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Adaptation finance and the infrastructure agenda

Smita Nakhooda and Charlene Watson

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Overseas Development Institute
203 Blackfriars Road
London SE1 8NJ

Tel. +44 (0) 20 7922 0300
Fax. +44 (0) 20 7922 0399
E-mail: info@odi.org.uk

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This paper draws on the work of the Overseas Development Institute (ODI) on climate finance, including efforts to monitor the provision and impact of climate funds.

More information is available at: http://www.climatefundsupdate.org

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Abbreviations and acronyms

ARC	Africa Risk Centre
ASAP	Agriculture Smallholder Adaptation Programme
ADB	Asian Development Bank
CCA	Climate change adaptation
CCRIF	Caribbean Catastrophe Risk Insurance Facility
COP	Conference of the Parties
DFI	Development finance institution
DRR	Disaster risk reduction
EBRD	European Bank for Reconstruction and Development
ESG	Environmental, social, governance
FDI	Foreign direct investment
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas
GRESB	Global Real Estate Sustainability Benchmark
ICI	International Climate Initiative
IFAD	International Fund for Agricultural Development
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LAC	Latin America and the Caribbean
LDCF	Least Developed Countries Fund
LDC	Least developed country
LIC	Low-income country
MDB	Multilateral Development Bank
MIC	Middle-income country
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
ND-GAIN	Notre-Dame Global Adaptation Index
NGO	Non-governmental organisation
ODA	Official development assistance
OECD DAC	Organisation for Economic Co-operation and Development/Development Assistance Committee
PPCR	Pilot Programme on Climate Resilience
PPP	Public–private partnership
SADC	Southern African Development Community
SCCF	Special Climate Change Fund
SIDS	Small island developing state
SuRE	Standard for Sustained and Resilient Infrastructure
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Adaptation to a changing climate is now essential to sustainable development. In order to protect and support development progress, adaptation introduces myriad considerations to factor into financing and investment decisions. Infrastructure is one example: access to appropriate infrastructure can support adaptation and resilience to climate change, but the wrong choices may increase vulnerability. How choices are made to meet future needs for infrastructure services such as roads, energy, water and sanitation will have long-term implications for development pathways. Infrastructure assets in all countries will be subjected to the impacts of climate change. This paper reviews international efforts to support adaptation, and their linkages with efforts to mobilise new finance for infrastructure.

Adaptation in practice

The international community has sought to encourage national efforts to understand adaptation needs and vulnerability in the form of global climate policy processes, and increase financing for adaptation efforts in developing countries. Adaptation finance flows were estimated at less than 10% of identified climate finance flows. Four funds have been created under the United Nations Framework Convention on Climate Change (UNFCC), channelling more than $1.5 billion for adaptation activities. There is growing interest in increasing access to insurance against climate risk, particularly in developing countries. Many climate funds have supported consultation and capacity-building efforts in the context of strengthening national climate change and adaptation (CCA) policies, and raising awareness of climate risk. But these efforts have often been quite separate from the concrete investments that have been made in physical infrastructure. There is widespread recognition of the need to find new ways to engage the private sector in financing adaptation solutions to managing climate risk, although climate risk-management measures are difficult to single out from wider business strategies. National governments are a principal source of adaptation finance, and even the poorest countries are spending substantial sums of their national budgets on climate-sensitive activities aimed at supporting adaptation. Several developing countries have also set up national adaptation funds, often resourced with a mix of international and domestic finance.

Adaptation, climate risk and the infrastructure finance agenda

Infrastructure investment is a key target for all of these activities. Efforts to increase access to infrastructure services, and to upgrade existing infrastructure in developed countries, present an opportunity to integrate climate resilience in design and operations, preventing costly retrofitting later. Investments in infrastructure (and infrastructure-dependent sectors) will be exposed to climate risks that are increasingly significant for private investors. There is much more to adaptation than building sea walls to protect against flooding, or more robust infrastructure that can withstand possible impacts. Adaptation is fundamentally about risk management and finding climate-resilient approaches to development.

Supporting adaptation and strengthening the resilience of future infrastructure investment

While there have been efforts to understand the costs of adaptation to climate change, the existing practice of conflating the costs of the impacts of climate change, including residual damage and the actual costs of adaptation measures, have been unhelpful in informing investment decisions. Information that identifies the different risks that climate change can pose at different stages of investment may be more helpful. More attention needs to be given to the impact of climate risk throughout the infrastructure design and investment cycle. From an investment perspective the understanding and disclosure of climate-related risk is in its infancy.

There continues to be a need for better information on climate risk (both the scope of possible impacts, and likely probability) in formats that can meet the needs of different actors across the infrastructure investment chain. The need for such information has been recognised by the G20 and the Financial Stability Board.

A better understanding of the impact of climate change on the maintenance and upkeep of relevant infrastructure is also required, as well as continued and strengthened emphasis on upfront policy, planning and siting regulations to ensure that these better reflect possible climate risk, in the context of concrete investment choices. More inclusive, accountable and informed decision-making processes can help achieve these goals. Such strengthened governance can also create opportunities to ensure investments better meet the development needs, including for those who are poor and vulnerable. This presents potential niches for adaptation funds, including the newly established Green Climate Fund.

The capacity and incentives of financial institutions to respond climate risks must be strengthened. Public finance can support efforts to bridge these information gaps, but the information generated must be better tailored to users' needs.

Seizing this opportunity can safeguard the impact and sustainability of anticipated and desired investment in infrastructure services. Failing to do so, would further threaten a reversal of the hard won development gains of recent decades.

1. Adaptation to climate change: a key issue for development

The impacts of climate change are already being felt and will have profound implications for future development and economic prosperity. The risks posed by climate change and the need for adaptation is now essential to sustainable development. The Intergovernmental Panel on Climate Change (IPCC) describes such climate risk as a function of vulnerability, hazard and exposure to the changing characteristics of the climate system, while adaptation refers to the process of adjustment to actual or expected climate change and its effects (IPCC, 2014). Adaptation measures need to address these aspects of climate risk, even when the probability of an event remains uncertain (Smith and Stern, 2011).

Development pathways influence risk by changing the likelihood of climate events and trends, both through emissions effects and also by altering the vulnerability and exposure of human, socioeconomic and biological systems (Oppenheimer et al., 2014). The inextricability of adaptation and development are well recognised: in many ways, adaptation represents 'good development' (Burton, 2002; McGray et al., 2007; Jones et al., 2012). Indeed, investment in adaptation can bring immediate development benefits even when there is great uncertainty regarding climate risks (IPCC, 2014). Adaptation is linked to and complemented by the notion of strengthening resilience, or the ability of interconnected systems to resist shocks (Tanner et al., 2015).[1] A proactive approach to reducing climate risk through mitigation and adaptation as well as strengthening resilience will protect development gains that have already been achieved. Inaction, on the other hand, threatens these hard-won gains and future sustainable development.

Managing climate risk introduces myriad considerations to factor into financing and investment decisions and systems. This is exemplified by choices about how to meet future needs for durable assets in roads, energy, water and sanitation, which are defined in this paper as infrastructure. Dealing with the rising risk of climate impacts caused by rising concentrations of greenhouse gases (GHGs) in the atmosphere will often involve higher upfront investments. This does not always mean spending *more* money, but spending it *differently*. For example, there are many ways to deal with climate risk in a road project. Some might involve higher costs: additional concrete so it can withstand climate-related impacts, higher quality materials or improved sidings and drainage. These higher upfront investments could reduce longer-run costs, climate impacts and damage incurred over its lifetime. There might be a need to spend more on maintenance because of increased wear and tear. But there are options that do not cost more. A less costly road might be built on the assumption that it will eventually have to be moved. Alternatively, it might be decided to build the road elsewhere, or not build it at all and prioritise investing in roads in less climate-vulnerable areas.

Both existing and new infrastructure assets will be affected by climate change in all countries. New investments in infrastructure, especially in developing countries, can be designed and managed to reflect climate risk, preventing costly subsequent retrofitting (Stafford Smith et al., 2011). Low-emission and climate-resilient infrastructure will not only reduce its own vulnerability, but can also reduce the vulnerability to climate change of society more broadly by ensuring that these assets function – meeting basic needs – despite climate shocks and stresses.

This paper considers the implications of climate risk for future infrastructure investment. Most adaptation action has its origins in national needs and processes, and is anchored in country-level action. To provide a global overview of the current state of play, however, this paper focuses on international efforts to support adaptation, with an emphasis on the needs of developing countries. Chapter 2 presents adaptation as a risk response, while Chapter 3 outlines adaptation in practice, including how the costs of adaptation are commonly understood, and the roles of existing sources of adaptation finance. Chapter 4 reviews climate risks for infrastructure in more detail. Chapter 5 considers the implications of particular climate risks presented in developing countries for their infrastructure finance efforts. Chapter 6 concludes with options for an improved approach to financing resilient infrastructure.

1 Resilience framings are often presented as a complement to the limits of adaptation as a concept: in that there may be impacts to which adaptation is impossible, but to which systems may be able to become resilient.

2. Fit for the future: adaptation as a response to climate risk

Adaptation is difficult to define and identify, and is inextricable from development (Brown and Kaur, 2009). In Paris at COP21 of the UNFCCC, a global adaptation goal of 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response' in the context of efforts to keep climate change well below 2°C was adopted. What counts as adaptation depends substantially on context and circumstance. In this analysis we consider climate change as posing a range of risks – understood as a combination of the magnitude, likelihood and consequences of a climate-related event (UNDP, 2005). These can be addressed by governments, businesses, communities or individuals using basic principles of risk management – namely avoiding, reducing, sharing or accepting and managing risk (see Deloach, 2000; COSO, 2014; Bekefi et al., 2008: Table 1). Adaptation may not be feasible with available technologies, for example, or it may be too expensive, resulting in residual risk even after adaptation (see Parry et al., 2009).

Adaptation measures have often focused on helping countries to deal with high-impact events or disasters, such as hurricanes and floods. But climate change will also manifest more gradually through slow-onset changes in rainfall, shifting average temperatures and sea-level rise. Climate change threatens existing and future assets either directly, through flood or storm damage, or indirectly, such as through under-performance or scarcity of resources, such as water.

Adaptation has tended to focus on 'concrete' or 'hard' adaptation to climate change: physical investments that leave a tangible footprint (Fankhauser and Burton, 2011), as opposed to 'soft' measures that involve much wider shifts in approach. Some hard adaptation measures may introduce new potential risks and vulnerabilities to climate change or 'maladaptation' (Box 1). There is a need for a range of adaptation measures beyond 'building sea walls', for example by restricting activities such as the siting of human settlements, socioeconomic activity, property and infrastructure in highly vulnerable areas, and strengthening institutional capacity to anticipate, manage, and be resilient to climate risk.

Box 1: Adding new climate risk through maladaptation

Maladaptation is a process that 'may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future' (IPCC, 2014). Failure to manage current and future climate risk in planning decisions is an example of maladaptation that can lock societies in to development pathways that make them more vulnerable for decades to come. This can be the case especially for infrastructure investments that are often long-lived and difficult to reverse, such as roads, ports or urban developments, and the costs associated with such lock-in can be significant (Jones et al., 2015a).

A number of different factors can lead to maladaptive outcomes. These include an unwillingness or inability to invest in or prioritise adaptation strategies above other development priorities. Poor use of climate information or misunderstanding of the uncertainties associated with the impacts of climate change can also lead to maladaptation. Investments in large-scale hydropower that fail to consider future changes in the distribution of rainfall, for example, could lead to increased future climate risk for those communities that depend on such power facilities (Lambruso, 2014). Decisions to adapt too early may also lead to maladaptation if they preclude other more appropriate measures, or they manage long-term risk well, but short- and medium-term risks less well (Jones and Carabine, 2015).

Foreseeing potentially maladaptive outcomes is fraught with challenges. This is particularly true in developing countries where the economy is growing rapidly, there are significant demographic shifts and much infrastructure is yet to be built. The costs of maladaptation are potentially too high to ignore, however, and therefore need to be taken into account in policy decisions.

Many adaptation measures will promote resilience to other shocks and stresses on development. For example, adaptation might involve protecting and enhancing the provision of ecosystem services, creating new economic opportunities, and strengthening financial inclusion, particularly to enable the poorest to avoid or escape from poverty traps. Investment in climate-related disaster risk reduction (DRR) may also stimulate innovation and boost economic activity (Tanner and Rentschler, 2015). Such positive development outcomes are often the result of forward-thinking institutions that make inclusive and informed decisions, fostering adaptive capacity and institutional strengthening (McGray et al., 2007; Jones et al., 2010).

