraisal and Evaluation*, 2018

ⁱ. For the valuation of GHG emissions, see Green Book, sections 6.43/44 and Appendix A2.39-43.

^j. Department for Business, Energy and Industrial Strategy, United Kingdom, *Valuation of Energy Use and Greenhouse Gas: Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government*, April 2019; *Valuation of Energy Use and Greenhouse Gas: Background Documentation*, April 2019

Box 2.6 continued

many energy-intensive industries, and intra-EU aviation. The government publishes traded carbon values for use in project appraisals.^k For example, the central values provided for 2020, 2021 and 2022 are £13.84, £20.54 and £27.24 per tCO₂e in 2018 constant prices, respectively, and rising to £80.83 per tCO₂e in 2030. For projects in non-traded sectors, prices are provided in sets of data tables. For example, for the same years, 2020, 2021, 2022 and 2030, the prescribed carbon prices are £69, £70, £72 and £81 per tCO₂e.^l Note that the traded carbon prices converge with the non-traded prices from 2030 onwards. The non-traded carbon prices are estimates of the long-term damage caused by GHG emissions. The social prices of carbon are derived from studies in 2007 that estimated a central price of £25 per tCO₂e for emissions in 2007.^m

^k. Department for Business, Energy and Industrial Strategy, United Kingdom, *Updated Short-Term Traded Carbon Values: Used for UK Public Policy Appraisal*, April 2019

^l. Department for Business, Energy and Industrial Strategy, United Kingdom, *Data tables 1 to 19: supporting the toolkit and the guidance*. <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal>

^m. Department for Environment, Food and Rural Affairs, United Kingdom, *The Social Cost of Carbon and the Shadow Price of Carbon: What They Are, and How to Use Them in Economic Appraisal in the UK*, Dec 2007

3. Australia and New Zealand

Both Australia and New Zealand use carbon pricing on GHG emissions in transportation projects. As of 2016, Australia used a price of A\$34.75 per tCO₂e based on abatement costs and New Zealand used NZ\$40 per tCO₂e based on damage cost estimates.ⁿ

ⁿ. See Appendix 5: “Greenhouse gas emissions and the carbon price” in Dobes, Leo, Joanne Leung and George Argyro, *Social Cost-Benefit Analysis in Australia and New Zealand: the State of Current Practice and What Needs to be Done*, The Australia and New Zealand School of Government, ANU Press, 2016

4. OECD countries

Many, if not most OECD countries specify a price for carbon emissions, particularly for projects in the transportation sector (see for example, Australia and New Zealand above). All EU countries regulate their energy and some industrial sectors through the EU ETS and some also impose carbon taxes as discussed in Section 1.4 above. Typically, OECD country carbon prices are in the range of \$30 to \$80 per tCO₂e in 2020. In all cases, the price of carbon rises significantly over future years, and in some countries, such as Germany and Sweden, it already reaches €145 per tCO₂e by 2030 and continues to climb over future years.^{o,p}

^o. OECD, International Transport Forum, *Adapting Transport Policy to Climate Change: Carbon Valuation, Risk and Uncertainty*, OECD Publishing, Paris, 2015.

^p. Smith, Stephen and Nils Axel Braathen, *Monetary Carbon Values in Policy Appraisal: An Overview of Current Practice and Key Issues*, Environment Working Paper No. 92, OECD, 2015

effectively capture a large share of the global GHG externality.⁸¹ Green finance and bonds are discussed further in section 4.2 below.

⁸¹ Jayawardena, Migara S., M. Baher El-Hifnawi, Gangadhar P. Shukla and Yan Li, *Scaling-Up Renewable Geothermal Energy in Indonesia: An Integrated Approach to Evaluating a Green Finance Investment*, Knowledge Series 015/13, World Bank, May 2014

In addition to the World Bank⁸² and other regional multilateral development banks conducting CBA that recognizes the GHG emission reduction externalities, many national governments have also introduced the requirement to include a value on impact caused by a project on GHG emissions over the past decade. Box 2.6 presents the carbon prices specified by some selected countries for use in CBA of projects.

2.7. Institutional capacity to support climate-smart CBA and PIM

The quality of public financial management (PFM) systems and public investment management (PIM) systems have been the subject of extensive scrutiny and review by international aid agencies, international financial institutions and the countries themselves over recent decades as noted in section 2.1. The general conclusion is that developing countries are generally struggling to strengthen both their PFM and particularly their PIM systems. Strong PIM systems require major commitments of political and financial capital to design and implement. As noted above in *Tier 2* and *Tier 3*, making PIM system climate smart is an added major demand on the institutional capacity of a government. It requires gathering and managing the information on current and past natural hazards, forecasting the future occurrence of natural hazards or extreme climate events, tracking the nature and costs of natural disasters as they occur, developing a capacity to explain the vulnerability of different projects, sectors and regions in a country to different intensities of natural hazard, and then integrating this information into the planning, design, appraisal and approval of projects. It also has to have the capacity to estimate and value the net GHG emission impacts of public sector projects. Clearly, it is easier to add these features onto an existing well structured PIM and project appraisal system than onto weak existing capacities. Some countries that are less immediately or urgently threatened by growing natural hazard and disaster incidence have the luxury of possibly spending more initial effort in strengthening their basic PIM system, but clearly there are countries where growing natural disasters represent more of a looming existential threat through major and repeated tropical cyclones, riverine floods, rising sea levels and recurrent major droughts. In such cases, it becomes necessary to identify some crucial emergency steps that should be undertaken within their financial and human resource capacities. These steps could include:

1. Identification and focus risk analysis and adaptation efforts on key or essential infrastructure and utilities in specific regions or locations that are at high risk of disaster impacts.
2. Implement construction and land use regulations that limit access to low lying flood plains and target key adaptations that would significantly enhance the resilience of infrastructure and facilities.

⁸² World Bank, *Shadow price of carbon in economic analysis*, Guidance Note, Nov 12, 2017

The task of building the data bases and expertise on past and projected climate-related disasters, the vulnerabilities of projects, sectors and regions, and how to adapt infrastructure and facilities to become more resilient is important at national, regional and local levels. This collection of detailed data on existing and proposed infrastructure and facilities and their climate risk vulnerabilities represents a major and time consuming task that most developing countries will only accomplish over the long-term. Fortunately, in the immediate term, an array of organizations have gathered data on climate hazards and disasters by sector and country/region/locality that can provide a strong starting point for government agencies collecting climate data as well as those involved in developing government economic strategies and investment plans. These data sources are listed in Annex A6.3. Key amongst these is the World Bank *Climate Change Knowledge Portal*, which is effectively a user friendly means of sourcing this type of data and acts as a clearing house for the information collected by other specialized agencies. This type of climate risk data can then feed into the set of climate risk assessment tools for countries, sectors and projects that are listed in Annex A6.2. The World Bank also has the *Climate and Disaster Risk Screening Tools*. These tools provide a qualitative approach to risk screening at the national level to risk rate sectors and at the sector risk-rating level. The challenge is then to expand and deepen the assembling of climate, disaster and asset-specific risk data, including through the participation of professional sector experts and local officials. In addition, the officials involved in project appraisal should be trained in the techniques of integrated project appraisal, including risk analysis. Ultimately, this should lead to the capacity to estimate the loss functions for climate-related hazards of varying intensity for vulnerable projects that forms the core of appraising the net benefits gained from project adaptations as elaborated in Annex 7.

3. A Climate-Smart Toolkit for Planning and Finance Ministries

Building on the climate-smart PIM framework presented in Chapter 2, this section proposes practical guidance and tools for planning and finance ministries (or departments, as the country case may be) to mainstream climate screening and assessment in their public investment management to build the resilience of their infrastructure while contributing to climate-change adaptation. Ministries responsible for finance and planning are often integrated organizations, but in some countries are two separate ministries. In either case, collectively they are the key players in a government to give direction and coordinate the strategic and investment planning and the budget and financial operations of the government. Accordingly, ministries of finance and planning (MoF&P) are targeted here as key actors to ensure that they play key roles in insuring that a government at both central and subnational levels operates a climate-smart PIM system that enhances the performance and resilience of the infrastructure and facilities in the country. A list of twelve tasks is identified here that the MoF&P should be undertaking or ensuring that the task is decentralized or delegated to another ministry, department or agency (MDA.) All of these tasks are elaborated elsewhere in this report.

1. Integration of climate-change mitigation into sector strategies and plans

National GHG emission reduction goals are typically divided among the contributions that different sectors make to meeting the goal. Climate-change mitigation policies and programs (including regulatory programs, carbon pricing interventions, etc) as well as public investment choices (especially in energy, transportation, agriculture and forestry sectors) contribute to the sector plans meeting the emission reduction goals. This integration of the climate-change goals into the sector strategies and plans assists in the screening of projects entering project appraisal. While project appraisal itself can help select among alternatives that will contribute to the goals, well developed sector planning that makes use of the evaluation of prior projects, can result in more efficient new project screening and selection and more rapid appraisal of economically attractive projects that contribute to GHG emission reductions. Importantly, the plans and projects of SOEs (especially where SOEs are major players in the energy and transportation sectors) should be integrated or coordinated and reviewed by the central government agencies.

2. Estimation of net GHG emissions changes from policies, programs and projects

A key variable in the valuation of the benefits of climate-change mitigation is the time profile of the net changes in GHG emissions arising from new mitigation policies and programs and from project choices. This requires estimating the incremental emission impact of the new policy, program or project. The GHG Protocols, introduced in Section 1.4 above, include the methods for estimating the incremental emissions.⁸³ It is important

⁸³ GHG Protocol, *Mitigation Goal Standard: An accounting and reporting standard for national and subnational greenhouse gas reduction goals*, WRI et al; GHG Protocol, *Policy and Action Standard: An accounting and reporting standard for estimating the greenhouse gas effects of policies and actions*, WRI et al

that these estimation skills be introduced to officials responsible for sector plans and project design and appraisal.

3. Hazard data management.

Hazard monitoring and forecasting is a key starting point in climate-sensitive PIM. It requires a country to have adequate capacity nationally and in coordination with international agencies to collect, store, analyze and forecast natural hazard (extreme weather, earthquake, tsunami, etc) information. This may require enhancing the monitoring stations as well as institutional development of the national technical agencies responsible. Ultimately, the output of these agencies should feed into (i) the disaster early warning and management systems of the country, and (ii) the national and subnational sector planning agencies. Ideally, such agencies should receive exceedence probability distributions for different hazards by location, or at least for the major hazards for key infrastructure and facilities in locations that are vulnerable. While national capacity is being developed, a country can fall back on the available tools from international institutions such as the World Bank Climate and Disaster Risk Screening Tools,⁸⁴ and ThinkHazard!⁸⁵

4. Disaster early warning and management

A critical element of the resilience of a region or community to a natural hazard is the receipt of an early warning of an imminent disaster along with a plan on how to respond to the type of disaster. Typically, this should allow the movement of people, vehicles and other movable equipment away from the disaster area to minimize loss of lives and property. From an MoF&P perspective, this would require the allocation of funding to support the agencies responsible for managing the early warning systems and the disaster management.

5. Monitoring disaster damage and economic losses

Crucial data to the planning and assessment of adaptive investments to improve the resilience of an economy to natural hazards is the collection of the data on lives lost and otherwise affected, property damaged and the loss of economic services from damaged infrastructure or disrupted services. Some data is systematically collected across countries and years, for example, by the Centre for Research on the Epidemiology of Disasters (CRED) at the Universite Catholique de Louvain (UCL) in the Emergency Events Database (EM-DAT). To use this economic loss data in a more precise way to help plan adaptive investments for a government the data ideally needs to be more disaggregated so that it can be linked to infrastructure and facilities in a specific location threatened by specific natural hazards. Hence, monitoring the the damage and economic losses by location and sector should become part of he routine monitoring required by the MDAs.

⁸⁴ For details and use of tools go to <https://climatescreeningtools.worldbank.org/>

⁸⁵ Global Facility for Disaster Reduction and Recovery (GFDRR), ThinkHazard!, <http://thinkhazard.org/en/>

The MoF&P should provide guidance on the recording and reporting of damage and economic losses arising from natural disasters.⁸⁶

6. Economic loss function estimation

In order to estimate the potential avoided losses expected from investments designed to enhance the resilience of infrastructure or facilities to disasters arising from extreme natural hazards, the exceedance distributions estimated for a type of hazard in a specific region or location need to be combined with the damage and economic loss information to generate the expected economic loss functions for a project in a particular location. Such economic loss functions are the basic inputs into the design and appraisal of adaptive investments to enhance resilience.

