Chapter 15: Investment and Finance

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Table of Contents

Executive summary

[Note to reviewers: More on policy options to come; certainty language to come]

Climate financing needs have increased compared to AR5 levels driven by shorter period remaining until 2050/2030, relatively low mitigation investment activity in the past several years and rising levels of adaptation costs and losses and damages linked to climate-related extreme events. Average annual mitigation investments required come in between [*placeholder- to be updated in SOD* xx – yy] trillion USD for 2020–2030 with annual adaptation action expected to add between [*placeholder- to be updated in SOD* xx – yy] trillion USD. The increasing frequency and intensity of extreme weather events related to climate change and resulting in billions of dollars of damage and costs to GDP in affected countries, and value chain impacts globally, exacerbate the diverse needs for financing risk mitigation and climate resilient action across countries.

Climate funding, which has increased modestly over past years, remains significantly below required levels. Climate-related pledges, commitments and announcements by finance providers and investors, both public and private, have not necessarily translated into climate mitigation and adaptation action/results on the ground. Investments and financing remain insufficiently aligned with climate mitigation and adaptation objectives and needs (variously estimated), in part due to challenges in building capacities at institutional, local and national levels as well as inertia and foot-dragging among investors and finance providers, both public and private. The absence of concerted investment action and policies by the financially most well-endowed and biggest historical contributors to climate change, even in their own countries, is particularly notable, and the process by which some are now departing altogether from the Paris climate finance commitments is alarming for globally coordinated action.

Significant gaps exist across all sectors and regions with varying dominance and outlook for accelerated deployment of funding. [More to come based on updated AR6 model database analysis]

To close the gaps additional funding will play a crucial role. On the supply-side, public climate finance from developed countries will need to flow in greater quantity, with speed and predictability in both commitments and disbursements. This would be in alignment with the intention and sentiments expressed in the Paris Agreement. Significant action will also be needed to increase the concrete demand for such funding by translating the 1.5°C ambition into NDCs, national strategies and ultimately a pipeline of economically viable interventions. Both political will and leadership are central, financial sector can only do so much. Private climate finance flows and access are deeply affected by political uncertainty and credible public commitments to supporting public finances, policies and regulations, especially in wealthy developed countries with the largest sources of savings.

The ability to mobilize funding varies on a country level. The costs and risks of financing for local communities and cities, remain excessively high in many developing countries in addition to their general economic vulnerability and indebtedness. The mismatch between capital and investment needs, home bias considerations and risk perceptions between developed and low and lower middle income countries, represent a major challenge for commercial funding. A significant need for international climate finance – most likely exceeding the Copenhagen commitment – exists, taking into account current effects of climate change on already stressed public budgets in vulnerable and poor countries. Renewed levels of credible public finance commitments among developed countries to increased cross-border flows of climate finance to developing countries, as well as to credibly expedite their own climate mitigation commitments, budgets, investments and actions are needed in the immediate near-term (2020–2030), and not just by 2050.

There is strong evidence of a negative correlation between per capita incomes, credit ratings, institutional capacity of countries and international private climate finance flows, and positive correlation to their sharply rising costs towards those economies. While limited pipelines, limited absorptive capacities as well as restricted institutional capacity of countries in low income settings are often stated as challenge for an accelerated deployment of (commercial) funding, well-structured patient interventions and funding for capacity building and low carbon and climate resilient development are possible with the public sector needed to play an important role and require sufficient funding from international donors / climate finance institutions.

However, while large in absolute size, climate financing needs are relatively quite small compared to the total size of world incomes (GDP) and investments (GFCF) and the net amounts are even smaller (when netted against reallocations from alternative climate inefficient investments in fossil fuels and others). Nevertheless, a generally deteriorating environment for stepped-up (public) climate financing over the next crucial decade (2020–2030) is expected because of rising macroeconomic uncertainty and inadequate global policy coordination:

1) more unstable and slowing GDP growth at individual country levels and in aggregate because of worsening climate change impact,

2) increasing uncertainty with regard to the economic viability and growth prospects of selected macro-economically critical sectors which increases in the presence of some climate tipping points being reached in the near term,

3) rising public fiscal costs of adapting to rising climate shocks affecting many countries, which are negatively impacting already high public indebtedness and costs of financing,

4) rising financial and insurance sector risks and stresses and impacts of climate change systematically affecting financial institutions and raising their credit risks, and

5) current sharply slowing global macroeconomic growth, and prospects for near-term recession, and hence rising financial risk, both from secular stagnation and cyclical reasons (independent of ongoing climate change) which are negatively impacting climate financing possibilities generally at the global and national levels in the ‘near-term’.