Developing countries may be hit harder by the impacts of climate change, in part because their socioeconomic conditions and physical assets, such as property, are poorly suited to the current climate, let alone to future climate change (Fankhauser and McDermot, 2013). This 'adaptation deficit' may result in mounting losses, particularly evident when extreme weather events hit (Burton, 2004; UNFCCC, 2007). Developing countries characteristically have fewer resources and capacity to deal with such risks. Adaptation is ultimately about supporting people, particularly the poorest, to deal with the impacts of climate change in their context. Building climate-resilience considerations into development can improve development outcomes for all.

Table 1: Managing climate risk: exemplary measures

Climate risk-management response	Explanation	Explanation
Avoid	Bypass the risk	– Retrofit existing investments – Land-use planning to restrict investment and settlement in high-risk areas – Introduce or change regulations and standards – Introduce licenses, user fees and labelling – Introduce incentives for relocation to less climate-vulnerable areas
Reduce	Decrease the exposure, potential impact or likelihood of an event	– Invest in research and adoption of more drought- and flood-tolerant crops – Improve water-use efficiency and build water-storage capacity – Stabilise and protect ecosystems, such as mangroves, forests and wetlands – Design and adopt early-warning systems – Enhance public health programmes to prevent the spread of vector-borne diseases – Build dykes, sea walls and other flood-mitigation measures – Build knowledge, capacity and diversify livelihoods – Set aside land corridors for movement of wildlife – Extend social protection for those most affected, particularly after climate shocks – Public awareness campaigns and other educational and informational initiatives – Switch activity or resource use to one better suited to climate change
Accept and share	Accept and plan for if the risk is realised	– Plan early-response measures – Identify evacuation routes and plans – Make formal or informal savings to respond to impact – Identify access to loans for response – Repair, reconstruct assets and build back better – Mutual and reserve funds
	Transfer the burden of climate impacts	– Seek and provide access to insurance, e.g. from crop failure – Seek reinsurance – Build social safety nets – Build social networks and informal risk pooling
Residual risk	Stakeholders may still have to deal with the impacts of risks that cannot be adapted to, either due to technology or cost limitations.	

3. Adaptation in practice: costing and financing

In this section we discuss the relative costs of action on adaptation, and review current efforts to finance it. In theory, adaptation action becomes worthwhile when the benefits of the proposed measure outweigh the costs (see UNFCCC, 2010). Estimates of the total costs of adaptation in developing countries range from $4 billion to $100 billion annually if global temperatures rise by 2°C above pre-industrial temperatures (Chambwera et al., 2014). Accurately costing adaptation is extremely difficult, however, with numerous methodological complexities making it hard to make precise estimations (see Box 2).

Box 2: Costing adaptation

Several studies have attempted to assess the costs of adaptation in developing countries for a 2°C rise in global temperature above pre-industrial times. Estimates range from $4 billion to $100 billion per year. This enormous range reflects the nature of the uncertainty regarding climate change impact and action. It is difficult accurately to estimate the costs of climate change for a number of reasons including:

- The complexity of the biophysical pathways that will be affected by climate change make it hard to predict what adaptation measures will be necessary and when.
- Cost estimates are typically based on a 2°C rise in global temperatures. The degree of adaptation required will depend on the success of mitigation action with adaptation costs to temperate changes of over 2°C change in a non-linear way.
- Costs will depend on whether the intention of adaptation is to minimise all or part of expected impacts, to return wellbeing to pre-climate-change levels, or to maintain the current level of risk.
- While some investments in adaptation (such as dams and sea walls), may last for 50 to 70 years, others, for example in health, have much shorter timeframes over which costs and benefits will be seen. The time horizon and the rate at which the future is discounted will greatly affect cost estimates.
- Over time, economic development, technological advances and cultural norms and values may change to enhance or reduce the capacity of systems to avoid limits. Thus limits to adaptation may be alleviated over time, but these are hard to predict in cost estimations.
- A number of sectors are omitted in adaptation cost estimates because of the lack of data. Ecosystems, mining and manufacturing, energy, retail and tourism, for example, have very limited data and rarely feature.
- Some countries are poorly adapted to their current climate and there is no consensus on whether and how to include this 'adaptation deficit' in cost estimates.

Table 2 overleaf summarises the best estimates of the costs of adaptation at a global level. The studies often build upon each other, drawing on the same data sets and methods. Few studies cover all relevant sectors. As can be seen, many estimates of the costs of adaptation have focused on 'incremental' investments over and above a baseline level of projected investment in assets and activities (World Bank, 2010). A focus on incremental costs often results in overlooking the impact of softer behavioural and regulatory adaptation measures, such as investments in institutional capacity, and other technical skills that may influence the effectiveness of broader adaptation measures.

National or regional-level estimates of the cost of adaptation are not always consistent with global estimates. They often use different definitions of adaptation costs, different methods and include different sectors, making comparisons difficult or impossible. National cost estimates may be able to capture the costs of the institutional and policy changes required for adaptation, as well as private adaptation measures. Few countries, however, have systematically costed their adaptation needs. As a result, it is hard to derive accurate estimates of the aggregate costs of adaptation to climate change from national studies. In 2011, the United Nations Development Programme

Table 2: Estimates of future adaptation costs

Study	Costs of adaptation (US$ bn/year)	Timeframe	Sectors	Methods
World Bank (2006)	9-41	Present	Unspecified	Costs of climate proofing foreign direct investment (FDI), gross domestic investments and Official Development Assistance (ODA)
Stern (2007)	4–37	Present	Unspecified	Update of World Bank (2006)
Oxfam America (2007)	>50	Present	Unspecified	World Bank (2006) plus extrapolation of cost estimates from national adaptation plans and projects financed by non-governmental organisations (NGOs)
UNDP (2007)	86–109	2015	Unspecified	World Bank (2006) plus costing of targets for adapting poverty-reduction programmes and strengthening disaster-response systems
UNFCCC (2007)	28–67	2030	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure	Planned investment and financial flows required from the international community
World Bank (2010)	70–100	2050	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure; extreme events	Improvement on UNFCCC (2007); more precise unit cost, inclusion of cost of maintenance and port upgrading, risk from sea-level rise and storm surges

Source: *IPCC Fifth Assessment Report (Chambwera et al., 2014).*

(UNDP) published the results of its efforts to support stakeholders in 15 countries to complete assessments for climate change investment and financial flows. While the individual country needs assessments varied substantially, the total estimates of the need for finance were in the order of $5.5 billion a year in 2020 rising to $7.1 billion a year in 2030 for one or two sectors in each of the 15 countries. Similarly, the UNFCCC secretariat supported governments to complete assessments of their financial needs in 2010, resulting in cumulative short- and long-term estimates of adaptation costs of between $161.5 million and $20.69 billion per country.

The United Nations Environment Programme (UNEP) recently coordinated an initial assessment of the 'adaptation gap', based on a synthesis of existing research on the costs of adaptation at the global and national levels. It suggested that in the least developed countries (LDCs) alone by 2025/2030 costs could be between $50 billion and $100 billion a year. For all developing countries, it implied costs of $150 billion by 2025/2030 and $250 billion a year by 2050 (UNEP, 2014). These figures include both adaptation and residual costs – making them higher than other existing estimates – and are based on the best available regional costs, taking uncertainty into account, rather than through bottom-up analysis or modelling.

At the national level, since 2001, LDCs have made initial assessments of the costs of high-priority adaptation measures by developing National Adaptation Programmes of Action (NAPAs). The total cost of the actions listed in the NAPAs by 2014 totalled $2.4 billion (NAPA Database, 2014), with costs of individual projects ranging from tens of thousands to tens of millions. But NAPAs were never intended to represent a full costing of country needs, simply to represent high-priority actions that will take place over differing timeframes, and identified through very different processes.

Adaptation needs are likely to change over time, rendering estimates of costs quickly out dated. This is in part because vulnerability to climate change is a result of economic, social and institutional factors that are changing – often rapidly – particularly in developing countries. It is also because the understanding of 'good adaptation' measures is evolving including thanks to improved and greater availability of climate-related information. These issues further complicate efforts to estimate the costs of adaptation.

Adaptation under the UNFCCC

Attention to the need to adapt and strengthen resilience has grown as the impacts of climate change are increasingly felt. Countries are already making many efforts to understand

and respond to the impacts of climate change. In this context, the international community has recognised the need to increase support to developing countries that are highly vulnerable to the impacts of climate change and which have also least contributed to this global problem. International climate policy has raised awareness of this issue, prompting greater efforts to understand adaptation needs in vulnerable countries. It has also sparked new initiatives to mobilise finance to support adaptation in developing countries.

The UNFCCC, in particular, has catalysed several efforts to increase understanding of the implications of climate change for developing countries. One of the first measures was to support LDCs to develop NAPAs. Under the UNFCCC the LDCs have also established an Expert Group to support efforts to build knowledge about effective adaptation action and guidelines to support relevant initiatives. In 2006, the Conference of the Parties (COP) initiated the Nairobi Work Programme aiming to support the creation of knowledge on adaptation action, including by the private sector,[2] by collecting information on adaptation options and implications. In 2010, an Adaptation Committee was created, tasked with providing technical support and guidance to the parties to promote enhanced and coherent action on adaptation, including by facilitating information-sharing and stronger stakeholder networks. In 2013, the COP also established the Warsaw Mechanism for Loss and Damage associated with Climate Change Impacts. Focusing on the residual impacts where adaptation is either not possible or ineffective, the mechanism seeks to address the economic impacts of both 'extreme events (such as hurricanes and heat waves) and slow onset events (such as desertification, sea level rise, and ocean acidification) in developing countries that are particularly vulnerable to the adverse effects of climate change' (UNFCCC, 2015).

The nature of potential links between the Loss and Damage mechanism and adaptation finance has been one of the most difficult issues in the UNFCCC negotiations. It is hard to distinguish between adaptation from loss and damage. While developing countries have raised the need for mechanisms that can potentially compensate them for damage induced by climate change that has been caused largely by the historical actions of developed countries, the latter have rejected this notion. The mechanism mandate is largely focused on information-gathering and collation efforts, complemented with stakeholder engagement and the mobilisation of relevant expertise, including to enhance understanding of risk-management approaches, and to catalyse financial, technology and capacity-building support.

More recently, all countries have been encouraged to establish National Adaptation Plans (NAPs), which have an emphasis on the longer-term institutional transformations required to enable successful adaptation. These processes are underway with initial support from the Global Environment Facility (GEF) through UNDP, although there remain questions about how NAPs will be funded and ensuing actions financed at a wider scale. In their Intended Nationally Determined Contributions (INDCs) countries have also had the opportunity to identify relevant adaptation actions that they will take. More than 121 countries (86% of those which submitted INDCs, and most developing countries) included adaptation measures in their offers (Mogelgaard and McGray, 2015). In most cases the adaptation elements of INDCs represented a synthesis of existing adaptation efforts and prior plans, rather than a concerted projection of future adaptation needs. Several also included estimates of the financing requirements for implementing these actions as part of their INDCs, though the basis for costing is not clear or consistent (Hedger and Nakhooda, 2015).

International Adaptation Finance

Historically, most climate finance has supported efforts to reduce emissions in developing countries (Nakhooda et al., 2014). Total flows of finance from public and private sources that support adaptation to climate change were estimated at $25 billion in 2014, representing less than 10% of total all climate finance flows identified (CPI, 2015). Public finance for adaptation through dedicated climate funds and initiatives has increased steadily since 2011, however, and now accounts for about 30% of finance approved by these institutions (CFU, 2015). The need to provide finance to help developing countries adapt to the impacts of climate change has attracted growing attention in international policy processes. UNFCCC agreements on climate finance call for scaling up adaptation finance, and a 'balance' between support for mitigation and adaptation activities in climate finance.