7. Climate-sensitive land use and construction regulations

A general approach to incrementally raise the resilience of infrastructure and facilities and to reduce their GHG footprint and to enhance or protect the climate-change mitigation properties of land areas is to introduce climate-sensitive land use and construction regulation. MoF&P should require the appropriate MDAs to review and recommend changes to regulations to enhance the resilience of structures to expected extreme hazards and to support green buildings and facilities. Due consideration should be taken as to the effectiveness and affordability of any new regulations. Where regulations are changed, ex post evaluations should be conducted or arranged by MoF&P at least every 10 years and certainly after natural disasters have occurred to assess the effectiveness and economic benefits arising from the changed regulations.

8. Public Investment Management guidelines

A basic prerequisite to making a PIM system climate sensitive is to ensure that the existing PIM system is clearly defined and operational. This typically means that a PIM manual or guidelines exist that are backed up by legislation and regulations concerning public financial and investment management. The guidelines should cover all the core functions of PIM. Importantly they should specify the appraisal methodologies required and the channelling of projects by size and complexity as to the required screening, appraisal and technical review levels required. MoF&P should review and update, and if necessary, introduce a PIM manual to form the basis of introducing the climate-sensitive features into the PIM system.

⁸⁶ For example, Box 2.2. Canada: All Hazards Risk Assessment (AHRA) in OECD, *Disaster Risk Financing: A global survey of practices and challenges*, Paris 2015 gives a comprehensive framework for measuring the full direct and indirect damages and economic losses.

9. Screening projects for natural hazard vulnerability and climate-change mitigation contributions

MoF&P should ensure that project screening includes checks on compliance with environmental (including climate-related impacts from changes in GHG emissions) and climate-sensitive land use and construction regulations. In addition, where large projects or infrastructure and network systems are vulnerable to natural disasters, the project should then be required to undergo design and appraisals for potential gains from adaptive investments.

10. Climate-sensitive project designs and appraisal for vulnerable projects

For large projects or infrastructure and network systems that are vulnerable to natural disasters, MoF&P should build the capacity to conduct full integrated appraisals including the use of adaptive real options using the available economic loss function information for the natural disasters to which it is vulnerable.

11. Climate-sensitive budget allocation policies

MoF&P should develop budget allocation policies to fund (i) risk reserves and/or hazard insurance premiums, (ii) added capital costs of cost-effective resilience features, (iii) positive externalities from reductions in GHG emissions and (iv) adequate operating and maintenance funds for climate sensitive projects.

12. Monitoring and evaluating project performance, particularly for climate-related impacts and valuation of disasters

A routine function of MoF&P is to ensure that the operation of all projects and programs are subject to monitoring of their financial and service delivery performance and also subjected to various levels of evaluation. In the context of a climate-sensitive PIM system, MoF&P needs to ensure that (i) the climate impacts of any changes in greenhouse gas emissions and (ii) the measurement and reporting of any actual natural disaster damages and economic losses are conducted.

4. Financing and budgeting for climate-impacted investment management

4.1 Insuring against natural disasters

The OECD (2015)⁸⁷ provides an overview of the disaster risk assessment and financing practices of 29 OECD and APEC countries. Generally, given the inadequacies of the private insurance markets handling the systematic risks associated with extreme weather-related and other natural disasters, governments establish contingent risk reserve funds to use in disaster recoveries and/or establish direct insurance agencies or indirect reinsurance agencies to complement or gap-fill the private insurance markets.⁸⁸ In addition, to these financial approaches, a country can self-insure through investments in real adaptations to infrastructure and facilities and in disaster management practices to improve the resilience of the economy and lower the expected costs of extreme hazards. For small and lower income countries, however, the ability to self-insure against extreme weather-related and other natural disasters, which can have significant costs (say, in excess of 5% of GDP), is restricted and becomes more so if a country suffers repeated disasters over the medium term. Countries need to seek wider risk pools to make disaster insurance more feasible. One approach is to establish regional disaster risk pools that can more than halve the cost of disaster risk insurance. These pooled insurance facilities also access the international reinsurance company pools to spread risks even more widely. Three regional disaster risk insurance facilities have arisen since 2007.

1. Caribbean Catastrophe Risk Insurance Facility (CCRIF) SPC^{89,90}

The CCRIF SPC was established in 2007 to provide parametric insurance for hurricanes and earthquakes to Caribbean governments. CCRIF SPC offers Earthquake (EQ), Tropical Cyclone (TC) and Excess Rainfall (XSR) policies to its current 19 member Caribbean governments and EQ and TC policies to Central American governments (one member country, Nicaragua) and will be offering Loan Portfolio Cover (LPC) policies to financial institutions in Caribbean countries. Member countries can purchase coverage up to a limit of approximately US\$100 million for each insured hazard. As of 2017-18, 15 member countries have received 38 payouts totaling \$139million.

⁸⁷ OECD, *Disaster Risk Financing: A global survey of practices and challenges*, Paris 2015

⁸⁸ See Tables 3.3 and 3.4 in OECD, *Disaster Risk Financing: A global survey of practices and challenges*, Paris 2015

⁸⁹ Caribbean Catastrophe Risk Insurance Facility (CCRIF) SPC, *Understanding CCRIF: A Collection of Questions and Answers*, Cayman Islands, Revised February 2016

⁹⁰ Caribbean Catastrophe Risk Insurance Facility (CCRIF) SPC, *Annual Report 2017-18*

2, Pacific Catastrophe Risk Insurance Company (PCRIC)

PCRIC is a Pacific-owned insurance company⁹¹ that provides earthquake and cyclone coverage to its member countries (Cook Islands, Republic of the Marshall Islands, Samoa, Tonga, and Vanuatu.)⁹² The World Bank is now supporting PCRIC to provide more complete coverage to rural areas, and is exploring the feasibility of an insurance product for volcanic risk. In its sixth season, 2017-18, the PCRIC has secured protection of \$45 million for its member countries.

The World Bank also established the **Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)** to catalyze actionable risk information efforts in the region. PCRAFI provides 15 Pacific countries with disaster risk modeling and assessment tools to help them better understand, model, and assess their exposure to natural disasters. This regional initiative has enabled market-based financial solutions and better disaster- and climate-risk planning

3. African Risk Capacity Insurance Company Limited (ARC Ltd)

ARC Ltd based in Bermuda carries out commercial insurance functions of risk pooling and risk transfer in accordance with national regulations for parametric weather insurance against severe drought events in its 33 African member countries. ARC Ltd currently offers a maximum coverage of US \$30 million per country per season for drought events.

ARC Ltd is an affiliate of the African Risk Capacity (ARC),⁹³ which is composed of ARC Agency (a Specialized Agency of the African Union) and ARC Ltd. The ARC Agency coordinates the overall program and provides capacity building to member countries including the operations of the disaster risk insurance program, early warnings of droughts and the development of a contingency plan required for participation in the insurance program.

All three disaster risk insurance programs are based on parametric insurance. A parametric insurance product can be defined as an insurance contract where the ultimate payment or contract settlement is determined by a weather or geological observation or index, such as average temperature or rainfall over a given period or the intensity of an earthquake or windstorm. Parametric insurance payouts are not based on individual loss adjustments, but are determined according to the measurement of a highly correlated index.⁹⁴ For example, ARC uses entity uses *Africa RiskView*, an advanced satellite weather surveillance and software (developed by the UN World Food Programme (WFP)) to estimate and trigger readily available funds to African countries hit by severe weather events. This approach

⁹¹ The PCRIC is a captive insurance company that is owned by the PCRAFI Foundation, both were established by legal statute in the Cook Islands in 2016 with the Foundation being governed by a Council of Members that own the captive Insurer PCRIC.

⁹² <https://www.reinsurancene.ws/pacific-catastrophe-risk-insurance-company-increases-reinsurance-19/>

⁹³ <https://www.africanriskcapacity.org/about/>

⁹⁴ See, for example, Box 3.3 in OECD, *Disaster Risk Financing: A global survey of practices and challenges*, Paris 2015

allows rapid disbursement of funds within 2 to 4 weeks of the severe weather event being measured so that the country can initiate recovery and social protection programs rapidly before a complete assessment of the damage and affected persons has been made.

While the establishment of the regional disaster risk insurance facilities is an important enhancement to the disaster risk management, it is clear that there is still scope for increasing the size and scope of these facilities. The coverage of disaster insurance needs to be raised closer to the rising level of damage per disaster occurrence as shown in Table 2 now exceeding a billion dollars on average. This will likely require broader multinational risk pooling than currently available in the regional facilities. There are initiatives moving in this direction.

The World Bank established the **Disaster Risk Financing and Insurance Program (DRFIP)**⁹⁵ in 2010 to improve the financial resilience of governments, businesses, and households against natural disasters. The initiative supports governments to implement comprehensive financial protection strategies, and brings together sovereign disaster risk financing, agricultural insurance, property catastrophe risk insurance and scalable social protection programs. Often, it also helps governments work with the private sector to facilitate public-private partnerships.

In addition, the World Bank with the support of the UK and German governments is setting up a new \$145 million **Global Risk Financing Facility (GRiF)**⁹⁶ to pilot and scale up support to strengthen the resilience of vulnerable countries to climate and disaster shocks. The GRiF will be supported by and build on the work of existing programs, including the InsuResilience Climate Risk Financing and Insurance Program MDTF jointly established by BMZ, DFID and the World Bank, the Centre for Global Disaster Protection which was jointly established by DFID, and the World Bank, and InsuResilience Solutions Fund (jointly established by BMZ and KFW.) These programs currently form the Program Alliance of the **InsuResilience Global Partnership**.

The development objective of the GRiF is to strengthen financial resilience of vulnerable countries by enabling earlier and more reliable response and recovery to climate and disaster shocks, and over time to a wider range of crises, through establishing or scaling up pre-arranged risk financing instruments, including market-based instruments like insurance. It will focus on helping poor and vulnerable people, and the economy, services and infrastructure they depend on, to recover more quickly when a disaster strikes. GRiF will be partnering with the regional insurance facilities discussed above.

⁹⁵ <http://www.worldbank.org/en/programs/disaster-risk-financing-and-insurance-program>

⁹⁶ <https://www.worldbank.org/en/topic/disasterriskmanagement/brief/global-risk-financing-facility>

4.2 Climate finance and green bonds

Climate impacts are global in nature and reach. Taking measures in one country to mitigate climate-change impacts yields global external benefits that do not all accrue to the country. For developing countries, in particular, this poses a challenge for governments to spend scarce resources where the country is not the direct main beneficiary of the global externality. As noted in Section 2.6 above, external funds, therefore, can play a key role in facilitating countries to undertake climate-change mitigation programs and projects. Climate finance and green bonds are two such sources of external funds.

Climate Finance⁹⁷

Climate finance refers to the financing arranged by Multilateral Development Banks (MDBs, viz. the World Bank and regional development banks) to support projects and programs to for climate-change mitigation and adaption and related activities. Climate finance by MDBs rose from \$27 billion in 2011 to \$43.1 billion in 2018. The majority of these funds (about three quarters) were targeted at mitigation and public sector projects. In 2018, some 71% of the funds were provided as loan finance, while the remainder included policy-based and results-based finance, guarantees, grants and other instruments. The MDB-provided climate finance also managed in 2018 to leverage some \$68 billion in co-finance. This co-finance came from a range of sources: some 60% from the public sector either directly from the public sector in the country or from other development banks and institutions, etc., and the remainder came directly or indirectly from the private sector.

Green bonds^{98, 99}

Green bonds are issued by financial and non-financial corporations, central and local governments, government-backed entities and development banks to finance green-oriented projects, largely climate-change mitigation and adaptation projects. Green bonds are growing rapidly. In 2019, US\$257.7 billion in green bonds were issued, up 51% from 2018, by 496 issuers in 51 jurisdictions. Bonds were used for projects in energy (31%), buildings (30%), transport (20%), and water (9%) followed by waste, land use, industry and ICT. There is a voluntary review and certification process to ensure that green bonds comply with Green Bond Principles.