Regionally, the current focus of the global climate investment needs policies and opportunities tends to be on the big four (China, USA, EU-28 and India) and the G-20 generally (UNEP Emissions Gap Report (2019). But attention must accelerate on low-income Africa. This large continent currently contributes very little to global emissions, but its rapidly rising energy demands and renewable energy potential versus its growing reliance on fossil fuels and ‘cheap’ biomass (especially charcoal use and deforestation) amid fast-rising urbanization makes it imperative that institutional investors and policy-makers recognize the very large 'leap-frog' potential for the renewable energy transition as well as risks of lock-in effects in infrastructure more general in Africa that is critical to hold the global temperatures rise to well below 2°C in the longer-term (2020–2050). Overlooking this transition opportunity, rivaling China, India, US and Europe, would be costly. Policies centered around the accelerated development of local capital markets for energy transitions - with support from external grants, supra-national guarantees and recognition of carbon remediation assets - are crucial options here, as in other low-income countries and regional settings.

The focus on private sector funding and the mobilization has consequently further increased. While the private sector has been a key driver of increased financial flows towards the renewable energy sector, it is uncertain whether other sectors can attract as much investor appetite and offer viable investment opportunities to the extent seen in renewable energy. Concerns need to be raised on whether adequate efforts are being made to build more appropriate public structures, support and competencies to steer and manage private sector involvement efficiently.

Two major challenges for private sector driven finance will be to increase the readiness for a fast and massive scale-up of climate finance and to signal this readiness to policy makers to back-up more ambitious emission reduction commitments and climate action. The first includes but is not limited to standardized financial products and liquidity in local capital markets but also transparency on climate related impacts of investments to foster demand from investors. It also requires public-private cooperation to allow private sector to create a track record in new segments/regions, within a context of safeguards, standards and integrated into national climate change policies and plans.

Progress has been made in the public and private sector with regard to the awareness on carbon risks and resulting systemic risks. However, significant knowledge gaps and inertia with regard to physical and transition risks need to be addressed quickly to facilitate the implementation of robust risk management in financial and governmental institutions to maintain financial and economic stability and manage climate impacts.

The delayed deployment of climate funding and consequently limited alignment of investment activity with the Paris Agreement will result in significant carbon lock-ins and stranded assets. This holds true for all major sectors, but in particular for transport and urban infrastructure. A delay of alignment of related investment activity with Paris and the SDGs will have massive negative and in the mid-term hardly reversible effects on mitigation potentials and will further increase systemic risks within the financial sector.

15.1 Key findings from AR5 and other IPCC publications

For the first time in IPCC, the AR5 included a separate chapter on Finance. This Chapter assesses three main questions.

The first is the scale of global needs. Section 15.2 assesses both qualitatively (where, why and how) and quantitatively (how big) the transformational scale of needs for climate finance is in the near-term (2020–2030 to 2035) to achieve significant progress towards longer-term (2050–2100) goals of limiting temperature rise and adapting to climate change.

The second is assessing recent progress on climate finance flows. Section 15.3 measures the current progress towards that goal, using a variety of sources of data and definitions.

This leads logically to the third and most important question of all: The gap in transformational climate finance needed – measuring if the glass is a quarter-full, half-full, or close to being achieved – and what can be done to accelerate near-term progress in the next critical decade. Sections 15.6.1-15.6.7 then deal with options for closing this gap.

Continuing the chapters' narrative, Section 15.4 turns to a discussion of the nature of the current gaps and drivers of transformational climate finance with respect to instruments, regions, sub-sectors, and cross-border climate finance flows.

Section 15.5 examines the macroeconomic considerations to accelerated climate finance flows, requiring political leadership for large-scale globally coordinated fiscal and monetary policy actions, including the increased role for sovereign guarantees and central banks.