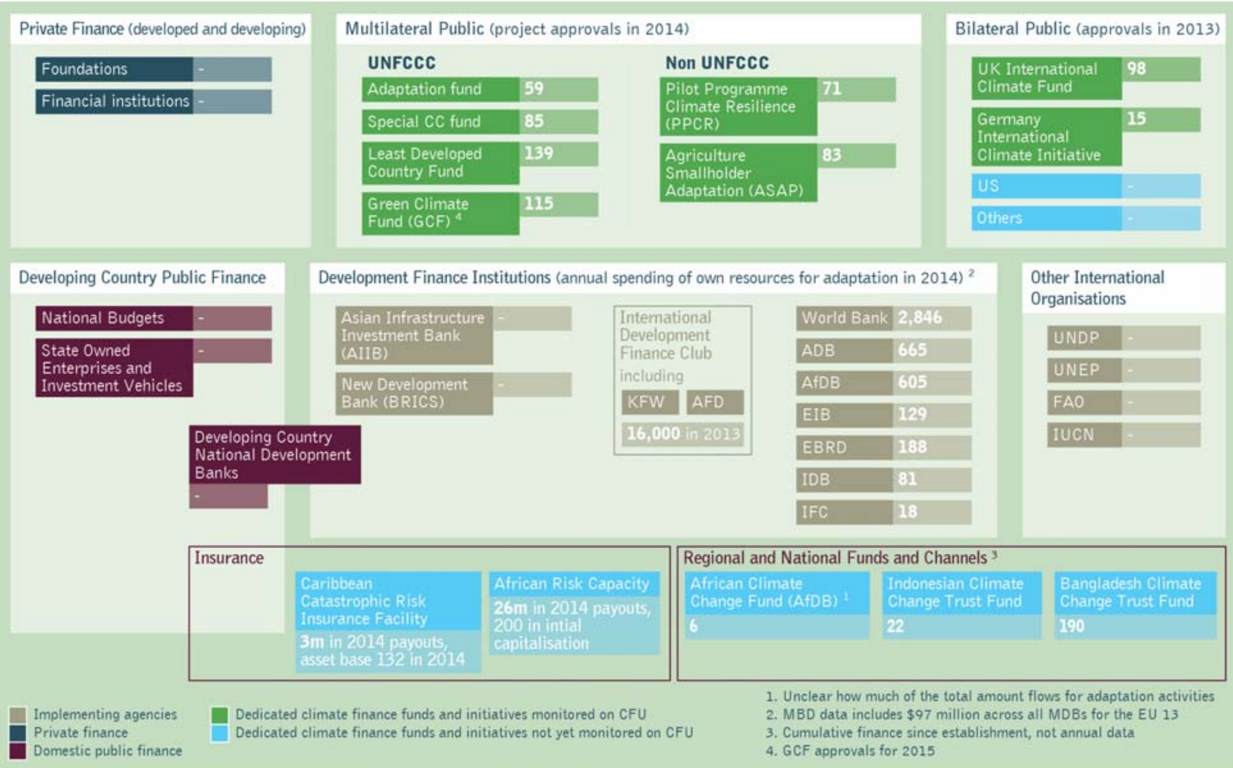
A substantial share of adaptation finance is also reported to the Development Assistance Committee of the Organisation for Economic Co-operation and Development Assistance (OECD DAC) as climate-related development finance (and adaptation as an objective of many development projects), as they also support development goals (Jones et al., 2012). Difficulties in identifying investment in adaptation activities are particularly relevant in relation to private-sector investment, as few private investors or companies currently report on adaptation actions and related spending (although some actions may be included in business continuity plans, environmental vulnerability assessments or other conventional risk-management strategies). Figure 2 presents a snapshot of current adaptation finance, and the multitude of actors that are involved in channelling and spending it.

By and large, adaptation funds have targeted some of the most climate-vulnerable and poorest countries (Nakhooda

2 A database of actions on adaptation can be found on the UNFCCC website as part of the Private Sector Initiative of the Nairobi work programme, often with NGO and public-sector partnership: http://unfccc.int/adaptation/workstreams/nairobi_work_programme/items/6547.php

et al., 2014). About 70% of adaptation finance through dedicated climate funds goes to LDCs, of which 41% targets African countries (Climate Funds Update, 2015). Fragile states have received very little funding, and there has also been a dearth of funding for many highly vulnerable middle-income countries (MICs).

Figure 1: The International Adaptation Finance Architecture (simplified, not to scale, figures in USD millions, correct as of December 2015)



UNFCCC Funds

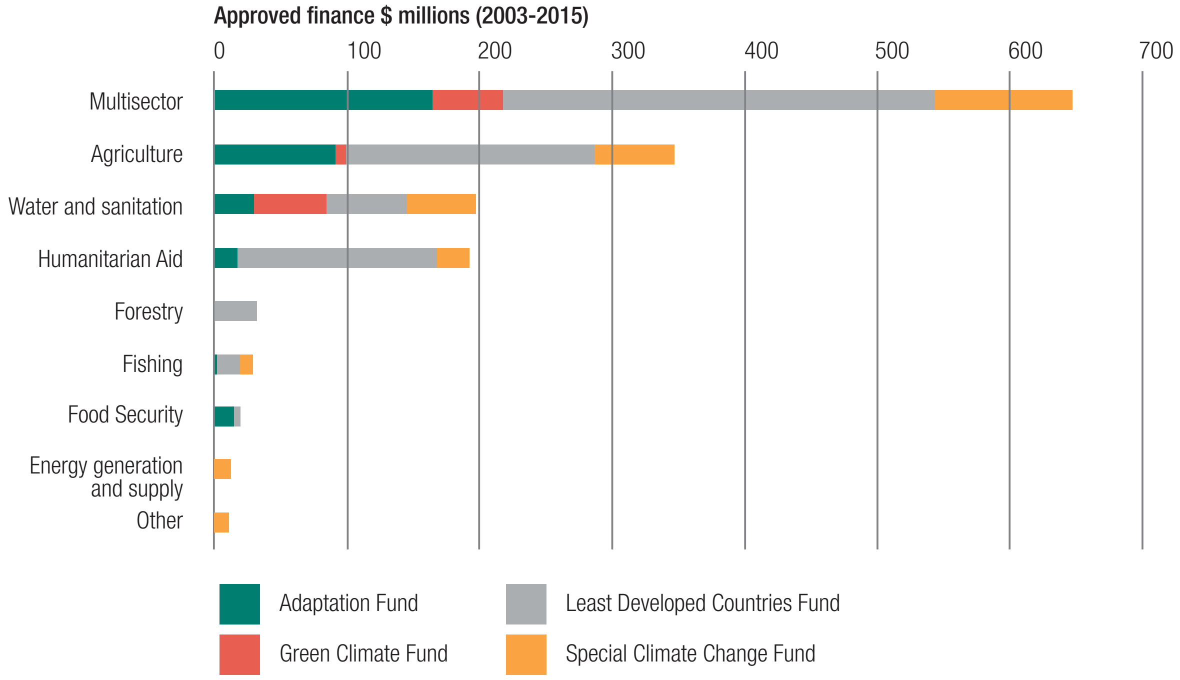
Since 2001, four funds have been set up to support adaptation action in developing countries under the guidance of Parties to the UNFCCC. These include the $934 million Least Developed Countries Fund (LDCF), which financed the completion of NAPAs, as well as individual projects identified through this process. The $349 million Special Climate Change Fund (SCCF) was also created, and has largely supported adaptation projects in developing countries. The Adaptation Fund, financed through a share of the proceeds from certified emission reductions from the Kyoto Protocol, is also significant despite its modest total capitalisation at $486 million since 2008. In recent years most of its funding has been raised from voluntary contributions from governments in developed countries, rather than carbon market revenue. One of the goals of the international community in establishing the Green Climate Fund (GCF), which has raised $10 billion, was to help increase support for adaptation through operating entities of the financial mechanism of the Convention. The Fund is to spend 50% of its money on adaptation (and 50% of adaptation finance is to be spent in LDCs, small island developing states (SIDS), and African countries).[3] The total approved for adaptation activities through these funds had reached over $1.5 billion by December 2015, a portion of which goes to infrastructure-relevant sectors (Figure 2).

Other international funds

Several further initiatives to support adaptation have been launched, although they are not under the direct guidance of the UNFCCC COP. In 2008, the World Bank-administered Climate Investment Funds were launched with a $1 billion Pilot Programme on Climate Resilience (PPCR), working in partnership with regional development banks to explore options to finance adaptation at scale in a relatively small number of countries.[4] The International Fund for Agricultural Development (IFAD) manages an Agriculture Small Holder

3 Tracked in grant equivalence.
4 By 2015 the total capitalisation of the PPCR had increased to $1.2 billion.

Figure 2: Adaptation finance approved through the UNFCCC Funds by sector



Source: *Climate Funds Update, 2015.*

Adaptation Programme (ASAP). Several bilateral development agencies have also launched programmes with a particular emphasis on adaptation, including the European Commission-managed Global Climate Change Alliance (GCCA) and several of the programmes financed through Germany's International Climate Initiative (ICA).

Insurance

The insurance industry is increasingly engaged in understanding the implications of climate-related events and risks for the existing portfolio of products and clients. The sector has been one of the most visible in its response to climate risk, not least because climate change can increase its business costs. Initiatives include raising awareness of disaster risks, lobbying for more proactive government action, developing new modelling and risk-assessment capabilities, as well as supporting concrete adaptation action by investing in information, and tailoring the terms and conditions of existing policies, and developing new products to address relevant risk (Lal et al., 2012; Agrawal et al., 2011).

There has been strong international interest in options to increase access to insurance in poorer countries (where the insurance industry is much less established) and for poorer people (who may not be able to afford conventional insurance policies) as part of efforts to strengthen the resilience of economies to climate change, and to make financing available in cases of climate-induced disasters (Mitchell and van Aalst, 2008). Insurance can help to share and spread financial consequences, providing the assurance of help to recover from events. Access to insurance can also affect the wider economy, allowing business continuity to support growth and innovation.

Insurance is not always viable. Private insurers may withdraw when risks become difficult to insure at affordable rates. This may require governments to step in, sometimes by forming partnerships with private insurers. There can also be significant moral hazard if incentives to manage climate risk are reduced as a result of access to insurance. Associated policies and careful design of the insurance on offer, such as risk-based premiums and deductibles, may help manage these issues. Well-designed programmes may also incentivise risk management.

In recent years several initiatives aimed at increasing public access to insurance against catastrophic events, including those induced by climate change, have been established. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) was the world's first multi-country risk pool to offer parametric insurance. It was established with support (including technical advice) from the World Bank and initial donor funding, but is now also funded by membership fees from Caribbean countries. Among other functions it helps to mitigate short-term cash-flow problems that small developing economies suffer after major disasters, including those that result from climate change.

The Africa Risk Capacity (ARC) Centre was established on a similar model as a specialised agency of the African Union. The ARC consists of a Specialised Agency, which supports analysis and assessment of vulnerabilities and risks, using data sets and software to support prediction of severe events, and an associated financial affiliate. As with the CCRIF, payments are triggered by substantial deviation from the models and therefore give liquidity in the immediate aftermath of climate-related events, as opposed to following lengthy reporting of losses. At present, the ARC offers a maximum coverage of $30 million per country per season for droughts that occur once in five years or less. It seeks to encourage countries to invest in adaptation policies, planning and other measures that will strengthen resilience to climate-related impacts, particularly drought.

In 2015 the G7 committed to increase access to insurance against climate risk in developing countries to cover at least 400 million people by 2020. A range of public and private insurance initiatives to this effect were also launched at the 2015 COP 21 meeting in Paris, including new initiatives from the UN Secretary-General, and the International Cooperative & Mutual Insurance Federation, which launched the 5-5-5 Initiative. This initiative is a micro-insurance strategy that seeks to protect 25 million previously uninsured people in the poorest areas of five countries by 2020. It is clear that this will be an important frontier for new efforts to finance adaptation, with clear linkages for infrastructure.

The private sector

Adaptation has the potential to create new markets and growth opportunities in the private sector. These include developing and deploying new technologies and solutions, new financing products, and other initiatives that can generate significant returns on investment (SEI, 2009; Agrawala et al., 2011). The insurance, tourism, energy and utilities, and food and beverage sectors have been most active to date (Averchenkova et al., 2015). There are also many opportunities across the built environment and construction sector, including in reducing the impacts of energy demand, and establishing water-recycling systems, ‘green roofs’ and domestic flood defences (Agrawal et al., 2011). Private sources of finance may be able to support adaptation measures but will be exposed to climate risk.

It is increasingly clear that climate risk undermines productivity and business growth, which affects the bottom line. Such awareness is gradually permeating across the private sector. In 2014, for example, the rating agency Standard & Poors recognised climate change as a major threat to countries’ continued prosperity and creditworthiness (Standard & Poors, 2014), while the high-profile Risky Business report found that by 2050 US coastal property worth between $66 billion and106 billion will be below sea level, average annual crop yields could decline by 50–70% by 2100, and outdoor labour productivity could decline by 3% by the end of the century (Risky Business, 2014). A recent World Economic Forum Survey ranked ‘failure of adaptation measures’ by business and government among five of the global risks with highest impact (World Economic Forum, 2014). Climate-related disasters are likely to increase in frequency and intensity as a result of climate change, with ever more devastating impacts for business (Watson et al., 2015; Crawford and Seidel, 2013). As one example, in 2011 floods in Thailand forced 14,000 businesses to shut down nationwide. The knock-on effects were severe: car companies in Malaysia, the USA, Canadaand Japan had to slow or halt production due to a lack of parts. Major car companies faced losses of billions of dollars: for Japanese companies alone, it is estimated that this disruption cost Toyota $1.25 billion, and Honda $1.4 billion (ISDR, 2013).