⁹⁷ Multilateral Development Banks, *2018 Joint Report on Multilateral Development Banks' CLIMATE FINANCE*, June 2019

⁹⁸ Climate Bonds Initiative (CBI), *Green Bonds: The State of the Market 2018; Climate Bonds Taxonomy*, October 2019; and *2019 Green Bond Market Summary*, Feb 2020

⁹⁹ International Capital Market Association (ICMA), *Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds*, June 2018; *Green Project Mapping*, June 2019

4.3 Budget issues and trade-offs raised by climate change

For smaller and lower income countries that are vulnerable to natural disasters, the overwhelming challenge is that a significant disaster is a fiscal destabilizing event. Such countries have limited capacity to set aside disaster risk reserves, and typically have to fall back on international donor emergency assistance for short-term social protection and medium-term recovery of infrastructure, facilities and service delivery. As discussed above, more **cost-effective disaster risk insurance** has the potential to play a larger role to allow countries to self-insure against a larger share of disaster recovery costs. Donor countries and multilateral institutions should play a growing role in assisting the expansion and broadening the types of disaster risk insurance.

In the medium term, with the growth in the number and size of natural disasters, country budget allocations face the challenging trade-off between funding disaster recovery and increasing allocations to investment in more resilient infrastructure and facilities and disaster management. It is clear that both in recovery or replacement investments and in development investments, the government needs to ensure that all such new investments consider the all **resilience enhancing investment designs**. The key consideration is ensuring that all such real options considered should be expected to increase the net benefits that eventually flow from the project. This is crucial to underpin larger current investment allocations to gain future lower costs. The appropriate project design and appraisal capacity needs to be in place to screen and appraise the projects that are being put forward. If these cost-benefit criteria are adhered to, then added allocations to new and replacement investments with positive net benefits are not a trade-off with current expenditures.

International donor countries and institutions face a similar dilemma of whether to increase foreign aid allocations to emergency relief or to investments that enhance country resilience to future natural disasters. An answer is to grow the allocations to resilience investment and disaster insurance strengthening faster than to emergency relief. Again, the key issue is establishing PIM systems in countries that can support the design and appraisal of new projects with enhanced preventative and resilience features to ensure that projects with positive net benefits are being designed and selected. This should include an initial identification of key assets in transportation and utility systems that need protective or adaptive investments rather than a system-wide approach that can be added over the medium term. Added resilience and lower cost recoveries not only need “hardened” or more weather-resilient infrastructure, but also importantly involve relatively low cost investments with possibly quicker pay-back times in **disaster management** such as

1. early warning systems and procedures by radio, TV, web-based communication with smart phones, etc.;
2. disaster management planning, training and programs for the public sector;
3. public education programs in disaster mitigation (such as improved construction features of housing) and how to respond to early warnings; and

4. additional ground-based weather stations, if needed, to improve weather monitoring and forecasting.

While strategic capital investments can improve the resilience of the country to disasters going forward, ensuring **adequate operating and maintenance (O&M) funding** in the current budget is crucial to underpinning current public service delivery from existing infrastructure and facilities, it also ensures the resilience of such assets to weather-related disasters. For example, the proper maintenance of road surfaces, drainage systems, retaining walls, dam walls, bridge supports, etc all improve the survival chances of infrastructure and facilities to flood waters. Aside from ensuring the adequate O&M funding of at least the key vulnerable infrastructure and facilities, O&M funding is also a key criteria in all new public investments. To sustain expanded public assets in the future requires growth in general revenues to cover the O&M requirements of the different additional assets. Without growing real revenues, a government faces a severe constraint in its ability to expand the assets it can operate and maintain going forward. Governments need to review the adequacy of their O&M funding of their existing assets, with a particular focus on weather-event vulnerable assets, and also recognize the constraints that real revenue growth places on the incremental investments the government can sustain going forward.¹⁰⁰

¹⁰⁰ Graham Glenday, *Capital versus Current Final Expenditures in Ethiopia: What is the economically efficient and financially sustainable mix?* World Bank, Ethiopia Public Expenditure Review: Background Paper, Oct 2014,

Annex 1. Basic concepts and definitions relating to greenhouse gases

This annex provides definitions for some key variables and concepts that are core to the consideration of climate-change mitigation. Given the intensive technical work conducted under the United Nations Intergovernmental Panel on Climate Change (IPCC), the IPCC reports carry extensive glossaries giving the definitions of key variables and concepts.¹⁰¹ Another useful set of glossaries of climate-change terminology are provided in the series of reports by the Greenhouse Gas Protocol Initiative.¹⁰² Only a short list of some key technical terms underlying climate-change mitigation are provided here:

Greenhouse Gas (GHG)

In the context of climate change induced by the GHG emissions, under the Kyoto Protocol the focus is on six gases: carbon dioxide (CO₂); methane (CH₄); nitrous oxide (N₂O); and three fluoro carbons: hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF₆). Carbon dioxide and methane emissions are the GHGs that dominate the emission reduction efforts. There are other greenhouse gases in the atmosphere including water vapor and ozone.¹⁰³ Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect.

Greenhouse effect

The infrared radiative effect of all infrared absorbing constituents in the atmosphere. Greenhouse gases (GHGs), clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of GHGs increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a GHG concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing. Surface temperature and troposphere warm in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere

Radiative forcing

Radiative forcing is the change in the net, downward minus upward, radiative flux (expressed in W/m²) at the tropopause or top of atmosphere due to a change in an external driver of climate change, such as, for example, a change in the concentration of carbon dioxide (CO₂) or the output of the sun. For the purposes of the IPCC report, radiative forcing is further defined as the change relative to the year 1750 and refers to a global and annual average value.

¹⁰¹ See for example Annex 1 of IPCC, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment*. This Annex contains a 24-page glossary of key terms used in the climate-change assessment reports.

¹⁰² See for example The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard (Revised Edition), World Resources Institute (WRI) et al, which provides a 9-page glossary of terminology.

¹⁰³ For a list of well-mixed GHGs, see IPCC Working Group I (WGI) AR5 Table 2.A.1.

CO₂-equivalent (CO₂e) emission

The universal unit of measurement of GHG emissions to indicate the global warming potential (GWP) of each of the six greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common basis.

Emission credits, allowances, certificated emission reductions, etc in carbon markets and GHG emission reduction programs are all measured in **metric tonne of CO₂e**. Expressed more technically, CO₂e emission is the amount of carbon dioxide (CO₂) emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. The CO₂-equivalent emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon.¹⁰⁴ For a mix of GHGs it is obtained by summing the CO₂-e emissions of each gas. CO₂-e emission is a common scale for comparing emissions of different GHGs, but does not imply equivalence of the corresponding climate-change responses.

Global Warming Potential (GWP)

GWP is a factor describing the radiative forcing impact (degree of harm to the atmosphere) of 1 unit of a given GHG relative to 1 unit of CO₂. More technically, it is an index, based on radiative properties of greenhouse gases (GHGs), measuring the radiative forcing following a pulse emission of a unit mass of a given GHG in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide (CO₂). The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in causing radiative forcing. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame or GWP₁₀₀. Unless stated otherwise, this report uses GWP values calculated with a 100-year time horizon, which are often derived from the IPCC Second Assessment Report (see Annex II.9.1 for the GWP values of the different GHGs).

¹⁰⁴ See IPCC WGIII AR5 Annex II.9.1 and WGI AR5 Table 8.A.1 for GWP values of the different GHGs.

Annex 2. Overview of climate-change impacts across regions

Overview of some of the climate-change impacts (excluding storm and flood related impacts) across regions identified in the World Bank report *Turn Down the Heat (2014)*.¹⁰⁵

1. Unusual and unprecedented heat extremes: These are expected to occur far more frequently and cover much greater land areas, both globally and in the three regions (Latin America and the Caribbean, North Africa and the Middle East, and Europe and Central Asia) examined. For example, heat extremes in South East Asia are projected to increase substantially in the near term and would have significant and adverse effects on humans and ecosystems under 2°C and 4°C warming.

2. Rainfall regime changes and water availability: Even without any climate change, population growth alone is expected to put pressure on water resources in many regions in the future. With projected climate change, however, pressure on water resources is expected to increase significantly.

i. Declines of 20 percent in water availability are projected for many regions under a 2°C warming and of 50 percent for some regions under 4°C warming. Limiting warming to 2°C would reduce the global population exposed to declining water availability to 20 percent.

ii. South Asian populations are likely to be increasingly vulnerable to the greater variability of precipitation changes, in addition to the disturbances in the monsoon system and rising peak temperatures that could put water and food resources at severe risk.

3. Agricultural yields and nutritional quality: Crop production systems will be under increasing pressure to meet growing global demand in the future. Significant crop yield impacts are already being felt at 0.8°C warming.

i. While projections vary and are uncertain, clear risks emerge as yield reducing temperature thresholds for important crops have been observed, and crop yield improvements appear to have been offset or limited by observed warming (0.8°C) in many regions. There is also some empirical evidence that higher atmospheric levels of carbon dioxide (CO₂) could result in lower protein levels of some grain crops.

ii. For the regions studied in this report, global warming above 1.5°C to 2°C increases the risk of reduced crop yields and production losses in Sub-Saharan Africa, South East Asia and South Asia. These impacts would have strong repercussions on food security and are likely to negatively influence economic growth and poverty reduction in the impacted regions.

4. Terrestrial ecosystems: Increased warming could bring about ecosystem shifts, fundamentally altering species compositions and even leading to the extinction of some species.

¹⁰⁵ World Bank. 2014. *Turn Down the Heat: Confronting the New Climate Normal*. Washington, DC: World Bank. License: Creative Commons Attribution—NonCommercial—NoDerivatives 3.0 IGO (CC BY-NC-ND 3.0 IGO).

- i. By the 2030s (with 1.2–1.3°C warming), some ecosystems in Africa, for example, are projected to experience maximum extreme temperatures well beyond their present range, with all African eco-regions exceeding this range by 2070 (2.1–2.7°C warming).
- ii. The distribution of species within savanna ecosystems are projected to shift from grasses to woody plants, as CO₂ fertilization favors the latter, although high temperatures and precipitation deficits might counter this effect. This shift will reduce available forage for livestock and stress pastoral systems and livelihoods.

5. Sea-level rise: Has been occurring more rapidly than previously projected and a rise of as much as 50 cm by the 2050s may be unavoidable as a result of past emissions: limiting warming to 2°C may limit global sea-level rise to about 70 cm by 2100.

- i. As much as 100 cm sea-level rise may occur if emission increases continue and raise the global average temperature to 4°C by 2100 and higher levels thereafter. While the unexpectedly rapid rise over recent decades can now be explained by the accelerated loss of ice from the Greenland and Antarctic ice sheets, significant uncertainty remains as to the rate and scale of future sea-level rise.
- ii. The sea-level nearer to the equator is projected to be higher than the global mean of 100 cm at the end of the century. In South East Asia for example, sea-level rise is projected to be 10–15 percent higher than the global mean. Coupled with storm surges and tropical cyclones, this increase is projected to have devastating impacts on coastal systems.

6. Marine ecosystems: Substantial losses of coral reefs are projected by the time warming reaches 1.5–2°C from both heat and ocean.

Annex 3: A brief summary of public investment management functions

Project preparation functions

- 1. Project identification, guidance and screening.** The projects identified should be consistent with the strategic sector priorities and plans of a government as well as with the expected resource envelope of the sector and overall government. Sector priorities should be consistent with the identification of supply gaps in sector services and the results of ex ante project appraisals and ex post evaluations. Project documents should be screened for alignment with sector priorities before detailed design and appraisal is undertaken.
- 2. Formal project appraisal.** The formal conduct of cost-benefit or cost-effectiveness analysis of a project or program produces feasibility studies as the basis for project approval, budget selection and implementation. For new, large and PPP projects both prefeasibility and feasibility studies including financial, economic, risk and distributional analysis would be conducted. The level of effort in the conduct of the appraisal would be proportional to the size, complexity and risks involved in a project. Appraised projects go through one or more approval steps and selection criteria depending on the type and size of project.
- 3. Independent review.** An independent technical peer review process is used to assure the appropriateness of appraisal assumptions and methods and to avoid biases in estimates.
- 4. Project selection and budgeting:** Central ministries and government executive select projects from the pipeline of approved projects in line with sector priorities and consistent with available general revenues, loan financing and project grants for capital expenditures and in line with expectations of future recurrent revenues available to sustain added operating and maintenance expenses. Selected projects need to be subjected to legislative scrutiny in the process of authorization of the projects and appropriation of the funds.