Section 15.6 turns to a menu of options to closing the finance gaps in private financial markets. 15.6.1 looks at the availability and effectiveness of public sector funding of climate investments. 15.6.2 looks at enabling policy actions, 15.6.3 addressing knowledge-instrument gaps in assessing climate risks and transparency in financial systems, 15.6.4 expanding local capital markets, green bonds and cross-border guarantees, development of local capital markets is about scaling up, enabling and mobilising long term infrastructure financing (green bonds, guarantees, climate remediation assets), 15.6.5 widening the focus of policy action to cities and local communities, 15.6.6 climate risk-pooling and insurance options, 15.6.7 development of new business models, including gender and 'just transition' issues and payment for ecosystem services (including forestry and REDD+). 15.6.8 concludes on the relevance and complementary of approaches to address financing gaps identified in 15.4.

Section 15.6.8 then turns to the longer-term consideration of future transformational pathways, including large-scale, systemic behavioural change in climate finance.

The chapter concludes with some Frequently Asked Questions.

Attention begins in this section by summarising the findings of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5) (IPCC 2014), the Special report on the impacts of global warming of 1.5°C above pre-industrial levels (SR15) (IPCC 2018a), the United Nations Framework Convention on Climate Change (UNFCCC), related publications and recent developments. The Paris Agreement (PA) in 2015 (UNFCCC 2015) similarly added finance as one of its three overarching climate goals: 'making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' (Article 2.1c). The purpose was to recognise the transformational role of finance necessary to achieving the two long-standing climate goals (Article 2.1a to limit global temperature rise, and Article 2.1b to increase the ability to adapt to climate change), a fundamental change, even if much of the implementation issues were left for later (Bodle and Noens 2018).

One starting issue in climate finance that the AR5 finance chapter noted was the lack of clear definition and measurement of climate finance flows, which continues to the present day (see Section 15.3). What is not defined well cannot be measured well, and when measurement is a problem, agreement on policy is more difficult (Weikmans and Roberts 2019). The approach adopted in AR5 was to report ranges of available data on climate finance flows from diverse sources, and work within a broad definition as in the Biennial Assessments in 2014 and 2018 (UNFCCC 2014a, 2018) of the Standing Committee under the United Nations Framework Convention on Climate Change (UNFCCC): Climate finance refers to local, national or transnational financing – drawn from public, private and alternative sources of financing – that seeks to support mitigation and adaptation actions that will address climate change (UNFCCC 2014b). One structural element for this chapter is whether to cover climate finance relevant to mitigation or to include adaptation and loss and damage financing issues as well (see Box 15.1).

'START BOX 15.1. HERE'

Box 15.1 Mitigation and Adaptation Finance Need Examination Together

While mitigation finance deals with investments that aim to reduce global carbon emissions, and therefore appears separable in terms of sources of finance, needs and priorities (Lindenberg and Pauw 2013) from adaptation finance which deals with the consequences of climate change, they are not. One reason: Mitigation affects the scale of adaptation needs and vice-versa. If mitigation investments are ineffective in reducing global warming overall (as in last decade) and have asymmetric adverse impacts in lower latitudes and low-lying geographies, the scale of adaptation investments (and disaster financing) has to rise and more resources required as evident from integrated assessment models (IAMs) (Markandya and González-Eguino 2019). Conversely, if adaptation investments reduce risks or build greater resilience, they moderate mitigation (and disaster) financing costs. Similar policy coherence considerations apply to disaster finance, the scale of needs for which depends on success with both adaptation and mitigation (Mysiak et al. 2018). There is another reason. The same financial actors, such as governments and even the private sector, decide at any given time on their relative allocations of funding to mitigation, adaptation and disaster-risk from a constrained pool of resources. The trade-offs and substitutability between closely-linked alternative uses of funds, therefore, make it essential for a simultaneous assessment of needs – as in this chapter does. Climate finance versus the financing of other Sustainable Development Goals (SDGs) faces the same issue. Resources prioritising climate at the cost of non-climate development finance increases the vulnerability of a population for any given level of climate shocks, and vice-versa and additionality of climate financing is essential (Brown et al. 2010). Policy coherence is also the reason why mitigation finance cannot be separated from consideration of 'brown to green' issues and scaling-back spending on fossil fuels.