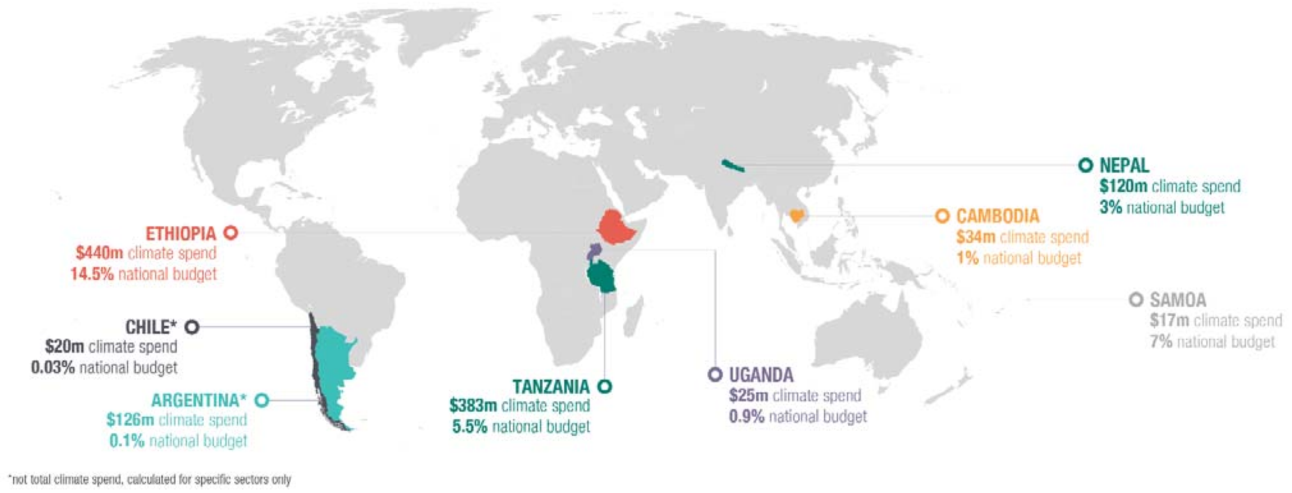
Private-sector actors are taking steps to manage physical risks of climate change. These include developing conventional business continuity or emergency-preparedness plans, conducting specific environmental vulnerability assessments, investing in upgraded equipment or infrastructure, transferring risk through insurance policies, and using climate-change-specific research or forecasting models to supplement conventional risk-management activities (Crawford and Seidel, 2013; Hertin et al., 2003). Private-sector actions that ignore climate risk may inadvertently increase vulnerability to climate change and these chains of impact are far less studied and understood.

Governments can establish policies and regulations to create an enabling environment for private-sector investment in climate-resilience, as well as to protect those that may bear short-term costs. These include reducing barriers to private investment such as over-regulation, insufficient access to affordable long-term finance and a high level of real and perceived uncertainty (such as first-mover risks and long payback periods) (Trabacchi and Mazza, 2015). In addition, governments can support efforts to make good information on climate risk easily available as a public good, fund research and development on adaptation solutions that are applicable across sectors, and support public–private partnerships (PPPs) that encourage adaptation and resilience, particularly where outcomes are public goods.

National climate finance

While the focus of our analysis on the international architecture to support adaptation, climate action is largely at the national level and domestically financed. All countries are beginning to spend more on responding to and dealing with climate risk, including some of the world’s poorest . For instance, Ethiopia spent more than 15% of its national budget on climate-related actions between 2008 and 2011. Spending in LDCs is often (unsurprisingly) concentrated on adaptation-related efforts, given strong synergies with overarching development needs, and relatively low GHGs (Bird, 2014). Although a growing number of countries produce information on expenditure on adaptation, reviews have been completed only in a small number of countries, which precludes a more comprehensive overview.

Figure 3: Selected annual public expenditure on climate change



Source: *Nakhooda et al., 2015.*

In addition, many countries (particularly developing countries) are setting up national funds aimed at raising and spending climate finance for adaptation. These include both highly vulnerable LDCs such as Angola, as well as large MICs such as India, which recently established a National Adaptation Fund financed from public resources. Evidence of the effectiveness of establishing dedicated funds with the sole goal of securing international confidence in national spending and management processes, as countries such as Indonesia have pursued, is inconclusive. Few funds have succeeded in mobilising more than between $20 million and $40 million. Bangladesh has created both a domestic fund for climate action, as well as a fund aimed at raising international resources, which is managed by the World Bank. This strategy has proved relatively effective, as the World Bank Bangladesh Climate Change Resilience Fund has mobilised more than $190 million. It is clear that finding effective ways to mobilise finance from a variety of sources (national and international, public and private), and incorporating a climate-risk perspective into investment decisions in all of these areas, will be necessary to achieve low-emission and climate-resilient development.

4. The implications of climate risk for global infrastructure finance

Infrastructure investment is high on government agendas given its contribution to economic growth, development and poverty reduction. Climate change, therefore, creates complexities and opportunities for anticipated investments in infrastructure in view of its vulnerability to the impacts of climate change. Making investments that consider climate risk in design and operation of infrastructure can help to protect infrastructure assets from climate change. This is particularly true in many developing countries in which significant investments in infrastructure are yet to be made. Early investment in climate-resilient options from the outset can avoid inefficiencies and costly retrofitting.

Ensuring that infrastructure is resilient to climate impacts also reduces the vulnerability of society at large. In poor countries (and for people living in poverty), a lack of access to markets and opportunities through transport-related services such as roads, or access to basic infrastructure for utilities such as energy and water, impede development opportunities – and therefore resilience – to the impacts of climate change. Providing access to appropriate infrastructure for basic economic and development needs can greatly reduce vulnerability. Investments in information and communication technology infrastructure can enable access to information and related tools that can help in anticipating and managing climate risk. For example, there is growing interest in the use of mobile phone technology for making weather-related information accessible to remote businesses and communities, and to strengthen and complement the reach of early-warning systems.

Protecting infrastructure from physical damage from climate-related events also supports the continuation of economic growth following the impacts of climate change. If a country is vulnerable to extreme events and changing temperatures, such events could leave people without access to electricity, water, health and emergency services and so less able to recover and rebuild (Guthrie and Konaris, 2012; Rydge et al., 2015). But climate-resilient infrastructure can achieve wider resilience and development gains. Building water-storage capacity and improving water-use efficiency could bring clean water and sanitation to more people, supporting better health as well as meeting basic needs and supporting agriculture, for example. Vulnerability to climate change is also reduced, of course, when investments in long-lifespan infrastructure, particularly for energy and transport, lay the foundations for a transition to a low-carbon economy rather than locking countries in to high-emissions pathways.

Steering developing global investment in infrastructure towards more climate-resilient approaches and assets, therefore, can support more lasting progress in eliminating poverty, reducing the potential for climate-related weather events to reverse development progress by pushing vulnerable people into poverty.

Figure 4 illustrates some of the ways in which choices regarding investment in infrastructure might be affected by the risks associated with climate change risk.[5] In the planning phases, these may alter the design specifications, including incorporating flexibility for later retrofits or upgrading, or the location of the infrastructure. New standards can also be helpful, and procurement can be designed to encourage adherence with standards that prompt attention to the climate-related resilience of proposed approaches and systems (see Box 3). Adaptation measures affect and therefore must involve the many parties involved in infrastructure, from construction companies to operators, government authorities, private investors, insurers and citizens.

Governments have a role to play in creating an enabling environment for climate-resilient infrastructure (Hallegate, 2011). Policies and funding can encourage the production and use of climate information. Regulation-based policies have an important role in making climate risks part of technical and procedural standards, such as building codes.

5 Work from the Rockefeller Foundation highlights the need for resilient systems to be: Reflective (accepting of new circumstances, and evolving based on emerging evidence), Robust (able to withstand impacts without excess damage), Redundant (spare capacity that can withstand pressures or surges in demand), and Flexible (able to change in response to new circumstances, by adopting new technologies or approaches). Other central qualities of resilient systems include being resourceful, inclusive and integrated (Rockefeller, 2014).

Box 3: Emerging sustainable infrastructure standards

Emerging sector standards may help to promote climate-resilient infrastructure, although to date there are no widely established standards.

The Standard for Sustainable and Resilient Infrastructure (SuRe) developed by the Global Infrastructure Basel and its stakeholders is intended to be a voluntary third-party verified standard for projects, rather than for companies or portfolios. Its first consultation period started in late 2015. It spans multiple infrastructure sub-sectors as well as the full lifecycle of infrastructure, measuring three proposed dimensions with 14 themes, including climate change. As part of climate, the standard considers emissions, energy efficiency, renewable energy, climate resilience and adaptability, emergency preparedness and ozone depletion. At present, climate resilience and adaptability grading requires specific a vulnerability assessment and 'bespoke' climate data and models.

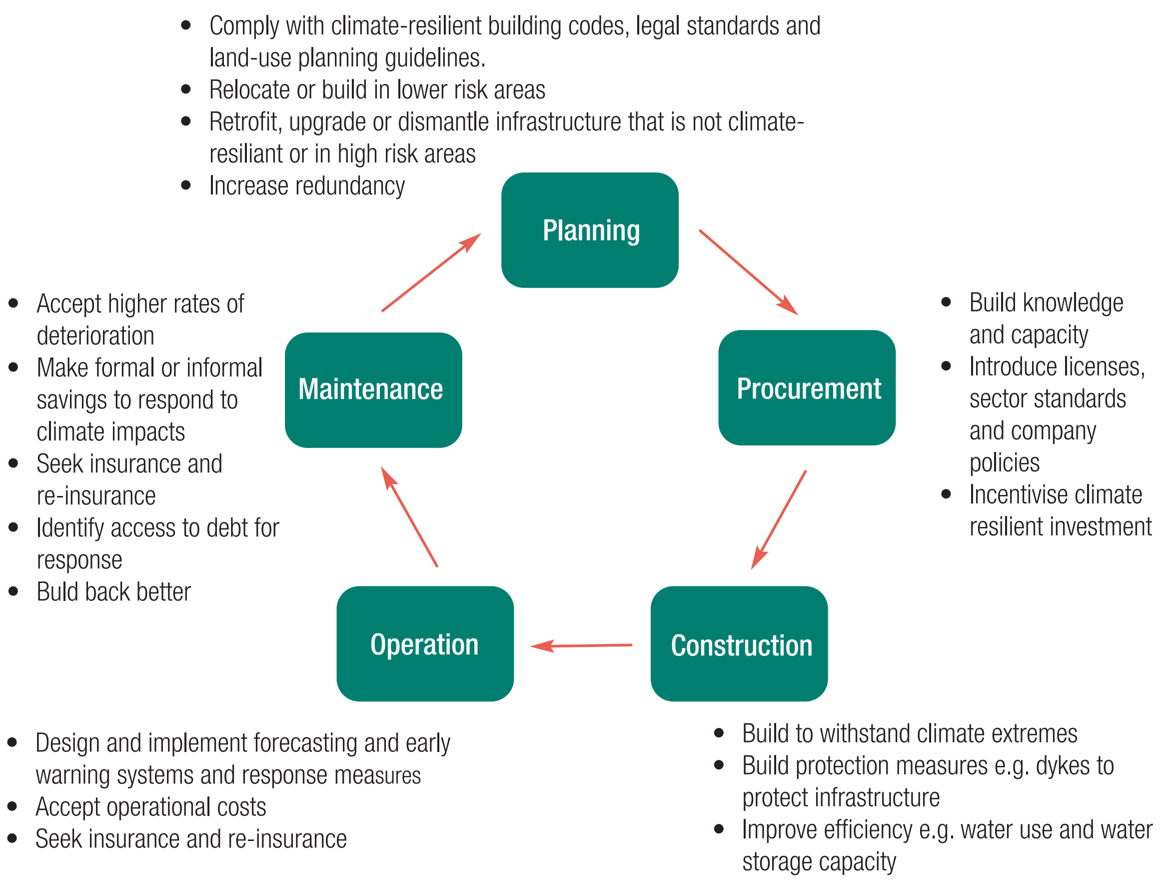
A Global Real Estate Sustainability Benchmark (GRESB) also under development, led by a working group of global institutional infrastructure investors with $1.5 trillion in total assets. It is intended to allow benchmarking of investors' infrastructure assets according to key environmental, social and governance indicators (ESG). Initiated in 2014, assessment covers eight categories of including climate change risk and resilience.

Multilateral Development Banks (MDBs) and other Development Finance Institutions (DFIs) have also developed tools to screen their investment portfolios for climate risk.

Market- or incentive-based policies can promote resilience in design, construction and operation such as penalties or subsidies. Institution-based solutions may allow pooling of resources, often crossing regional or country boundaries.

Direct government investment (or PPPs) to retrofit, absorb additional costs where they exist and increase resilience can also be relevant. These policies can both act as incentives and protect those that bear the cost of longer-term thinking.