Project implementation functions

- 5. Project implementation.** This involves the procurement of design, building and operating services to implement the project as well as the management of the implementation process including the control of expenditure commitments, the release of funds and the monitoring of implementation against cost and timing milestones that arise from the project design and implementation plan. Upon completion, the project needs to be tested, reviewed, and handed over to operators. Newly created assets registered.
- 6. Adjustment.** During the pre-completion period formal arrangements are required to make technical and/or financial adjustments to a project based on significant changes in the timing or economic environment affecting the project. Where the required project adjustments are large, the revised project may need re-evaluation, approval and budgeting.

7. **Service delivery.** Once the project is operational, it delivers services supported by recurrent funding and subject to performance monitoring. Project service delivery can be subjected to impact analysis relative the expected base line of services otherwise provided.
8. **Ex post program or project evaluation.** An independent external reviewer evaluates the project while still operating or as part of a decision to continue, terminate or restructure the project. Annual external audits would be conducted of financial operations and possibly also service delivery performance and presented to the legislature for scrutiny.

Annex 4: Overview of content of PEFA diagnostic tool

The 2016 revised Public Expenditure and Financial Accountability (PEFA) diagnostic framework has 7 pillars with 31 indicators and 94 dimensions plus an institutional review. The seven pillars are:

- 1. Budget reliability (3 indicators; 6 dimensions).** The government budget is realistic and is implemented as intended. This is measured by comparing actual revenues and expenditures (the immediate results of the PFM system) with the original approved budget.
- 2. Transparency of public finances (6, 12).** Information on PFM is comprehensive, consistent, and accessible to users. This is achieved through comprehensive budget classification, transparency of all government revenue and expenditure including intergovernmental transfers, published information on service delivery performance and ready access to fiscal and budget documentation.
- 3. Management of assets and liabilities (4; 13).** Effective management of assets and liabilities ensures that public investments provide value for money, assets are recorded and managed, fiscal risks are identified, and debts and guarantees are prudently planned, approved, and monitored.
- 4. Policy-based fiscal strategy and budgeting (5; 16).** The fiscal strategy and the budget are prepared with due regard to government fiscal policies, strategic plans, and adequate macroeconomic and fiscal projections.
- 5. Predictability and control in budget execution (8; 29).** The budget is implemented within a system of effective standards, processes, and internal controls, ensuring that resources are obtained and used as intended.
- 6. Accounting and reporting (3; 10).** Accurate and reliable records are maintained, and information is produced and disseminated at appropriate times to meet decision-making, management, and reporting needs.
- 7. External scrutiny and audit (2; 8).** Public finances are independently reviewed and there is external follow-up on the implementation of recommendations for improvement by the executive.

Annex 5: PEFA-style PIMI

Indicators and dimensions

Table A.5.1 gives PIM indicators and number of dimensions for the PEFA-style PIMI. The detail of the dimension and scoring are elaborated in the report on the development of the PEFA style PIM.¹⁰⁶

PIM core functions		PIM indicator #	PIM indicator description	Type ^a	Number of dimensions for indicator		
#	Function						
1	Guidance and screening	1	Sector analysis and planning	S	3		
		2	Strategic plans and investment guidance, project development and preliminary screening	S	3		
2	Formal Appraisal	3	Formal project appraisal procedures and guidelines ^b	S	5		
		4	Project appraisal capacity	S	3		
		5	Screening and selection of feasibility studies	P	3		
3	Appraisal Review	6	Independent review of appraisal	S	2		
4	Selection and Budgeting	A. Budget Preparation and Selection					
		7	Project selection and budgeting	S	4		
		8	Multi-year budgeting	S	2		
		9	Comprehensiveness of capital budget ^b	S	2		
		10	Comprehensiveness and degree of public and parliamentary access to capital budget information	S	4		
		B. Budget Outturn Performance					
		11	Development and capital budget execution rates: Aggregate expenditure outturn compared to original budget on a commitment basis	P	2		
		12	Composition of development and capital expenditure out-turn compared to adjusted original budget on a commitment basis	P	1		
		13	Project completion time and cost variances of completed projects	P	1		
		14	Stock and monitoring of capital expenditure arrears	P	2		
		5	Implementation	15	Procurement ^b	S	5
				16	Project implementation management	S	3
				17	Control, monitoring and reporting: physical and financial milestones ^b	S	4
				18	Project handover, asset registration and completion review ^b	S	5
6	Adjustment	19	Project adjustment	S	4		
7	Service delivery	20	Control, monitoring and reporting: financial and service delivery performance ^b	S	6		
		21	Service delivery	P	2		
8	Evaluation	22	Scope, nature and follow-up of external audit and ex post evaluation	S	4		
		23	Legislative scrutiny of external audit reports	S	3		
a. Type of indicator: S: structures or functions, on qualitative or quantitative basis; P: performance, on quantitative basis							
b. Indicators include dimensions of co-ordination with donor partner procedures							

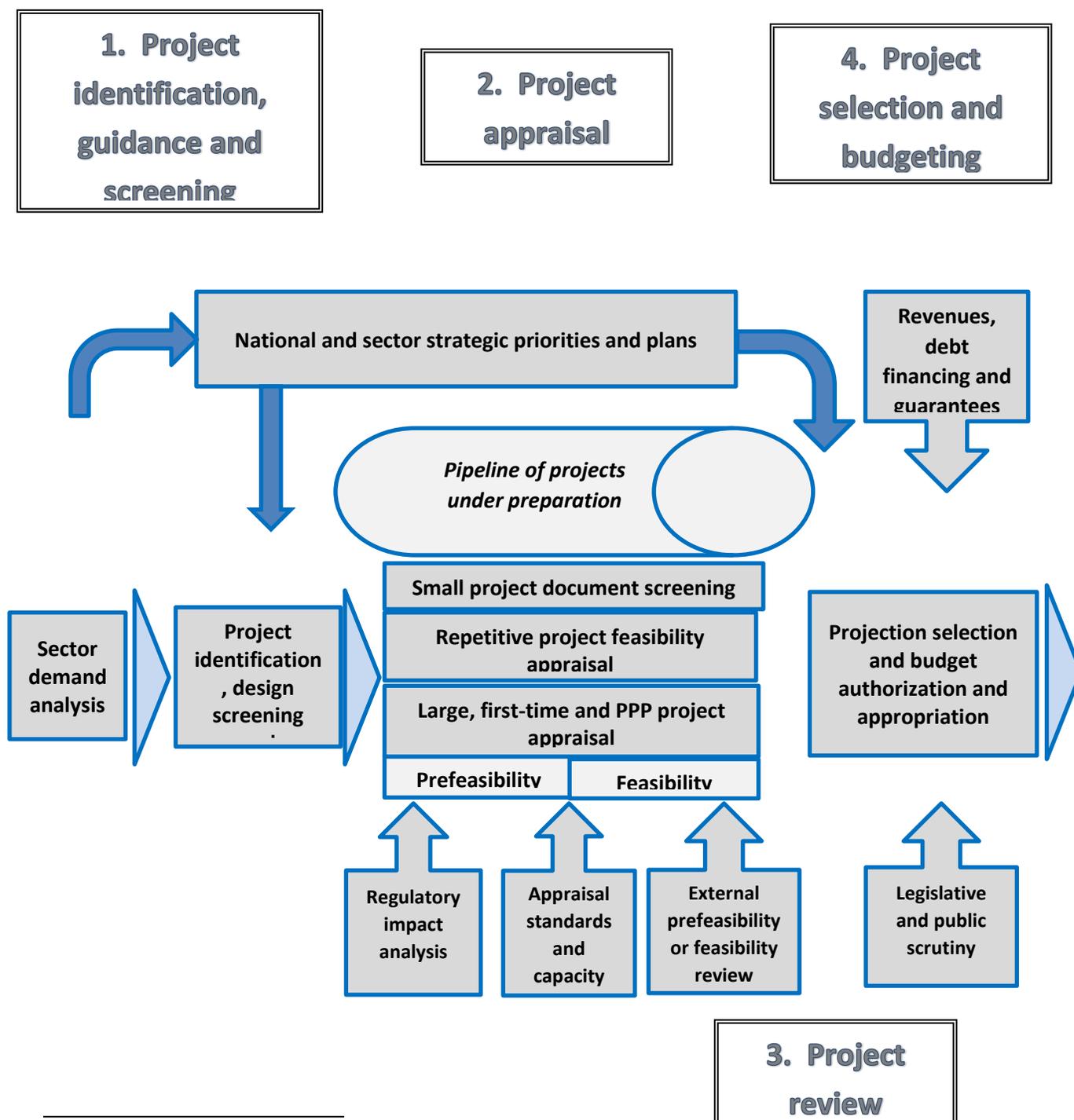
Project cycles and interactions with PIM functions

Figures A.5.1 and A.5.2 give the project cycles for the pipelines of projects under preparation

¹⁰⁶ Graham Glenday and G.P. Shukla, "Proposals to strengthen the PIM component of the PEFA framework and indicators," Report prepared for Public Sector & Governance, PREM, World Bank, October 2014

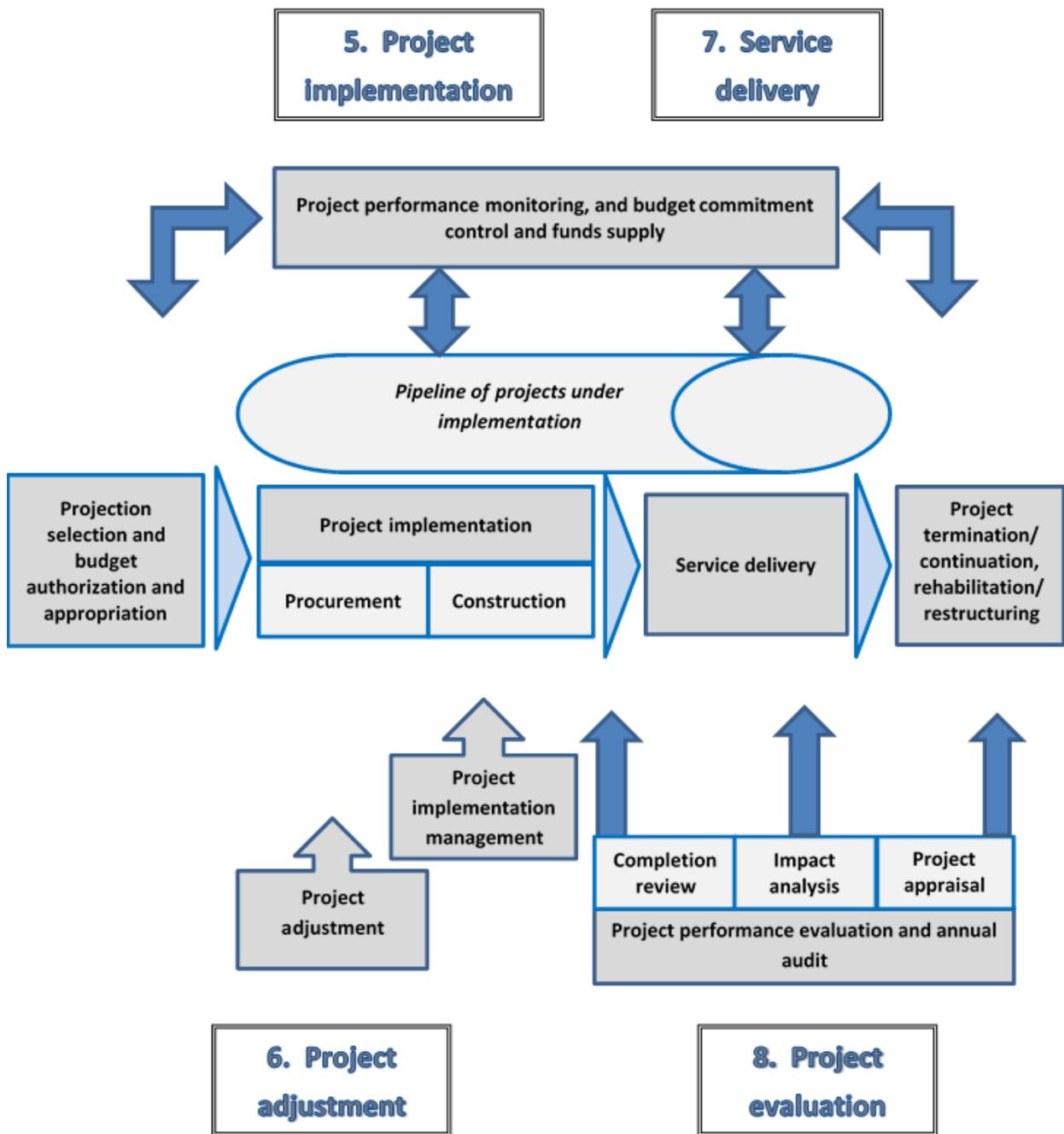
and under implementation, respectively. They also show how these pipelines interact with the PIM functions grouped into the eight essential PIM functions.¹⁰⁷

Figure A.5.1. Project Cycle: Project Preparation Functions



¹⁰⁷ Graham Glenday, "Public Investment Management (PIM) Reform Indicators," Report prepared for Public Sector & Governance, PREM, World Bank, April 2015

Figure A.5.2. Project Cycle: Project Implementation Functions



Annex 6. Climate Risk Screening Tools

Contents

- A6.1. Overview of Climate Risk Screening Tools**
- A6.2. World Bank’s Climate Risk Screening Tools**
- A6.3. Supporting Country Profiles and Risk Data**
- A6.4. National Risk Screening Examples**
- A6.5. Project Risk Screening Examples**

A6.1. Overview of Climate Risk Screening Tools

In the light of changing climatic conditions, institutions across the globe are assessing climate-change risks to enhance the resilience of their projects and programs. The table below identifies climate risk screening tools from different institutions.