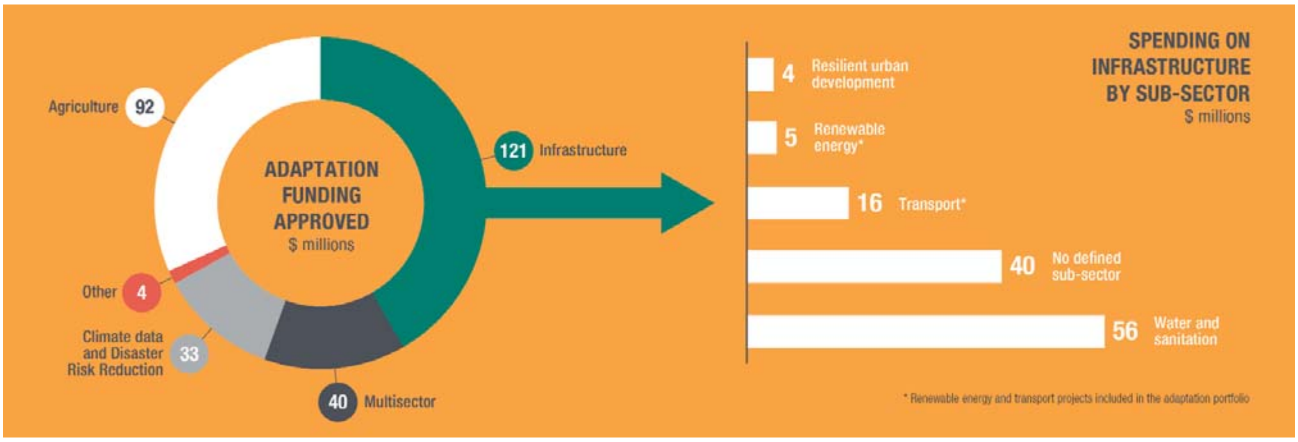
Figure 4: Exemplary adaptation measures to manage climate risk in the infrastructure lifecycle



Approaches taken by existing climate funds

Infrastructure investment has long been central to the spending priorities of climate funds. The approach to adaptation finance has evolved. About 15% of finance approved through multilateral climate funds ($421 million) since 2003 has supported infrastructure,[6] particularly for water and transport. As the levels of adaptation finance increase, countries are also seeking to use this funding to address adaptation needs. In 2015, 40% of approved adaptation finance from climate funds supported infrastructure projects (Figure 5).

Figure 5: Adaptation finance through dedicated climate funds supporting climate-resilient infrastructure in 2015



Source: *Nakhooda et al., 2015.*

There is often a strong association of adaptation with protective infrastructure such as sea walls that can protect coastal areas against flooding and sea-level rise, or dams aimed at securing access to water in vulnerable areas. Such projects featured prominently in many of the early NAPAs, but the range of infrastructure and associated approaches to resilience has evolved. Financing to build roads and irrigation systems now feature extensively in international climate funds.

The LDCF has supported adaptation in water supply and management, and road building. For example, in Timor-Leste it is providing funding with the Asia Development Bank (ADB) to increase knowledge and understanding of climate risks as well as reconstructing and rehabilitating roads with improved drainage, reinforced road surfaces and better road maintenance, and ministerial guidelines for more climate-resilient infrastructure. The SCCF has also supported energy generation and supply as a resilience measure. In Cambodia, it financed renewable energy technology in rural areas to build resilience to climate impacts by increasing household incomes and assets, and assisting in building resilience to drought by using solar pumping for irrigation. In Belize, the LDCF supports efforts to enhance the resilience of the energy system to the impacts of adverse weather and climate change. This complements a World Bank-funded Climate Resilient Infrastructure Project and reinforces energy-resilience measures outlined in Belize's National Climate Resilient Investment Plan. It will also support climate resilience in Morocco's ports.

Infrastructure is also dominant in the portfolios of funds such as the PPCR, which provides grant and concessional loans alongside MDBs' own capital. Some of these investments are at the energy–water nexus: for example the European Bank for Reconstruction and Development (EBRD) is using PPCR finance to address possible climate-related impacts on hydropower infrastructure in Central Asia. Because it works in only a small number of countries with higher levels of funding, the PPCR also seeks to pilot and demonstrate how climate risk and resilience may be integrated into core development planning. Infrastructure is also prominent in the adaptation finance portfolios of MDBs and other DFIs, alongside water and agriculture as the most prevalent sectors of intervention (Vivid Economics, 2015). The GCF is now providing combined finance of $55 million for urban water supply and waste-management infrastructure in Fiji, and integrated water systems in the Maldives.

To understand how concessional climate finance is being used to address climate risks for infrastructure, we reviewed documentation of selected PPCR-funded infrastructure

6 This includes the GEF, Adaptation Fund, Least Developed Countries Fund, Green Climate Fund, the Adaptation for Smallholder Agriculture Fund (ASAP), Global Climate Change Alliance, Global Environment Facility, Indonesia Climate Change Trust Fund, MDG Achievement Fund, Pilot Programme for Climate Resilience, and the Strategic Priority on Adaptation Fund.

projects. Such a review can offer lessons in how best to use adaptation finance in the future, although the climate risks clearly depend on the contexts. A major emphasis of the PPCR support for road development in Zambia (Box 4) has been to extend the economic impacts of increased road coverage in poor regions of the country, thereby strengthening resilience through increased productivity and access to markets for rural populations and businesses. In Cambodia, while the economic benefits of extended coverage were still a major consideration in the PPCR project (Box 5), addressing the possible impacts of extreme weather events was a more central outcome.

Box 4: Climate Resilience in Zambia's road network

In Zambia, the Kafue sub-basin project has a large transport infrastructure component. The intention is to ensure climate resilience in over 500km of roads and create an all-weather road from Victoria Falls, past the Kafue National Park and onwards to Lusaka. The project is anchored in the country's Sixth National Development Plan that calls for accelerated infrastructure development. Positive economic impacts are expected as a result of such infrastructure development, not least on tourism. With a focus on highly visible infrastructure, it will also have a demonstration impact for the rest of the country.

Climate-resilient infrastructure in Zambia will need to withstand floods and droughts, which are identified in the NAPA and National Climate Change Response Strategy as major climate risks that undermine productivity. Zambia's Strategic Programme of Climate Resilience notes that the infrastructure, and specifically road-building sector, is particularly vulnerable due to obsolete safety standards (with inadequate attention paid to flood return periods, for example), lack of standard harmonisation across the Southern African Development Community (SADC), inadequate enforcement, weak contract preparation and management, weak penalties and enforcement for non-compliance, ineffective maintenance, and limited engineering capacity to model climate-related risks. In the Kafue sub-basin, few existing roads have been designed for all-weather conditions and most are gravel-based and prone to flooding.

The PPCR investment has focused on different aspects of making roads more climate-resilient. Finance was budgeted for the revision of design standards and codes of practice, as well as training for contractors and regulators. Revised standards built on improved hydrological and morphological modelling in the sub-basin. Training included adequate review of bidding documents to ensure that procurement and upgrading took into consideration design studies (on the status of the road, drainage considerations, as well as increasing stress levels and surface temperatures) and made appropriate choices in response.

The project is also intended to reduce maintenance costs for key transport infrastructure (both the annual cost and the frequency of periodic maintenance). The responsibility for maintenance will fall to the Road Development Agency of Zambia and the National Road Fund Agency, which has the mandate to raise, manage and disburse funds for the management of the road network. While it is not clear if maintenance costs are set aside in the PPCR project, a 'Road Fund' with ring-fenced financing has been established to secure stable road-maintenance funds.

The extent to which there are express links between impacts and insights from these interventions and wider adaptation and resilience measures in given country is not always clear: in Zambia the road development project has been designed with building codes tailored to anticipated impacts in the sub-basin, and the programme includes plans for how these codes and approaches can evolve to inform national practices and standards. At face value, Zambia's PPCR project presents a comprehensive look at various stages of the infrastructure lifecycle. Cambodia's PPCR project takes a much more narrow focus on buttressing planned infrastructure, complemented with some efforts to strengthen government capacity on climate change.

Box 5: Climate Proofing Provincial Roads in Cambodia

In Cambodia, one element of the PPCR support is for the climate 'proofing' of provincial roads – the principal mode of transport in the country – in four provinces. With the intention to mainstream climate risk in transport infrastructure, it includes an assessment of climate risk of the road network in the project area, adjustments to civil works design, hazard mapping as well as ecosystem-based adaptation measures. Engineering solutions include road elevation in flood areas as well as alteration of sub-grade construction materials to withstand higher moisture content. The project also intends to take 'no-regrets' adaptation measures, piloting water capture and storage systems and ecosystem restoration.

In total, 157km of roads will be rehabilitated and upgraded to all-weather standards. By 2017 it is also intended that the Ministry of Public Works and Transport should mainstream climate risks into provincial road planning, maintenance and budgeting (responsibility for rural roads remains with the Ministry of Rural Development, while the Ministry of Public Works and Transport is responsible for national and provincial roads). This requires the adjustment of policies and manuals to take into account climate risk (including 100-year flood design and routine use of hazard maps), training both at ministry level and in engineering qualifications, maintenance works to be aligned with climate projections, budget allocations to take into account key vulnerabilities in priority roads and, ultimately, the increased provision and continuity of climate-resilient roads.

The project documentation notes that to achieve increased road-asset management, maintenance budgets will need to increase from $350 per km in 2010 to $400 per km in 2017, but this reflects the anticipated volume of traffic and its impact on wear as opposed to climate change-related risks specifically.

In general, interventions supported with climate finance from multilateral funds appear to have buttressed pre-existing infrastructure plans and pipelines, rather than prompting more serious reflection on the options and implications for meeting the relevant need. The focus has been on upgrading or rebuilding infrastructure in order to withstand impacts, rather than on fundamental planning regarding where to locate infrastructure, or issues related to the maintenance of infrastructure that may be subject to greater wear and tear. In some cases 'engineering' solutions are being complemented with ecosystem-based adaptation approaches aimed at strengthening natural supporting infrastructure to enhance resilience (Box 6). More generally, reporting on the impact of funded projects is quite scant, and the analysis presented in this section is based on project design documentation. There will a need for more work to take stock of progress made in practice as results are reported.

Box 6: Green versus grey infrastructure: ecosystem-based adaptation measures

Capitalising on the inherent ecosystem services that coral reefs, wetlands and forests provide, green, ecosystem-based approaches to CCA can reduce the need for grey engineering approaches such as sea walls, dykes, water reservoirs and filtration systems, for example. Ecosystem-based or hybrid approaches can be more cost effective than grey approaches, particularly in water, sanitation and hygiene, coastal planning, and protection infrastructure. The table below presents how the costs of green ecosystem-based approaches compare to grey engineering options. While they do not present directly comparable data, they highlight that decision-making should consider ecosystem-based adaptation options.

There are broader benefits to ecosystem-based approaches beyond adaptation that should also be considered. In particular, the array of ecosystem services that result are of great value to local communities (and in the case of mangroves or forests, they can provide benefits more broadly such as climate change mitigation).

'Green', ecosystem-based approaches	Grey engineering approaches
Coastal planning and protection	
In the Turks and Caicos Islands, the protection provided by coral reefs against erosion and wave damage is valued at $16.9 million per year.	The cost of using dykes and levees for coastal protection for the Turks and Caicos Islands has been estimated at 8% of GDP, or $223 million investment plus annual maintenance costs. The cost of 7.32km of levees to protect Cockburn Town on Grand Turk alone is estimated at $36 million with annual maintenance of approximately $6 million, while the cost of a sea wall would be approximately $125 million with $3 million annual maintenance costs.
If the wetlands around New Orleans were to be restored for coastal protection, estimated costs are: marshland stabilisation $2 per m^2, marshland creation $4.30 per m2 and freshwater diversion $14.3 million.	The cost of grey engineering solutions for coastal defence in New Orleans is high. Approximate unit costs are: $7–8 million per km to heighten a dyke by 1 metre; $5.3–6.4 million per km to heighten concrete floodwalls; $5.3 million per km to heighten closure dams (in water) by 1 m; and, $21–28 per m2 to armour levees.
In the Maldives, establishment of marine-protected areas to conserve coral reefs and other coastal ecosystems, would cost approximately $34 million in start-up and approximately $47 million annually (scaled up from calculations for a smaller protected area). Approximately $10 billion per year could be generated in co-benefits through tourism and sustainable fisheries.	The cost of building hard infrastructure such as sea walls, breakwaters and other forms of coastal protection to replace the natural reefs has been estimated at $1.6 billion–$2.7 billion depending on the measure.
Water, Sanitation and Hygiene	
Approximately 9 million New York City residents receive 90% of their water, or 1.3 billion gallons per day, from the Catskill-Delaware watershed. Protection of the watershed has cost the city $150 million per year over the past ten years.	The one-off cost of a water-filtration plant sufficient to filter water for New York City would have been $6 –$8 billion with annual operating costs of $300 million.
The Paramo wetland ecosystem above the Colombian capital Bogotá, lies within a National Park and protected by the public water utility (EAAB) to supply drinking water to most of the city's inhabitants, with an estimated initial investment of $8.3 million to protect 60,000 hectares. The wetland filters out contaminants and traps sediment so efficiently that the water it delivers to the city's treatment plant needs only chlorine treatment for disinfection. This service saves an estimated $3.5 million per year on capital and treatment costs for the city.	The cost of building the water reservoir and potable treatment plant that will supply water to the Bucaramanga, Giron and Floridablanca municipalities in Colombia up to 2032 is estimated at $127 million. The one-off investment in water-filtration facilities required for a service comparable to the Paramo wetland ecosystem is approximately $19.6 million.

Source: *Adapted from Jones et al., 2012*

5. Infrastructure exposure to climate risk

The need for infrastructure varies in different countries, in part, determined by the level of economic development, the condition and extent of existing infrastructure and predicted future demand. While the greatest demands are in developing and emerging economies, developed countries also need to replace and maintain existing infrastructure (Standard & Poor's, 2015; Risky Business, 2014). Yet, the way in which infrastructure is planned, procured, constructed, operated and maintained offers major opportunities to secure future development benefits. As developing countries seek to bridge the infrastructure gap,[7] they have the potential to ensure that all new investment is in sustainable infrastructure.

This section considers the exposure of investment in major infrastructure assets in developing countries to selected climate-related impacts. In this way, it illustrates the nature of climate risk for these investments as well as the potential impacts on development. Data on recent infrastructure spending and projected investment is presented in McKinsey and Company (2013), established with the aid of demand projections from the OECD, International Energy Agency and Global Water Intelligence. The data considers seven infrastructure sub-sectors: airports, railways, roads, ports, power, telecommunications and water. This analysis presents airports, railways and roads together as 'transport' and focuses on this sector alongside water and power. The nature of the underlying data means that it is not possible to specify in any more detail a particular technology, design, location or type of asset from this dataset. The projected investment in infrastructure assets considers the period from 2013 to 2030.[8]

Finance needs by country are estimated based on projected GDP and on historical spending as a percentage of GDP. The underlying assumption is that demand will be based on the infrastructure stock necessary to support the economy in 2030. Infrastructure finance needs will also be based on the productivity of infrastructure. This is not modelled in this this dataset, although it could

Table 3: Countries included in McKinsey and Company's (2013) historical and estimated infrastructure spending data

Region	Income Level	Countries included
Africa	LIC	Kenya, Zimbabwe
	LMIC	Cameroon, Egypt, Morocco, Nigeria, Senegal
	UMIC	South Africa, Tunisia
	HIC	–
Asia (inc. the Middle East)	LIC	Bangladesh
	LMIC	India, Indonesia, Pakistan, Philippines, Sri Lanka, Viet Nam
	UMIC	China, Iran, Jordan, Malaysia, Thailand
	HIC	Bahrain, Israel, Kuwait, Qatar, Saudi Arabia, Singapore, South Korea, United Arab Emirates
LAC	LIC	–
	LMIC	Bolivia, Honduras
	UMIC	Argentina, Brazil, Colombia, Costa Rica, Ecuador, Jamaica, Mexico, Panama, Peru, Venezuela
	HIC	Chile, Uruguay

Source: *McKinsey & Company 2013.*

7 Efforts towards closing the infrastructure gap are visible, for example, in the 2015 Financing for Development outcome, and in the Sustainable Development Goals (SDGs).

8 Monetary amounts from McKinsey 2013 have been converted to constant 2012 US$ using the Consumer Price Index as a deflator.

Box 7: Climate impact indices applied in the analysis

Overall climate change vulnerability score

The Notre-Dame Global Adaptation Index (ND-GAIN) is managed by the University of Notre Dame. It estimates the vulnerability to climate change in water, food, health, human habitat, ecosystem services and infrastructure. Vulnerability is a function of climate risk – comprising exposure and sensitivity – and adaptive capacity. The ND-GAIN Index also establishes a country's 'readiness' score to absorb and apply financial resources to adaptation. This includes components of a country's business environment and governance factors. We focus here on the vulnerability score in order to avoid co-variation with other factors affecting infrastructure investment. Furthermore, the ND-GAIN index is not used in conjunction with other climate impact indices used in the analysis given the lack of independence between the variables. The country score is generated from 36 indicators, weighted equally and scaled or arithmetically averaged, with a higher score indicating greater vulnerability to climate change. The indicators used by ND-GAIN are impacts projected to occur at – or around – 2030. Scores range from 0 to 1, with the most vulnerable countries scoring between 0.5 and 0.6 (see also Chen et al., 2015).

Table 4: Components of the ND-GAIN Vulnerability Score (equally weighted)

	Exposure	Sensitivity	Capacity
Food	Projected change of cereal yields	Food import dependency	Agricultural capacity (fertiliser, irrigation, pesticide, tractor use)
	Projected population change	Rural population	Child malnutrition
Water	Projected change in annual groundwater runoff	Fresh water withdrawal rate	Reliable access to safe drinking water
	Projected change of annual groundwater recharge	Water dependency ratio	Dam capacity
Health	Projected change in vector-borne diseases	Slum population	Medical staff (doctors, nurses and midwives)
	Projected change in deaths from climate-change-induced diseases	Dependence on external resources for health services	Access to improved sanitation facilities
Ecosystem Service	Projected change of biome distribution	Dependence on natural capital	Protected biomes
	Projected change in marine biodiversity	Ecological footprint	Engagement in international environmental conventions
Human Habitat	Projected change of warm period	Urban concentration	Quality of trade- and transport-related infrastructure
	Projected change of flood hazard	Age dependency ratio	Paved roads
Infrastructure	Projected change of hydropower generation capacity	Dependency on imported energy	Electricity access
	Projected impacts of sea-level rise	Population living under 5m above sea level	Disaster preparedness

Exposure to drought in 2030

This data is taken from Shepherd et al. (2013). The hazard index for drought projects how prone to drought various countries will be in 2030. Drought is measured by projecting rainfall deficits to estimate the length and intensity of abnormally dry periods for different locations. A value between 1 and 7 is attributed to each country, with a higher value reflecting a higher degree of exposure to drought in 2030. Note that each hazard index value represents the highest value occurring within a country's borders and is not an average measurement, a limitation to the application of this index.

Exposure to flooding

This assesses the increased likelihood of flooding in a country. It applies one of the ND-GAIN vulnerability components, i.e. projections of the percentage change in flood hazard during the 1990–2040 period. These projections follow the RCP 4.5 emission scenario, which assumes a global mean temperature rise of 1.8°C by 2100 (within the likely range of 1.1°C–2.6°C), relative to temperature levels in the 1986–2005 reference period. Data is presented as a percentage that represents the change between historical and predicted flood exposure.

Exposure to flooding is measured using data taken from Shepherd et al. (2013). The hazard index for flooding provides an indication of the projected exposure to flood events in various countries in 2030, based on historical data. A value between 1 and 7 is assigned to each country, with a higher value reflecting higher exposure to extreme heat in 2030. Note that each hazard index value represents the highest value occurring within a country's borders and is not an average measurement.

Exposure to high temperatures

This data is taken from Shepherd et al. (2013). The hazard index for extreme high temperature provides an indication of increased stress on agricultural systems, health and ecosystems in 2030, deriving from the 95th percentile of the daily maximum temperature. A value between 1 and 7 is assigned to each country, with a higher value reflecting higher exposure to extreme heat in 2030. Note that each hazard index value represents the highest value occurring within a country's borders and is not an average measurement.

Exposure to tropical cyclones

This data is taken from Shepherd et al. (2013). The hazard index for tropical cyclones provides an indication of impacts in 2030 based on probable tropical cyclone hazard models, based on a catalogue of the tracks, wind fields and rainfall footprints of past storms. A value between 1 and 7 is assigned to each country, with higher values reflecting higher exposure to tropical cyclones in 2030. Note that each hazard index value represents the highest value occurring within a country's borders and is not an average measurement. This is of course a substantial limitation in choosing where to locate infrastructure.

potentially reduce demand by up to 40% (McKinsey 2013).[9] It is acknowledged that the robustness of this data on projected infrastructure investment is limited, since it is based principally on historical trends rather than on future demand and takes no account of increasing efficiency of infrastructure and diminishing returns to adding physical infrastructure. Limited in coverage to just 43 developing countries[10] from three main regions, the dataset omits a number of smaller and less developed countries (Table 3).

The exposure to climate risks differs across countries and regions as a result of physical location and weather patterns, which means that different types of infrastructure face differing levels of risk according to their geography. With no single indicator of climate risk, the best available data from a variety of indices on climate impacts are applied in this analysis, focusing on climate extremes for each country in the dataset (Box 7). Given their interconnectedness, no aggregation of indices of climate risk was attempted. The climate indices used in the analysis are established at a country level and many presented as a maximum experienced rather than an average. There are limitations to this approach given that many climate impacts are highly localised, and future work might seek to address more specific geospatial dimensions of both infrastructure and associated climate impacts. Recognising its limits, this analysis is therefore provisional, picking out broad trends in Africa, Asia (including the Middle East) and Latin America and the Caribbean (LAC). More detailed analysis at the country level where data is likely to be more available and at a finer spatial scale, would make it possible to conduct a more sophisticated analysis of where infrastructure investment is likely to be located and its correlation with areas of high climate risk.

9 The McKinsey 2013 data differs from New Climate Economy projections of infrastructure demand since it uses different definitions of what is included in 'infrastructure'. The New Climate Economy estimate of $90 trillion by 2030, as opposed to $53 trillion, results from more comprehensive picture of upstream investments in the energy sector as well as what is included; the McKinsey estimate, for example, does not include irrigation.

10 The dataset of projected expenditure on infrastructure also includes 30 developed countries, defined as Non-Annex I countries under the UNFCCC.

Projected infrastructure investment and vulnerability to climate change

Combining estimates of total investments in water, energy and transport infrastructure with a measure of climate change vulnerability highlights the opportunities for developing countries to benefit by ensuring the resilience of new investments. Figure 6 presents a high-level overview of the total expected investment in infrastructure of the 73 countries for which analysis was possible – 43 developing and 30 developed – and their vulnerability to climate change as measured by the ND-GAIN Index (see Box 7). It shows that developing countries[11] have greater vulnerability to climate change than developed countries, but projected levels of total infrastructure investment from 2015 until 2030 remain comparable to developed countries in a number of instances. Steering investment in infrastructure in developing countries towards more climate-resilient approaches and assets has, therefore, the potential to support more lasting development progress, while also reducing the potential for climate-related weather events to reverse development progress and push vulnerable people into poverty.

Figure 6: Log of projected infrastructure investment in select developed and developing countries (2013-2030 in $ billions) and climate change vulnerability (ND-GAIN, smaller values represent less vulnerability)

Water infrastructure investment and projected climate impacts

The realities of climate change add new dimensions and complexity to persisting challenges of development, including ensuring water security and sustainability. In 2015 more than a billion people lack access to safe drinking water or improved sanitation (WHO, 2015). Considerable progress is needed in order to meet the SDGs pertaining to water access, particularly in LICs. The overall levels of investment in maintaining water ecosystems and water-related infrastructure are broadly regarded as highly inadequate, and existing water systems are highly inefficient (in use and operation) (WWAP, 2015). Metrics to factor climate risk and resilience opportunities into water-related investment are urgently needed. It is particularly important that these metrics ensure that prospective investments in water enhance resilience rather than inadvertently exacerbate risks.