Tool Name	Developer
Climate and Disaster Risk Screening Tools and Methods	WBG - more information under A5.2
Climate Finance Impact Tool	JICA
Caribbean Climate Online Risk and Adaptation Tool (CCORAL)	DFID, CDKN
Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL)	IUCN, IISD, Helvetas, SEI
Climate Impacts Programme Business Areas Climate Assessment Tool (BACLIAT)	UK
Climate Project Screening Tool	US Department of Agriculture
Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment	National Wildlife Federation
Climate Risk Management in ADB Projects	ADB
Addressing Climate Risk Management in IDB Operations	IDB
A Framework for Understanding and Addressing Climate Change	USAID
National Adaptive Capacity Framework	WRI

A6.2. World Bank’s Climate Risk Screening Tools

The World Bank has developed a wide range of methods and tools to conduct risk assessments for its investment projects and to assess vulnerability at spatial and sectoral levels. The table below identifies World Bank Group climate risk screening tools with short descriptions.

Tool Name	Description
WB Climate and Disaster Risk Screening Tools	Risk screening tools to help inform dialogue, consultation, and planning processes at the project, program and national level. The tools apply an Exposure–Impact–Adaptive-capacity framework to assess risks.
IFC’s Climate Risk Management Tools	Suite of sector-specific tools to assess impacts and risks to an investment, allowing to adjust project indicators to increase its climate resilience.
Decision Making Under Deep Uncertainty (DMDU) Methodologies	Summary of climate-related uncertainties and methods to deal with such uncertainty (e.g. cost-benefit analysis).
Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects	Useful resources for integrating climate risk management and adaptation to climate change in development projects, with a focus on the agriculture and natural resources management sectors.
Energy Sector Management Assistance Program (ESMAP) Hands-On Energy Adaptation Toolkit	An assessment of climate vulnerabilities and adaptation options in a country’s energy sector and raise awareness among key stakeholders.
Assessment Tool for Energy & Climate Adaptation (ATECA)	Assess climate-change vulnerability, risk and adaptation of the energy system at the country-level.
Climate Change & Health Diagnostic	This Diagnostic presents methods, case studies, and an online portal to identify priority actions and investments for climate action.
Moving Toward Climate-Resilient Transport: The World Bank’s Experience from Building Adaptation into Programs	It gives examples of potential impacts of climate change on transport systems, outlines a framework for integrating resilience in transport systems including case study examples.
WB Urban Risk Assessment	A flexible approach that project and city managers can use to identify feasible measures to assess a city’s risk.
Confronting Climate Uncertainty in Water Resources Planning and Project Design (Book)	Risk assessment of water resources projects that can serve as a decision support tool to assist project planning under uncertainty.

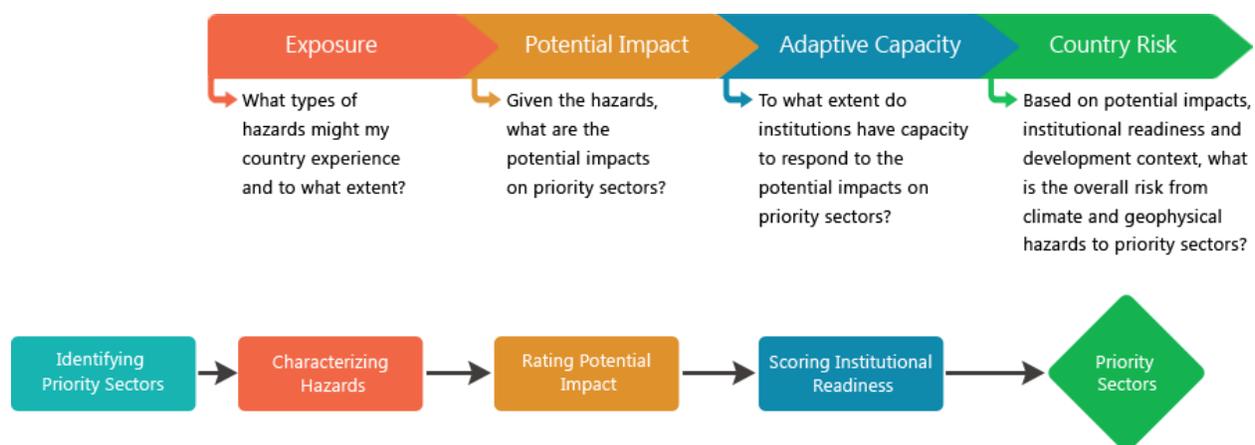
For the **World Bank Climate and Disaster Risk Screening Tools**¹⁰⁸, an *Exposure–Sensitivity–Adaptive-Capacity* framework is being applied. It is based on the risk analysis framework adopted by the Intergovernmental Panel on Climate Change (IPCC) and the framework for vulnerability assessment used by the United States Agency for International Development’s (USAID’s), with some modifications. The figures below show the risk assessment process at the national/policy and project level:

¹⁰⁸ For details and use of tools go to <https://climatescreeningtools.worldbank.org/>

National/Policy Level Tool

The national/policy level tool is designed to walk users through a series of steps to understand the level of risk posed by climate and other natural hazards at an early stage of planning and design of national or sector-wide strategies, development policy, institutional strengthening and/or reforms. The tool does this by making data on climate change (historic, projected) available in an accessible manner. The tool helps the user connect this information to the broader development context at the sector level. The tool includes an Institutional Readiness Scorecard (IRS), which provides a rapid assessment framework to score current client institutional and adaptive capacity at the national/sector level. There are four distinct, but interrelated, stages that users follow:

- **First**, the user identifies priority sectors required to achieve country goals, which the user will rate for risk in the rest of the tool.
- **Second**, the user gathers information on climate and other hazards in the country and rates the potential impact of the hazards on each priority sector.
- **Third**, the user rates the institutional readiness, which is a measure of the country's ability to respond successfully to the hazards.
- **Fourth**, the user determines overall risk by jointly considering the potential impacts and institutional readiness, along with the larger economic and social context that could influence the level of risk.

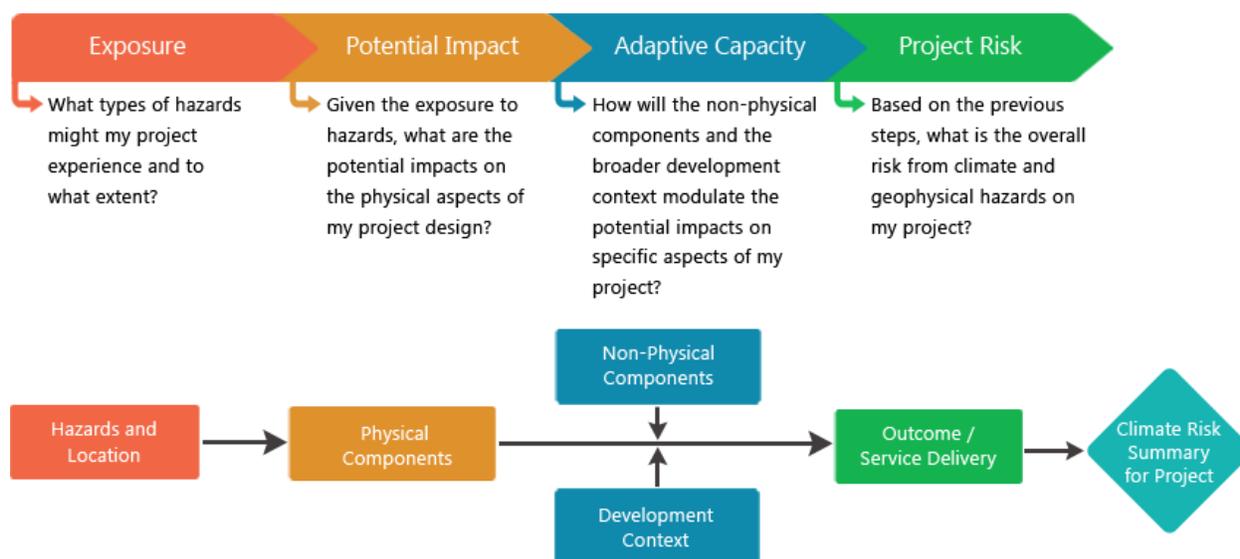


Project Level Tool

The project tools are designed to walk users through a series of steps to understand the level of risk posed by climate and other natural hazards at an early stage of project design. The tools do this by making data on climate change (historic, projected) available. The tools help users connect this information to project components and allow users to account for non-physical components such as institutional capacity and the larger development context. Through this process they help users arrive at the risk to the outcome/service level intended from the project. There are four distinct, but interrelated, stages that users follow:

- **First**, the user evaluates the extent to which their project/location will be exposed to each hazard.
- **Second**, the user combines this information with their understanding of the project's physical components to assess potential impact from each hazard.
- **Third**, the user examines how relevant non-physical factors, such as institutional capacity and the larger economic and social context, influence the level of risk posed to the project.

- **Fourth**, based on these considerations, the user rates the overall risk to the project outcome. A PDF of the overall project risk profile is produced.



Institutional readiness for climate and disaster risks

Guiding questions to score dimensions of institutional readiness:

1. Assess Awareness of Hazards

Are the risks from climate and geophysical hazards known throughout the institution?

- Is there evidence that the institution(s) includes the impacts from climate and geophysical hazards in national planning?
- Is there evidence that key personnel within the institution(s) recognize the potential for impacts from climate and geophysical hazards?
- Is there evidence that the institution(s) routinely monitors and analyzes data on recent impacts from extreme weather and geophysical hazards?
- Is there evidence that key personnel are aware of the social, economic, and environmental consequences of hazards?

2. Assess Ability to Conduct Hazard Risk and Impact Assessments

Does the institution have the ability to conduct assessments of exposure to climate and geophysical hazards and assessments of their potential impact?

- Is there evidence that the institution(s) has developed or used climate data to consider future impacts?
- Is there evidence that the institution(s) has conducted risk assessments of hazards?
- Are the risk assessments rigorous (e.g., do they include quantitative assessment of extreme weather events?)

3. Assess Ability to Plan/Implement Adaptation Measures

Does the institution have the ability to plan and implement adaptation measures to enhance resilience to climate and geophysical hazards?

- Is adaptation considered in planning, development or investment strategies?
- Is there a framework for identifying and prioritizing adaptation-related investments?
- Are there adequate human and financial resources for adaptation programming?
- Are actions to address climate and geophysical hazards included in budgets?
- Is there an effective multi-agency coordination mechanism for disaster risk management?

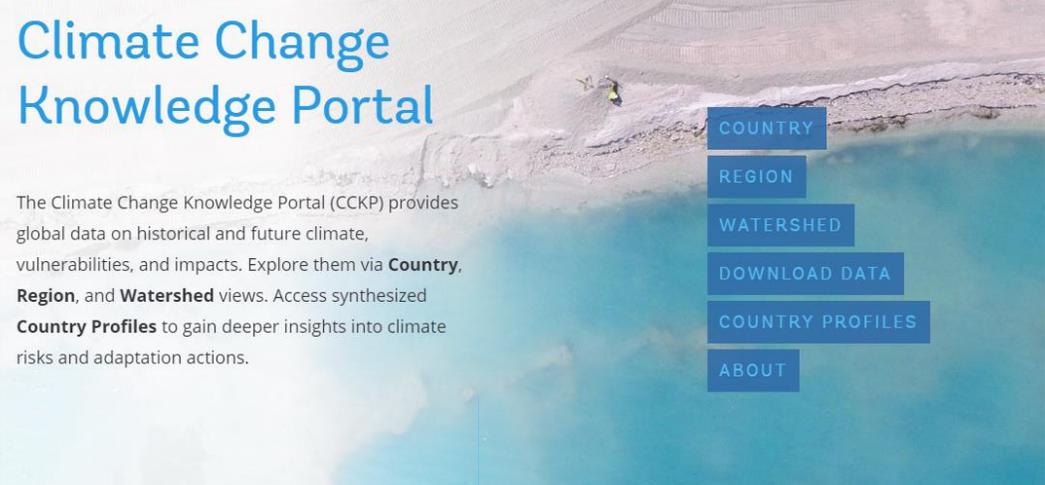
4. Assess Adaptive Management Capabilities

Is the institution sufficiently flexible to adjust adaptation approaches when there is new information about climate and geophysical hazards or when conditions change?

- Can the institution(s) identify adaptation options and pathways that will be robust under a range of climate and natural disaster scenarios and that will account for uncertainties?
- Is there a working system for monitoring and evaluating adaptation programs?
- Are there mechanisms for sharing lessons to improve existing risk management practices and structures?

A6.3. Supporting Country Profiles and Risk Data

The table below identifies climate risk data tools with short descriptions.

Tool Name	Description
Climate Change Knowledge Portal (CCKP) ¹⁰⁹	Recently refreshed, the CCKP acts as a “one stop shop” for climate-related information, data, and tools.
	
Country Adaptation Profiles	The Profiles provide a common platform to access, synthesize, and analyze the most relevant data and information for adaptation to climate change and disaster risk reduction.
ThinkHazard!	A web-based system enabling the consideration of impacts of hazards on new development projects by local areas in countries.
Open Data for Resilience Initiative (OpenDRI)	The OpenData for Resilience Index is a related free online tool to identify, assess and compare – for any location – the availability of key datasets for disaster risk management.
Country Climate Briefs	A webpage helping the user gain basic understanding of climate change in the country context and guides them to relevant, in-depth climate-change knowledge, tools and resources.
Intended Nationally Determined Contributions (INDCs) Platform	The Platform provides a full picture of the detailed targets, implementation plans, and, where available, self-reported cost estimates from countries that have submitted NDCs.
Spatial Agent App	The Spatial Agent Application visualizes a growing range of spatial and temporal development-related data.
Climate Smart Agriculture country profiles	The profiles synthesize complex information into focused outputs that compare in a visually appealing way the ‘climate smartness’ of many country activities and their adoption potential.

¹⁰⁹ <https://climateknowledgeportal.worldbank.org/>

A6.4. National Risk Screening Examples

Zambia

Policy frameworks:

- Climate-change considerations integrated into Sixth National Development Plan (2011-2015)
- Provinces and cities required to develop their own climate action plans
- Provincial authorities in Binh Dinh started developing sectoral plans with climate considerations

Governance/Coordination:

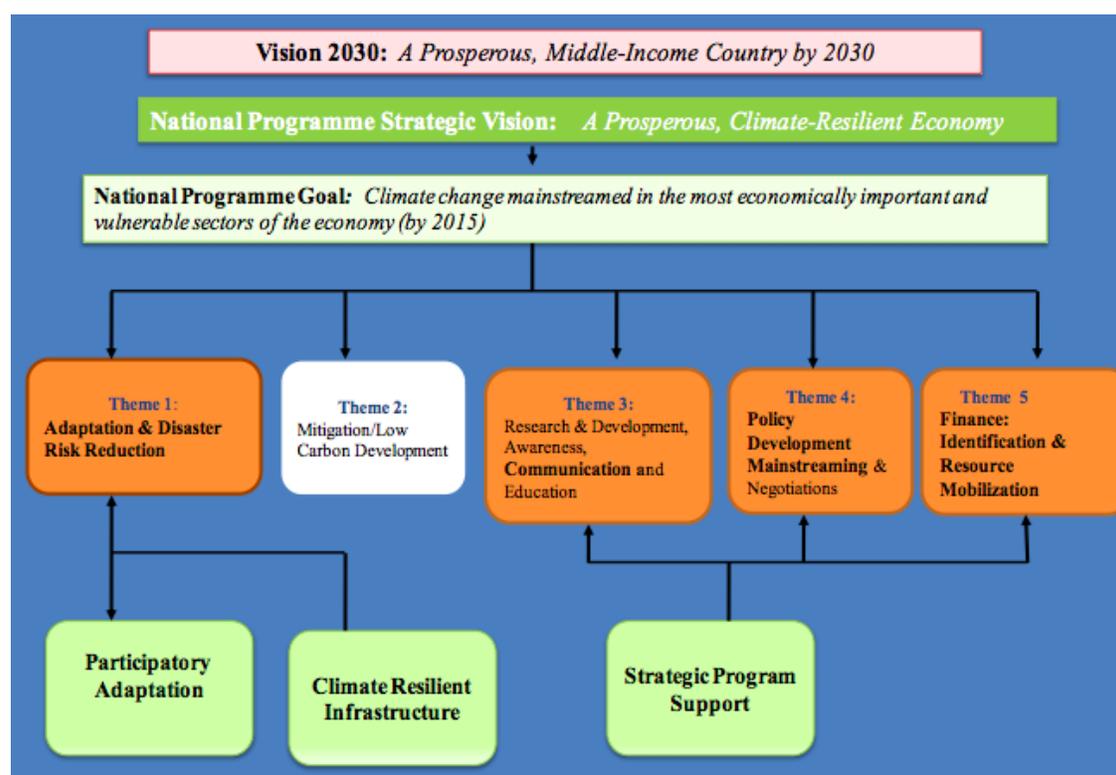
- Agreement on Institutional Arrangements for Climate Change (vis-à-vis stakeholder consultation)
- Decision makers sensitized about climate change and climate screening and information tools

Finance:

- Accessed US\$1.5 million from Pilot Program for Climate Resilience (PPCR) for formulating Zambia's Strategic Programme for Climate Resilience (SPCR) to mainstream climate resilience into national development planning
- SPCR disburse an increment of 30% as an incentive for local plans to become climate resilient
- Climate risk financing harmonized (index based insurance, Contingency Fund)

Adaptive Capacity/Technological measures:

- Design standards and codes were reviewed and incorporated into EIA requirements
- Pilot interventions supported, along with capacity building initiatives at all levels



Cambodia

Policy frameworks:

- Cambodia's Climate Change Strategic Plan (CCCSP) was developed by the Ministry of the Environment
- The CCCSP established a national Climate Change Monitoring and Evaluation framework as well as a climate-change financing framework
- The development of the CCCSP was synchronized with the process of revision of the five-year National Strategic Development Plan (NSDP) to facilitate climate mainstreaming in development planning

Coordination:

- CCCSP developed in an interdisciplinary and inclusive manner, bringing together key ministries and stakeholders
- There is a shift from project- to programme-based approaches and community-level interventions

Governance:

- A Climate Change Technical Team (CCTT) was established, responsible for technical activities and advice related to climate-change issues

Finance:

- A Climate Public Expenditure and Institutional Review (CPEIR) was conducted in 2012

Mexico

Policy frameworks:

- General Climate Change Law proposed in 2010 and approved in 2012
- The Law strengthened the Special Programme of Climate Change (PECC 2009-12)

Coordination:

- Mainstreaming recognized as 'essential' for inter-sectoral and inter-institutional coordination
- Membership to inter-ministerial commission for climate change increased from 7 ministries to 13 ministries including the National Institute of Ecology and Climate Change (INECC)

Finance:

- An annex was created in the national budget where different institutions could establish how much public funds were allocated for climate-change activities
- Accessed US\$501 million Climate Change Development Policy Loan from World Bank in 2008 for supporting, inter alia, mainstreaming climate change in government policy

A6.5 Project Risk Screening Examples

Using Climate Risk Screening to Enhance Project Design

Screening operations for climate and disaster risks is an important first step to better understand project-related climate risks, identify the need for further detailed assessment during project preparation, and raise awareness about potential climate-change adaptation and resilience options for project design. Screening also facilitates an initial identification of climate co-benefit opportunities upstream, particularly those related to adaptation.

The following operations provide good case study examples highlighting the synergies between climate and disaster risk screening, the integration of resilience measures in project design, and the capture of climate co-benefit opportunities.

Maldives - Climate Change Adaptation Project (CCAP)

The development objective of the Climate Change Adaptation Project (CCAP) for Maldives is to demonstrate climate adaptive planning and management through the adoption of a multi-sectoral approach in Addu and Gnaviyani atolls. One of the five components is on mainstreaming climate change into island development planning aims to build awareness and strengthen local government capacity to address climate-change adaptation issues relevant to island development and support tertiary level education in environmental management including climate-change adaptation and mitigation.

Mozambique Integrated Feeder Road Development Project

The objective of the project is to enhance road access in selected rural areas in support of livelihoods of local communities and to provide immediate response to an eligible crisis or emergency as needed.

Through the climate and disaster risk screening process, the project identified a number of climate risks to project investments related to extreme temperature, extreme precipitation and flooding, and drought, which could affect road infrastructure. At the screening stage, the project envisaged that the design of the project's road investments and the inclusion of targeted soft components related to policy development and implementation as well as capacity building, training and outreach could mitigate some of these risks.

In the final design, the project incorporates a Decision Making under Uncertainty (DMU) methodology for investment design and planning. Traditional planning approaches do not account for the benefits of building climate resilience in the road network, and often lead to suboptimal investment decisions. Recent findings have demonstrated that the hardening of road infrastructure may not be the optimal strategy to increase climate resilience, and in light of these lessons learned, the project is piloting an innovative methodology to incorporate the benefits of flood disaster resilience into project prioritization and economic evaluation. The project will also support enhanced integration of climate resilience in planning and management of road infrastructure including the use of a geospatial climate resilience tool to inform annual implementation plans.

48% of the total IDA committed amount of US\$150 million was counted toward climate co-benefits.

Nigeria Erosion and Watershed Management Project (NEWMAP) - Additional Financing

The objective of the project is to reduce vulnerability to soil erosion in targeted sub-watersheds.

Through the climate and disaster risk screening process, the project identified a number of climate risks to project investments related to drought and extreme precipitation and flooding. Drought could lead to vegetation reduction (both natural and project implemented). Extreme precipitation and flooding could lead

to flash floods or landslides inundating coastal erosion control structures implemented by the project, potentially resulting in exacerbated land degradation and erosion.

At the screening stage, the project envisaged physical infrastructure (including flexible engineering structures and vegetation measures) in the selected project sites that could channel and contain water runoff to halt land degradation and erosion. The project also envisaged various technical assistance and institutional capacity-strengthening activities designed to build resilience to climate shocks. It was acknowledged that such measures could help improve the resilience of selected sites, but that climate risks could not be fully addressed within the project's remit.

In the final design, the project incorporated erosion and watershed management infrastructure investments aimed at restoring major, high-risk gully systems and reducing vulnerability to further land degradation. The project will also provide support for integrated watershed management and livelihoods consistent with sustainable land management (e.g. establishment of woodlots, nurseries for plants, care of rehabilitated land, and small agribusinesses).

The project will also help build adaptive capacity by supporting the development of tools and approaches to increase institutional readiness on climate-change adaptation. The project will also finance climate-change mitigation activities through demonstration projects to test the viability and scaling-up of potential of low-carbon development options. Technical assistance will also be provided for the initiation and preparation activities in the country's Nationally Determined Contribution (NDC), in particular the issuance, deployment, and monitoring of green bonds.

100% of the total IDA committed amount of US\$400 million was counted toward climate co-benefits.

Malawi Shire Valley Transformation Project - Phase 1

The objectives of the project are to (i) increase agricultural productivity and commercialization for targeted households in the Shire Valley; and (ii) improve the sustainable management and utilization of natural resources.

Through the climate and disaster risk screening process, the project identified a number of climate risks to project investments related to extreme temperature, drought, and flooding, with potential impacts on water demand and availability for irrigation and drainage services, and on productivity of cropped areas. At the screening stage, the project envisaged that follow-on technical studies should incorporate these risks and inform both investments and the overall basin plan.