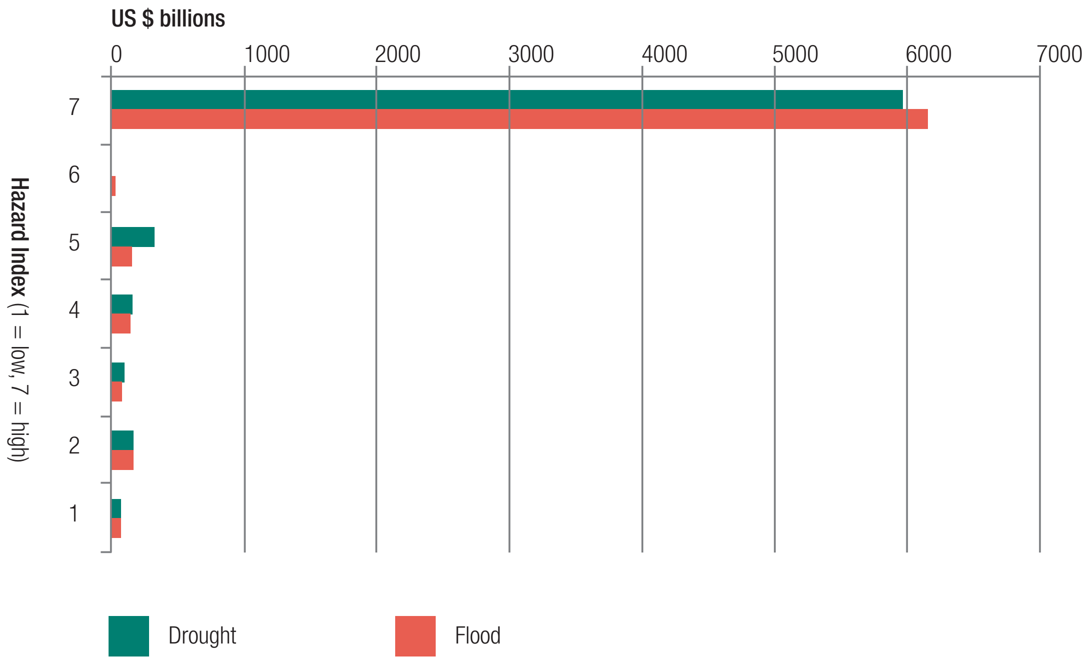
Climate-related risks that may affect water-related infrastructure include drought, floods and tropical cyclones. Drought in particular can have negative effects on water-related infrastructure. It can directly damage water-storage

11 Developing countries are considered here as non-Annex I countries under the UNFCCC.

and distribution networks as sediment builds in reservoirs with declining water levels, as well as damaging both under- and above-ground infrastructure due to 'shrink and swell' cycles in soils. Transporting water loads that has increased silting and sedimentation can also damage water-distribution systems, outlet structures and water-treatment facilities (Schwabe, 2013).

Figure 7 illustrates projected investments in water-related infrastructure located in developing countries subject to high risks of droughts and floods. While both the drought and flood indices take the highest value for a country rather than the average, the figure is intended to reflect that impacts radiate nationally from an economic and governance perspective (Shepherd et al., 2013). It also emphasises the danger of 'stranded' water infrastructure assets where climate impacts through increased droughts or flooding are not taken into account. More localised infrastructure investment data would be needed to establish what proportion of investment in a country would be prone to flood or drought risk.

Figure 7: Projected investment in water infrastructure (2013-2030) in 43 developing countries and level of exposure to drought and flood hazards in 2030



The African continent overall is the most exposed to a decline in water availability that is projected to accompany future climate patterns. Central to many African economies, agriculture will be dependent on increasingly variable and unpredictable rainfall patterns over time (WWAP, 2015). Particular vulnerabilities have been identified in Cameroon, Morocco, Nigeria, Senegal and South Africa, which are likely to experience moderately to severely stressed water supplies by 2050 (Luck et al., 2015). Cameroon and Nigeria are also predicted to experience an 8% rise in the likelihood of flooding by 2030. This will put additional stresses on water infrastructure in the region. With projected investment of $280 billion in water infrastructure by 2030 in just the nine African countries in the sample, including two LICs, an integrated approach to infrastructure building and resource use should be incorporated in water-sector decisions to mitigate risks to these assets.

All developing countries in the LAC dataset fell within the highest risk category for increased exposure to drought by 2030, while changes in the likelihood of flooding ranged between -2 and +8% in 2030. Because drought can both physically damage water infrastructure and affect the availability of the water it uses, LAC's high projected susceptibility to drought may threaten the $1,213 billion investment in water infrastructure planned over the next 15 years. Asia, the region with both the largest stock and projected investment, also has high hazard indicators for floods and droughts in 2030. As in other regions, it will need to make climate impact considerations for the $5,367 billion expected to be invested in water infrastructure by 2030.

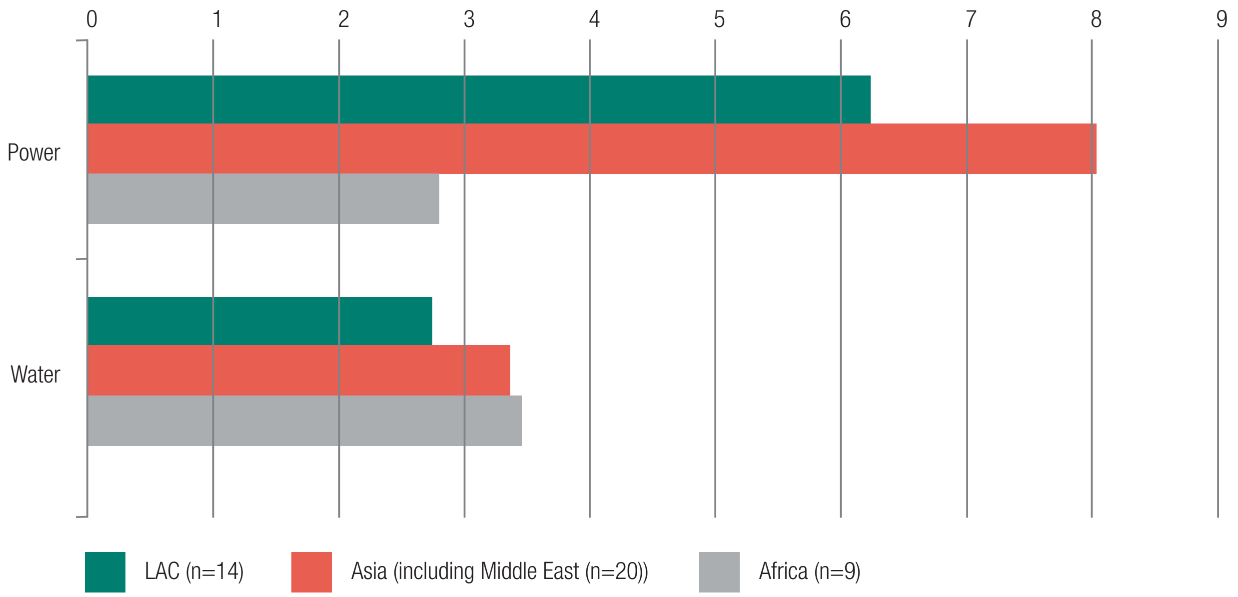
Avoiding or reducing the economic and social costs resulting from flood- and drought-related damage to water assets may require a range of integrated pre-emptive measures. Technical improvements and upgrades to existing infrastructure may be able to protect water distribution and treatment assets from sedimentation. By factoring climate-induced changes into decisions regarding the spatial distribution of water infrastructure development, policy-makers and developers can also help to minimise potential under-use of new water sector infrastructure assets.

Climate impacts on electricity and energy investments

There are still 1.2 billion people without access to electricity, a cornerstone of a productive economy, and the demand is increasing because of development and population growth (IEA, 2015). The highest volumes of investment in energy-related infrastructure are anticipated in the Asian region, even when controlled for population, and recent energy infrastructure spending is lowest in Africa (Figure 8).

Power and energy are generally associated with efforts to mitigate emissions given the large contribution of conventional energy to the global accumulation of GHGs. But energy and power infrastructure may also be heavily affected by climate change. Extreme heat threatens both the reliability and efficiency of electricity systems, both generation and transmission, and electricity generation may become less efficient if inefficient design forces plants to operate at a lower load factor to avoid overheating, and can cause brownouts or blackouts that are highly costly for both individuals and the wider economy (Aivalioti, 2015).

Figure 8: Regional infrastructure spending in 2012 for water and power sectors based on selected developing countries ($ per capita)

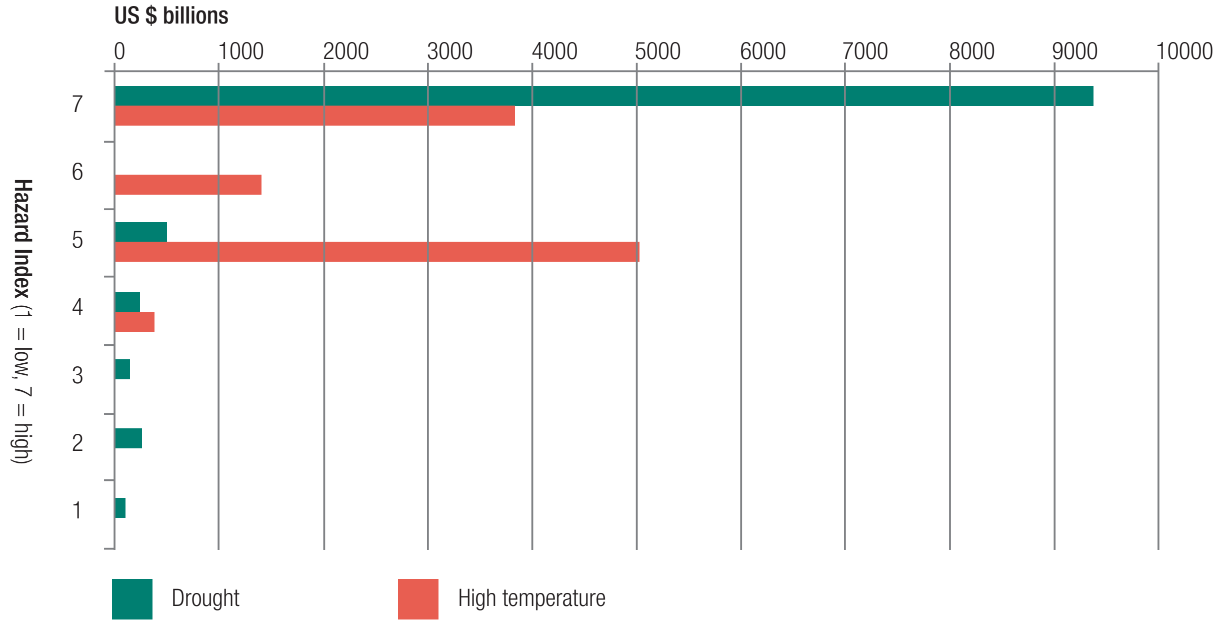


Extreme heat also leads to higher energy demands, such as for cooling systems, which place higher burdens on energy infrastructure. Conventional energy infrastructure is also often very water-intensive. Thermal power plants and nuclear power require water to cool the systems, and are therefore often sited close to water bodies. Hydropower obviously requires minimum water levels in order for turbines to operate at intended capacity. Disruptions to water systems as a result of climate change, such as droughts, can therefore have severe knock-on effects on the power sector. Projected investments in power infrastructure and climate impacts on high temperature and droughts are shown in Figure 9 for the developing countries in the data set. The links between access to energy services at a household level and resilience, including to the impacts of climate change, are increasingly recognised and there are, therefore, opportunities to promote access to energy as a means of adaptation (Perera et al., 2015).

Planned investments in Africa's power sector (totalling $440 billion in the nine analysed countries) will all face high exposure to extreme heat and fluctuations in water levels as a result of climate change in the 2030s. This raises questions about what climate-resilience measures are factored into design for the long-term sustainability of proposed mega-investments in hydropower in river basins across the continent. While there is substantial variation across the region with respect to climate impact and projected power-related infrastructure investment, there are countries with high exposure to extreme heat suggesting possible decreases in the efficiency of generation and high risk of water scarcity that warrant detailed consideration in new investment planning and design.

The 20 Asian countries in the sample, amounting to over $8,000 billion in predicted power infrastructure investment by 2030, are all extremely susceptible to extreme heat events that may both affect the efficiency of operations, as well as potential increases in demands for power. Many Asian countries are also at high risk of drought. Despite this, there are predicted increases in hydropower-generation capacity at more than 10% by 2030 in Pakistan, Philippines and Sri Lanka. Similarly nearly $2,000 billion is projected to be spent in LAC, where all sample countries have the highest hazard index for drought and all are predicted to experience small increases in hydropower-generation capacity by 2030, albeit by only a few percentage points.