In the final design, the project provided for deeper technical studies, notably a hydrology analysis that would take into account long-term trends and projections for run-off and water demand, as well as modelling of flood risks for cropped areas. Regarding the water productivity of irrigation and drainage investments, the project will introduce volumetric metering and charges at block level and will facilitate optimum in-field irrigation design. The project will also support sustainable natural resource management investments to mitigate climate risks, such as actions to address land degradation and protect upslope watersheds in conservation areas.

The project will help build adaptive capacity to adapt to weather shocks and longer-term climate risks at national government and local community levels. The project will build the capacity of and train government and Water User Federation stakeholders in long-term management of bulk infrastructure assets. Institutional and legal support will also be provided for Water User Association formation.

63% of the total IDA committed amount of US\$160 million was counted toward climate co-benefits.

Regional Disease Surveillance Systems Enhancement (REDISSE) Phase III

The objectives of the project are to: (i) strengthen national and regional cross-sectoral capacity for collaborative disease surveillance and epidemic preparedness in West Africa; and (ii) in the event of an Eligible Emergency, to provide immediate and effective response to said Eligible Emergency.

All project countries (Benin, Mali, Mauritania and Niger) are “hotspots” for climate-sensitive health impacts, meaning they are situated in a climate-vulnerable geographic region, with susceptible populations and with pre-existing burdens of infectious diseases which are likely to increase with climate change. The climate and disaster risk screening process identified extreme heat, rising sea levels, flooding, drought, and intense storms, as key hazards that could potentially lead to shifting disease vectors and degraded air quality, all or any of which affect human health and vulnerability to infectious disease. At the screening stage, the project envisaged providing support to build the adaptive capacity of project countries to address climate impacts on health. Project countries have explicitly included health considerations in their Nationally Determined Contributions (NDCs).

As part of the final design, the project builds in activities addressing surveillance and information systems, preparedness and emergency response, and human resource capacity that factor the impacts of climate change. For instance, the project will support the establishment of an early warning system for infectious disease trends prediction. This will include monitoring trends that occur in infectious diseases, namely climate-change impacts on infectious disease outbreaks in the region. The project will also support building the capacity to adapt to downstream climate impacts, including emergency responses with an all-hazards approach, and measures for risk mitigation of diseases exacerbated by climate change.

50% of the total IDA committed amount of US\$60 million was counted toward climate co-benefits.

Ghana Commercial Agriculture Project – Additional Financing

The project objective is to improve agricultural productivity and production of both smallholder and nucleus farms in selected project intervention areas with increased access to reliable water, land, finance, and agricultural input and output markets.

Through the climate and disaster risk screening process, the project identified climate risks related to extreme temperature and extreme precipitation and flooding, which could have damaging impacts on project investments related to irrigation and drainage, crops and land management, and storage and processing. At the screening stage, the project envisaged a focus on scaling-up the adoption of climate smart agriculture technologies and ensuring farmers do not cultivate in the fragile ecosystems.

In the final design, the project supports activities that promote climate adaptation through: (i) sustainable land use and enhanced food security (i.e. improved rainfed crop production technologies, rehabilitation and construction of agricultural storage infrastructure and support for commercial seed production, including targeted support for climate smart agricultural technologies focusing on the drier parts of the northern regions of the country); and (ii) supporting the rehabilitation and new construction of irrigation and drainage infrastructure which will reduce farmers’ vulnerability to drought risk.

50% of the total IDA committed amount of US\$50 million was counted toward climate co-benefits.

Annex 7: Climate-Informed Project Appraisal¹¹⁰

Climate-Informed Project Appraisal Methodology

This annex describes in some detail the conceptual framework, the empirical and statistical basis for the representative functions for hazards, losses, and probability distribution of losses that can be used by policy analysts to incorporate risk analysis under “deep” uncertainty into the project appraisal or cost-benefit analysis (CBA) and decision-making for budget approval of public investment projects.

Modelling Cost-Benefit Analysis (CBA) with Climate Uncertainty

Historically, policy makers and economists have mostly used deterministic modelling approaches for CBA of investment projects. This approach calculates the costs and benefits of a project (existing asset or new asset) based on project parameters derived from best estimates or mean values of the variables. Objective parameter estimates can be based on historical observations with some trend projections assumed by the analysts. Alternatively, expert opinion may be surveyed to get expert-based subjective estimates. The deterministic model can be expanded to include more information with the analyst normally making assumptions about tendencies and developing simulation analysis (where variables are defined by mean values and probability functions adopted on the basis of empirical and consulted evidence).

Caution is required when dealing with climate uncertainty as many models in practice will not adequately capture the inherent uncertainty in natural hazards and related losses, generating less robust results.¹¹¹ If the probabilities of climate-change impacts through parameter change (e.g. trends, frequencies, intensities) of hazards are incorporated, the behavior of key project variables that are a function of different intensities and frequencies of these hazards need to be tested and evaluated ex-ante. Therefore, to address the issue of deep uncertainties, we employ probabilistic modelling for hazards or disasters and related losses with different possible scenarios about the trends in the mean values and probability distributions induced by climate change. The conceptual framework for the modelling comprises four main components:

Hazard¹¹², Vulnerability Analysis and the Probability Functions for Expected Losses due to Climate Uncertainty

First, three components - Hazard, Vulnerability, and Risk Losses - are used to calculate annual expected losses, which are then a cost inputs in the CBA appraisal framework. These building

¹¹⁰ This annex draws heavily on a World Bank report prepared by Fernando Fernholz and a team from Duke University, “Climate Sensitive Public Investment Appraisal: General Methodology and Applications, St. Lucia,” Report prepared for the World Bank, June 2018.

¹¹¹ Michel Kerjan, E., Hochrainer-Stigler, S., Kunreuther, H., Linnerooth-Bayer, J., Mechler, R., Muir-Wood, R., Young, M., “Catastrophe Risk Models for Evaluating Disaster Risk Reduction Investments in Developing Countries,” *Risk Analysis*, 984-999, 2013

¹¹² More specifically, the hazard function models which periods have the highest or lowest chances of an event. The function is defined as the instantaneous risk that the event of interest happens, within a very narrow time frame. [Source: Data Science Central/Hazard Function]

blocks lead to the last step, which is real options approach to organize the decision making process for the purposes of optimization of investment and budgetary resources in the presence of deep climate-change uncertainty. Real options represent initially additional costs, which can be justified by the corresponding expected risk loss reduction that result from these additional investments. In other words, a net incremental benefit is achieved by added upfront costs to reduce future disaster losses. Each component is explained in detail below.

1. Hazard Analysis

Fitting an Extreme Value Distribution for Hazard Representation

A hazard function could be a single or a composite function of several variables that can negatively affect a project, a program or an economy. The aim of hazard analysis is to model the frequency of occurrence (or exceedance probabilities) and the intensities of climate variables like rainfall, wind speed or wave height, etc.¹¹³ Of particular interest is modelling the extreme values of the climate parameters because severe damage to life and property happens at these extremes. To obtain the exceedance probabilities of extreme values of climate variables we can use various functional distributions like Weibull, Gumbel, Generalized Pareto, Beta, Gamma, Logistic, Lognormal, Exponential Distribution, etc. The selection of a hazard function is based on efficiency criteria for best representative fit and availability of data. Box A7.1 defines an exceedance probability curve.

Box A7.1 1: Exceedance Probability Curve

An exceedance probability curve shows that the probability that the certain level of intensity of a variable will be exceeded. The exceedance probability curve can be drawn for climate variables like rainfall, wind speed, etc. or loss. The exceedance probabilities will decrease as the level of intensity of the variable increases because of the decreasing functional nature of the distribution.

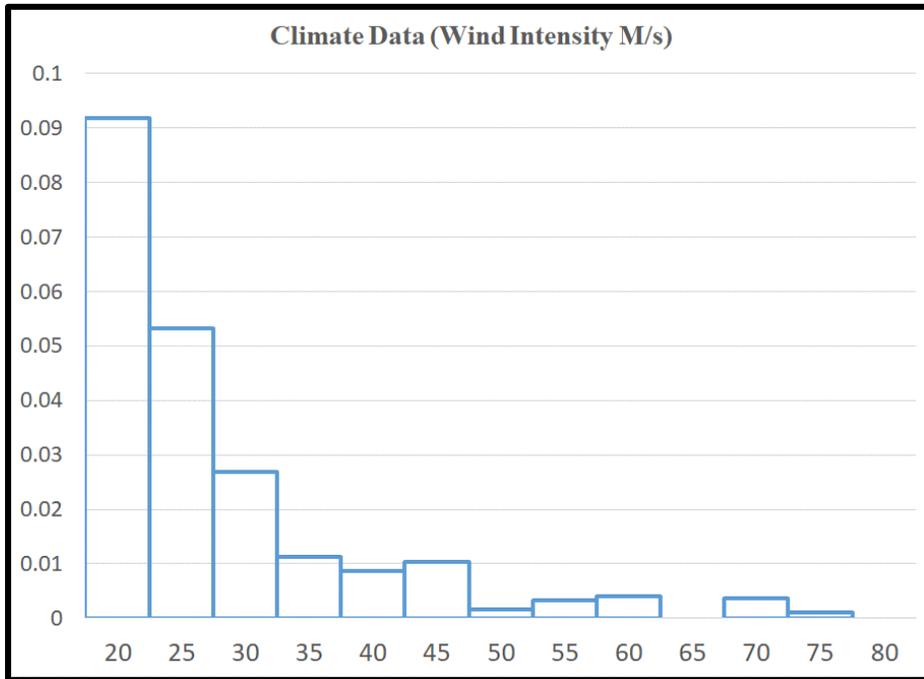
To understand which distribution best fits the local climate data and provides reliable probabilities, first a histogram using the variable intensity data is created. These histograms can be plotted using the climate parameters of our interest like rainfall, wind speed, wave height, etc. In the relevant range and for the assessment of damages, a decreasing function that asymptotically approaches the horizontal axis is observed. For example, the histogram in Figure A6.1, using the maximum wind speed data, shows the observation of frequencies decreasing, as the intensity of wind speed increases. The histogram is truncated at the threshold limit of 20 m/s. The threshold is an observation below which there is no catastrophic effect on the assets or services. This is only an example of a threshold; the value will depend on local context and specific asset or project.

Once the histogram has been created using the rainfall data, for example, different extreme value distributions are tested for a best fit with the histogram. An example of such a best fit choice is

¹¹³ Patricia Grossi and Howard Kunreuther (Editors) *Catastrophe Modeling: A New Approach to Managing Risk*, Huebner International Series on Risk, Insurance and Economic Security, 2005 Edition

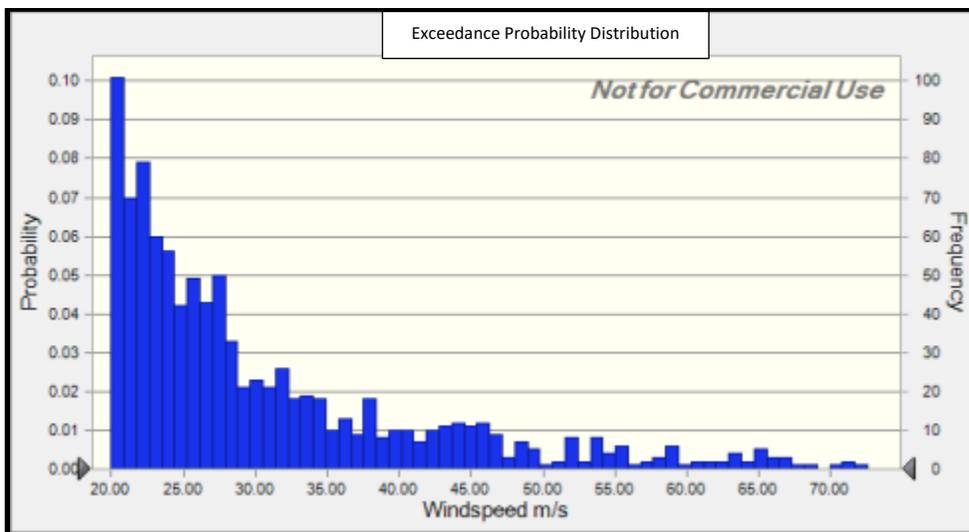
the Generalized Pareto Distribution (GPD), which can be used as a representative function for threshold exceedances.