Figure 9: Projected investment in power infrastructure in select developing countries (2013–2030) and high temperature and drought hazard indicators



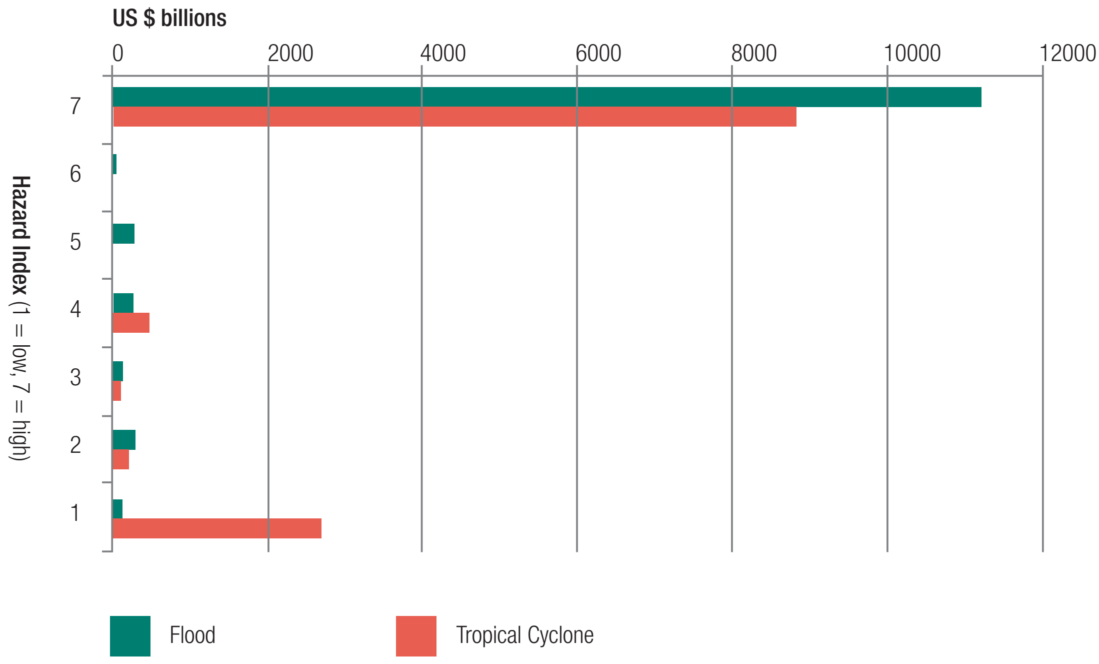
The available data on power investment and climate impact makes a strong case for all countries to invest in the efficiency and climate resilience of their systems, both existing and projected infrastructure. For power generation, anticipatory adaptation measures might include heat-related efficiency standards, cooling standards, and requirements on the geographical siting of plants. Large-scale thermal-generation facilities, for example, are situated in coastal areas. While data limitations make it difficult to estimate the value of existing and projected investment in power and energy in coastal areas, it is worth noting that there may be trade-offs between efforts to secure easier access to water for cooling and possible increased exposure to sea-level rise, coastal flooding and storm-related events. Steps to modernise, upgrade and heatproof power grids, including retrofitting current structures and incorporating new technologies and design structures, could also be necessary (Aivalioti, 2015). Several measures offer both adaptation and mitigation benefits while also enhancing the long-term resilience of households, communities and cities.

Transport-related infrastructure and climate impacts

Transport-related infrastructure is subject to a range of climate-related risks including increased frequency and intensity of extreme weather events such as flooding, related physical impacts, and sea-level rise particularly in coastal areas. Where transport infrastructure can withstand climate impacts there are clear benefits, such as the continuation of post-impact economic activity and access to important services. It can also add to economic activity irrespective of the occurrence of a climate-related disaster, opening up areas for economic activity and improving livelihood options. The proportion of paved roads in most African countries is well below the global average, for example. As efforts are made to extend road coverage, the durability of the assets and the livelihoods of those they are intended to benefit should include greater emphasis on climate-resilience considerations.

Figure 10 illustrates how these climate impacts can affect projected investments. The bulk of investments are in countries that are exposed to flooding and tropical cyclones.

Figure 10: Projected investment in transport infrastructure (2013–2030) in selected developing countries and exposure to climate hazards from floods and tropical cyclones

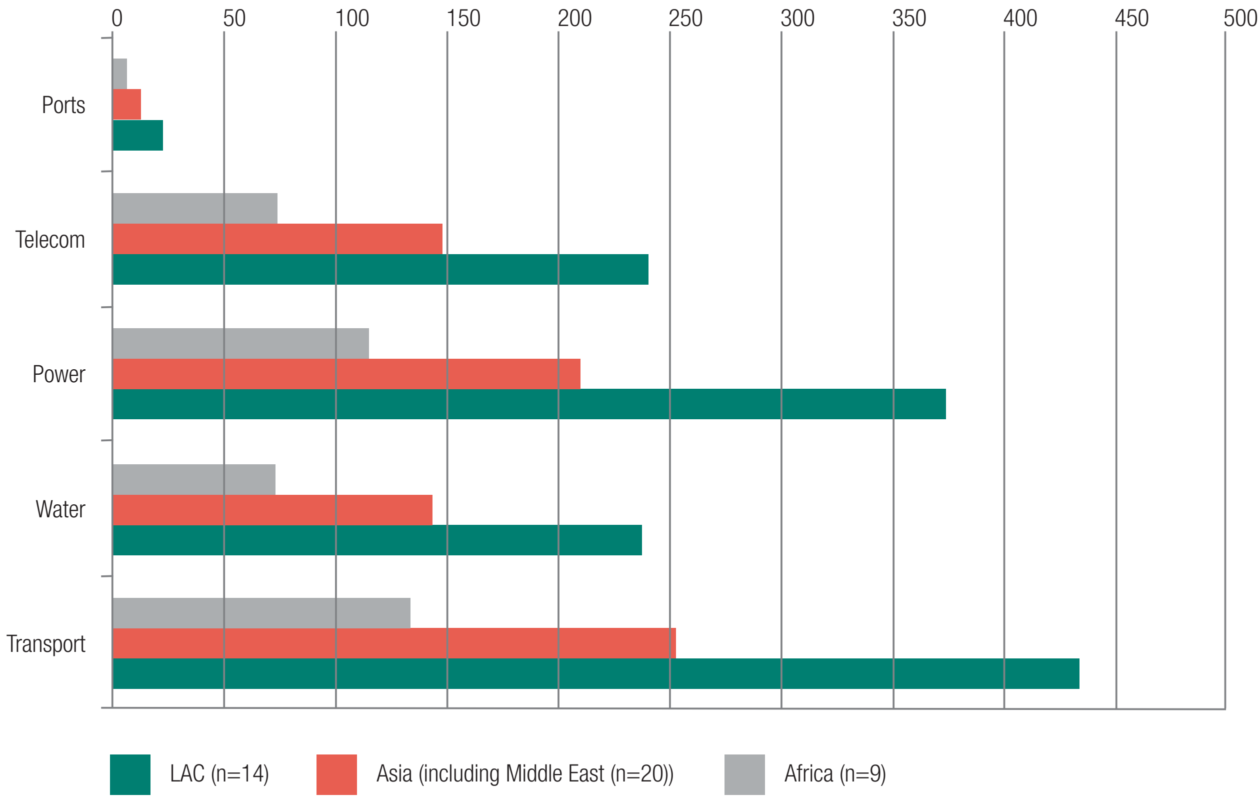


The largest projected investment in infrastructure in African countries is for transport (Figure 11). Total projected investment across the nine analysed countries exceeds $500 billion, although this does not account for growth beyond past trends. Flood hazards vary across the continent, highlighting the need for context-specific analysis in infrastructure planning. The hazard of high temperature is more ubiquitous, suggesting the need to use more temperature-resistant materials.

In Asia and the Middle East, an estimated $9,789 billion is predicted to be invested in the transport sector in the 20 countries included in the analysis. The bulk of this is in China, followed by India. Many Asian countries could see the huge investment in transport-related infrastructure that is exposed to flooding. For example, a more than 10% increased likelihood of floods is anticipated in China and Korea by 2030, as well as in India (+12.37%), Bangladesh (+11.17%) and Sri Lanka (+8.75%). Many countries in Asia are highly vulnerable to tropical cyclones that can necessitate reinforcement or additional measures to protect transport infrastructure. It will be important to explore both how best to invest in transport that supports a transition to low-emission development, as well as how to ensure these are situated and designed to take into account prospective climate changes. As discussed above, the approach taken to date has often been to buttress and reinforce infrastructure such as roads so that they can withstand storms, but there is increasingly a need for upfront planning for siting and optimal solutions for meeting needs.

More than $2,000 billion of investment is projected in transport-related infrastructure by 2030 in 14 LAC countries. Seven of these, accounting for more than half of this investment, have moderate likelihood of increased flooding: Colombia (+4.2%), Bolivia (+5.1%), Argentina (+5.59%), Brazil (+5.92%), Uruguay (+6.14%), Peru (+6.42%) and Ecuador (+8.2%). Although these countries are less exposed to the likelihood of flooding than many Asian countries, the large volumes of expected investment still make a compelling case for ensuring that these investments support greater resilience, rather than inadvertently exacerbate vulnerabilities.

Figure 11: Total projected infrastructure spending by region and sector (2013–2030, $ per capita)



6. Conclusions and recommendations

Our analysis confirms that increased climate variability and extreme weather events projected to occur over the next 15 years carry very serious consequences for built environments and the people who use them. Huge volumes of existing investment are at substantial risk. Even larger sums of prospective investment could either exacerbate exposure or help to support climate-compatible development. In order to insulate vulnerable areas and assets, there will be a need for major changes in the planning, design, operation and maintenance of infrastructure.

If efforts to extend access to infrastructure and to close the infrastructure finance gap are to meet the development agenda, they need to be provided in a way that is resilient to the impacts of climate change and variability. If the principles of resilience and good adaptation practice are applied to these investments and related decision-making processes, this could in turn enhance the benefits of these investments – particularly in developing countries, where immediate gains can be made, including for the poor and for poverty-reduction efforts.

It is imperative to mainstream a climate-risk perspective into development. Efforts to this end are already underway and must continue, and require more widespread changes in how adaptation is approached and understood. Lessons from the literature and practical experience of adaptation and efforts to strengthen resilience show that there is much more to adaptation than just building sea walls to protect against flooding, or more robust or redundant infrastructure that can withstand possible impacts. Adaptation is fundamentally about risk management and finding approaches to development that are climate resilient.

Our analysis has resisted quantifying the additional costs of adaptation and resilience measures. This is both because of the difficulties of doing this robustly, but also because the nature of costs differ substantially, may not always cost more than the counterfactual and may be offset by benefits over the lifetime of the investment. The existing practice of conflating the costs of the impacts of climate change, including residual damage and the actual costs of adaptation measures, have been unhelpful in informing investment decisions. Rather, we have sought to highlight the range of risks that climate change can pose along the infrastructure investment chain, and consider how these are being addressed in current investment practices.

Our analysis suggests that there is a need to pay more attention to the impact of climate risk across the infrastructure design and investment cycle. Many climate funds have supported consultation and capacity-building efforts in the context of strengthening national CCA policies, and raising awareness of climate risk. But these efforts have often been quite separate from the investments that have been made in physical infrastructure. Where climate finance has been used to strengthen the resilience of infrastructure, it has often been focused on the upfront capital costs of doing so. There is a case for more emphasis to be placed on how climate change may affect the maintenance and upkeep dimensions of relevant infrastructure. There is also a need for continued and strengthened emphasis on policy, planning and siting regulations to ensure that these better reflect possible climate risk in making concrete investment choices. More inclusive, accountable and informed decision-making processes can help achieve these goals. Such strengthened governance can also create opportunities to ensure that investments better meet development needs, including for poor and vulnerable sectors. Adaptation funds, including the newly established Green Climate Fund, can invest in institutional capacity to this end, and encourage improved governance.

There is a continued need for better information on climate risk (both the scope of possible impacts and likely probability), and in formats that can meet different needs across the infrastructure investment chain. Governments and regulators, service providers, investors and users all require different information provided in appropriate formats that enable a proactive response. Efforts to this end are beginning to take hold, as insurers invest in data-gathering and impact-assessment techniques, and other actors beginning to develop standards and guidelines to inform decision-making. But from an investment perspective the understanding and disclosure of climate impact-related risk is in its infancy. As other reports of the New Climate Economy have highlighted, this is an area ripe for further work, and more proactive efforts to understand and manage possible risks. Such measures are closely linked with wider efforts to strengthen resilience to shocks and stresses in the financial system, including efforts to extend access to insurance against disasters or create incentives for proactive approaches to DRR. The need for such information has been recognised by the G20 and the Financial Stability Board. In turn the capacity and incentives of financial institutions to respond to new information on such risks warrant attention and strengthening. International institutions such as the Green Climate Fund and other adaptation funds could have a substantial catalytic impact by beginning to foster and incentivise such outcomes through their investment strategies, and associated convening of key stakeholders. There remains an important role for public finance in helping to bridge these information gaps, but a possible need to focus on ensuring that the information generated is better tailored to users' needs rather than of a more general nature.

Many DFIs have begun to pay attention to these issues at the project and programme level, including as a result of incentives to account for climate-related spending. More proactive efforts to assess and respond to climate-related risks continue to be necessary, and are indeed a vital part of the infrastructure finance agenda. Efforts to strengthen collaboration in global infrastructure investment across DFIs and ensure their compatibility with a low-emission and climate-resilient future, such as those anticipated in the Addis Ababa Agenda for Action on Finance for development, present an important opportunity to strengthen understanding and practice. Seizing this opportunity can safeguard the impact and sustainability of anticipated and desired investment in infrastructure services. Failing to do so, would further threaten a reversal of the hard-won development gains of recent decades.

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Overseas Development Institute
203 Blackfriars Road
London SE1 8NJ
Tel +44 (0)20 7922 0300
Fax +44 (0)20 7922 0399

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