Figure A7.1: Histogram of Wind Speed Intensity, with a Minimum Threshold



Source: Author elaboration.

Figure A7.2: Pareto Probability Distribution for Wind Speeds using Crystal Ball Simulation Software.



Source: Author elaboration based on the histogram of data.

Figure A7.2 shows a Pareto Distribution fitted to the wind speed data. This plot can also be called the exceedance probability curve of wind speed. The same methodology can be used to estimate the probability distributions for rainfall or other variables. There will be a need to generate these parameters (and probability distributions) for each new data set requiring a fitted probability function. The fitted probability function is then used to obtain the probability of getting wind speeds above a certain intensity in a year. For example, the probability of being affected by wind speeds in excess of 50 m/s is about 1% in a year. Similarly, as we can see from the chart, the probability that the wind speed could exceed 70 m/s, in a given year, is 0.3%. These exceedance probabilities are then used to calculate the expected losses of future hazards. As expected, the exceedance probability decreases with the increase in the intensity of the wind. This is captured through the decreasing functional form of the distribution.

2. Vulnerability Analysis

Estimating Loss Functions

The next step in the analysis is to understand the economic impact of climate variables at different intensities on specific infrastructure assets and property. To undertake this analysis, there is a need to estimate or obtain the economic damages (measured in units of account or local currency) and other losses from the disruption in public services during different hazards in a given place or region of a country from various national and international damage assessment reports, or by talking to local stakeholders and government officials. The expected yearly loss would be the present value of the asset loss (which is a stock value) and the economic services disruption, which can last several years after the event has occurred. Once enough loss information has been gathered for different disasters, losses are plotted against corresponding climate parameter intensities. These data points can then be fitted with a best-fit function known as an economic loss function. The loss function (in economic terms) will be an increasing value of the damages and public services lost in relation to the intensity of the hazard. These loss functions can be estimated for specific sector or the whole economy.

Therefore, an example simple loss function for a particular project or asset can be estimated from the hazard and damage and loss data from several reports on damages can be shown as:

$$y = 1.456 e^{(0.1058x)}$$

Here, “x” represents intensity of a climate parameter like wind speed, and “y” is the corresponding monetary loss in the economy. It is important to note that these loss functions vary country by country and region by region. Therefore, every new analysis needs to estimate the parameters for a loss function from the existing data, considering the local damage information during the past hazards. Once the loss function for the sector of our interest (for example for roads and bridges) has been obtained, the expected losses during a given year due to hazards can be estimated. See Figure A7.3.

The probability distribution curve for losses in an economy can now be used to estimate the expected losses in a given year. This annual expected loss up to a certain level is the area under the probability distribution curve. We can calculate the annual or event expected loss in

economic terms by multiplying each damage value with its corresponding probability and adding all these results (expected losses) together to obtain annual expected loss. This methodology is then replicated for each of the future years of the project appraisal period.

One of the challenges in forecasting expected values of losses, however, is the rate at which the probability density function decreases with the intensity of the hazard while the economic loss function increases with intensity. If the rate of increase in the latter more than compensates the rate of decrease in the density of the hazards function, a probability distribution function for a loss that reaches infinity is obtained. In other words, we would not be able to find a solution, for example the distribution of expected losses and the mean values of the expected losses. This aspect needs to be studied carefully for each modeling exercise and checked for extreme results in practice.

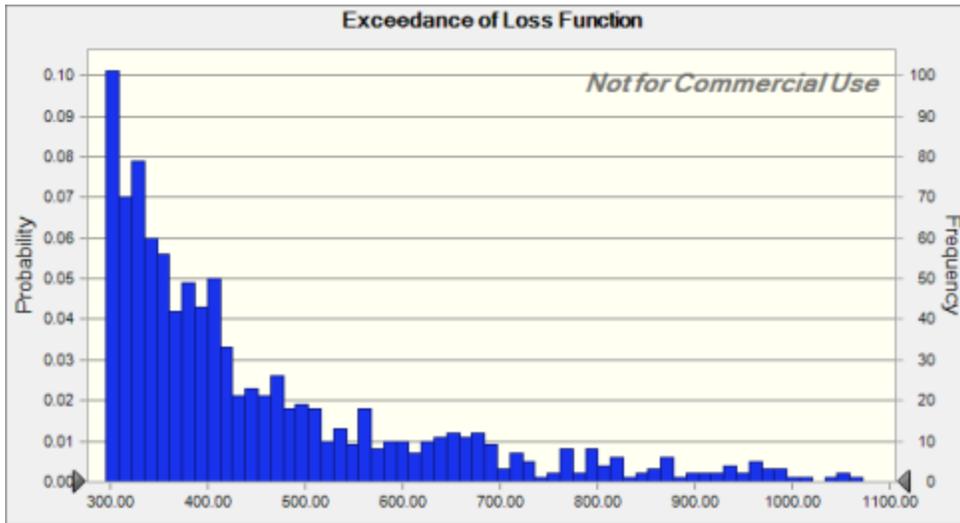
In general, both research and updating of parameter data are necessary to test and adopt functional forms (for both the density function of wind or rainfall for example) and the loss function. There are competing functional forms, and empirical analysis, observations, and experience, should help the selection of functions and their use in practice. Project appraisal documents and guidance need to include with examples the most commonly used functions with a practical methodology to determine the relevant parameters in each case.

3. Simulations and Risk Analysis

Calculating Expected Losses

In this step of the methodology, the probability distribution function obtained through empirical hazard analysis is combine with (multiplied by) the loss function from the vulnerability analysis to create a probability distribution for the expected hazard damages. This curve provides us information about the probability of having a loss (reconstruction costs and other related economic losses due to disruption of services) above certain value in a given year. For example, from Figure A6.3 the probability of having losses above \$ 700 (millions, say) is around 0.5%.

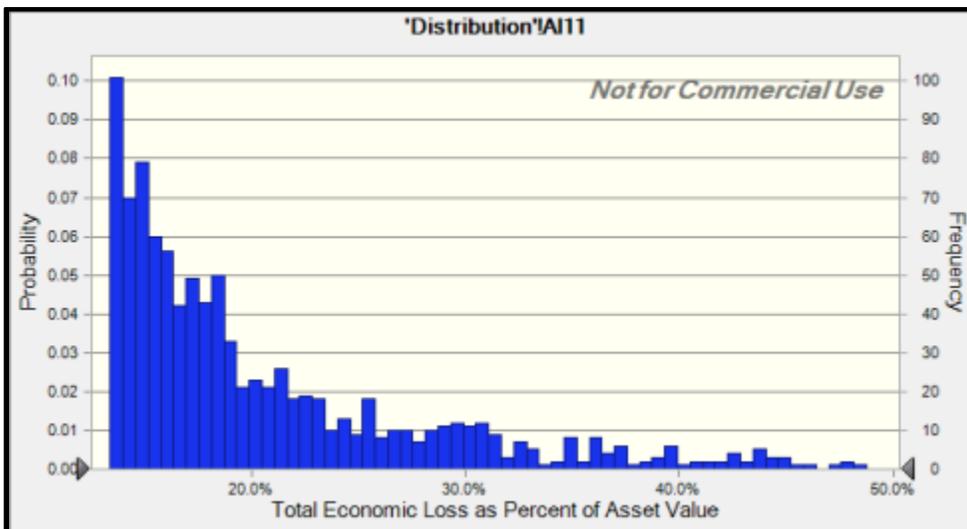
Figure A7.3: Example of an Economic Loss Function in Monetary Values



Source: Author elaboration

For more generalized use of the exceedance probabilities and damages, these can be expressed in percent of the asset values on the horizontal axis, allowing similar functions to be used for similar appraisals in the same location (if applicable). The representation in Figure A7.4, using losses as percent of the asset value, is useful for comparative analytical purposes within and across sectors.

Figure A6.4: Example of an Expected Economic Loss Function in Percent of the Asset Values



Source: Author elaboration, using previously described functions and Crystal Ball Simulation Software.

Cost-Benefit Analysis and Real Options:

Incorporating Climate Uncertainties in the Expanded Appraisal Model

The Jenkins-Harberger methodology¹¹⁴ is the building block for project appraisal and project selection. In this approach, at the core of cost-benefit analysis, public investment decisions are favorable when the net present values of economic benefits less economic costs from a project, including construction and operation, are estimated to be positive and favorable to the economy and society in comparison with other competing proposals. An integrated CBA takes into consideration various perspectives, namely, the economic, financial and distributional perspectives each including the risks and externalities (environmental and others) as appropriate to the perspective.

In the expanded analysis, the expanded analytical models incorporate the probabilities of parameters that might generate some marginal annual losses as a cost into the model. Using real options and simulations (for example with Crystal Ball) we compare the NPV of the project with and without the additional resilience measures or structures which would reduce the expected losses. Based on the calculated distributions of the resulting expected NPVs, we can assess the ranges for potential optimal solutions that would maximize net benefits, by reducing the expected annual losses.

The Expanded CBA Analysis: considerations for hazard events and single climate variable analysis

In the first instance, and in the absence of better information, it will be preferable to do the analysis of resilience and real options for each key component of the project or part of an asset separately and then as a project in aggregation. Some projects are more sensitive to rain impacts and flooding (e.g. water supply systems, roads), while others are more vulnerable to wind gusts above a certain level (e.g. elevated water tanks, bridges, etc.).

In addition, most hazards are a combination of different climate parameters like rain and wind. Thus, joint probabilities models for estimating hazard functions would make more sense theoretically. However, the research on joint probability distributions for climate-change variables is still developing and the gains from moving deeper in this direction are not practical. This is likely to change as more data and better models for climate related variables are developed and tested.

In the absence of more detailed data and models (such as joint probability distributions), we make informed assumption that our hazard function represents the combined effect of rain, storm surge and wind. The envelope hazard function is recommended for professional appraisal purposes. This means that wind, rain, and sea surge probabilities can be represented by one function that represents the outer envelope of the most damaging impacts from the combined or single variable distributions of physical observations.

¹¹⁴ Economic prices are estimated as the weighted average of supply and demand prices.

The Expanded CBA Analysis: considerations for hazard events and single climate variable analysis (*continued*)

The additional considerations in the presence of **deep uncertainty**, are to test different simulation scenarios under plausible assumptions, and check if the decisions are robust, meaning they always represent a net gain on expected values given a known investment in resiliency. This means that the investment costs to reduce climate-change related hazards, is smaller than the net savings of costs (avoided costs) that result from the real option to invest or to retrofit an existing asset.

Source: Climate Sensitive Public Investment Appraisal. General Methodology and Applications. St. Lucia. June 2018. DCID for World Bank.

Reviewing the evidence at local levels

It is important to review the databases from previous studies, government statistics and country reports. Specifically it is important to document and understand the challenges each country has faced in the case of growing uncertainties due to natural disasters. The gradual buildup of experience and assessments of scientific projections for future impacts of climate-change hazards and vulnerabilities of each sector and country is necessary taking the technical capacity available in the country into consideration.

Software

The models discussed above use Excel Software and can expand into risk analysis with readily available Excel based add-in software, such as Crystal Ball or @ Risk (this means the risk expanded version of CBA, with different assumptions and scenarios for climate-change trends and hazard intensities and frequencies).

Conclusions

In summary, properly conducted ex-ante appraisal of investments in real options for resilience would generate positive returns to the economy. Several studies in different parts of the world confirm these conclusions. Nevertheless, the selection of related investments and analysis of resiliency needs to be prepared carefully with continual updating of the data based on better research and information about possible hazards, losses and technical solutions to mitigate future expected damages and losses. Multidisciplinary expertise and multi-stakeholder inputs will help to verify and strengthen the assumptions and process. There is a strategic need to gradually incorporate into the models, more detailed engineering and other context measures into the project parameters to improve accuracy and efficiency in results of the analysis and ultimately in resource allocation.

It is critical in planning for climate-related impacts that science, engineering and policy needs to be integrated more effectively. Science and engineering, especially for climate-related

investment decision making, needs to inform policy analysis and decision making, for example, on investments, regulation, disaster management and safety requirements. Local capacity should be strengthened so that local officials can use the analytical frameworks and provide advice on investment decisions.

The role of insurance (local and international) and the role of the private sector (e.g. PPPs) where some risks could be shared in a more efficient manner should be explored further and incorporated more effectively to expand the use of expanded cost benefit models that include deep uncertainty for different shares of ownership and incentive structures.

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