'END BOX 15.1. HERE'

The AR5 concluded that published assessments of all current annual financial flows whose expected effect is to reduce net greenhouse gas (GHG) emissions and/or to enhance resilience to climate change, and climate variability showed an aggregate of 343–385 billion USD per year globally (medium confidence). Most of this went to mitigation. Measurement of progress towards the Paris Agreement commitment by developed countries to provide 100 billion USD per year by 2020 for both mitigation and adaptation to developing countries – a narrower issue than the overall levels of climate finances – continued to be a challenge because of lack of clear definition of such climate finance. The annual need for mitigation finance between 2020 and 2030 was cited briefly in the AR5 to be about 635 billion USD (mean), suggesting that the reported 'gap' in mitigation financing was relatively moderate than at less than one-half (IPCC 2014).

More recent published data from the Biennial Assessments (UNFCCC 2018) and the published Special Report Global Warming of 1.5°C (IPCC 2018b) reports have revised upwards the needs between 2020 and 2030 to 2035 to contain global temperature rise to specified targets of below 2°C and 1.5°C respectively by 2100: 1.7 trillion USD per year (mean) in the Biennial Assessments 2018, and 2.4 trillion USD per year (mean) for the energy sector alone (and three-fold larger if transport and other sectors were included). The resulting gaps in annual mitigation financing, using reporting of climate financing from published sources was about 67% for 2015, and 76% for the energy sector alone in 2017 (medium confidence, see Table 15.1), and larger if other sectors were included. While the annual reported flows of climate financing showed some moderate progress (see Section 15.3), from earlier 364 billion USD (mean 2010/2011) to about 560 billion USD (mean 2015/2017), with a slowing in the most recent period 2014 to 2017, the gap in financing has widened (medium confidence). The reported global absolute total mitigation finance was only about the same size as annual investments in the fossil-fuel sectors, oil and gas upstream and coal mining.

Table 15.1 Summary: Rising Recent Gap in Climate Finance Mitigation

Flows (USD Billion)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Source Document	AR5	AR5	AR5	LinearExtr	BA18	BA18	SR15	SR15
Total Flows Required (Mean Values)	**635**	**635**	**635**	**1,200**	**1,700**	**1,700**	**2,380**	**2,380**
Total 'Flows' Required (Range)	635	635	635	1,200	1,700	1,700	1,380 – 3,825	1,380 – 3,825
Developed (OECD[a]) *(share 65% falling to 37%)*	413	413	413	600	850	850	888	888
Developing *(35% rising to 63%)*	222	222	222	600	850	850	1,512	1,512
Total 'Flows' Actual (Mean Values)	364	364	374	440	488	563	554	560
Total 'Flows' Actual Range	343–385	343–385	343–405	339–541	392–584	445–680	427–681	442–706
Total Flows Actual (BA18)			**405**	**418**	**463**	**547**	**540**	**560**
Alternative Estimate (CPI 2018)						445	427	
Developed (OECD)	260	310	239	209	238	230	227	185
Developing	104	54	165	209	226	317	313	374
Discrepancy	0	0	-31	22	25	15	14	0
Financing Gap (Mean Values)	**271**	**271**	**261**	**760**	**1,212**	**1,138**	**1,826**	**1,820**
Developed	153	103	173	391	612	620	661	703
Developing	118	168	57	391	624	533	1,199	1,138
Memo: Global investment in oil gas, upstream			700	720	780	545	433	450
Coal mining and infrastructure							89	79

Source: Table is derived from a variety of sources and reported numbers, starting with the AR5 reporting for 2010/2011/2012 (IPCC AR5), the Biennial Assessments (UNFCCC and Standing Committee on Finance) 2017/2018 for the numbers for 2013/2014/2015/2016, the 1.5°C Report (IPCC) for the requirements of financing for 2017 onwards, with linear interpolation for numbers in transition years (2013) (IPCC 2018b). While ranges were reported in these Assessments, Table 15.1 shows both the ranges and the mean estimates of these reported ranges, supplemented by additional annual data reporting on component parts from the International Energy Agency (IEA), Global Climate Finance Update 2018 (CPI 2019), the OECD and a variety of other sources.

Note: Given the variations in numbers reported by different entities, changes in data, definitions and methodologies over time, and the caveats noted, there is medium evidence attached to the aggregate numbers shown Note: The Biennial Assessment 2918 (UNFCCC 2018) reports a 'High-Bound' estimate of 681 billion

USD and 'Low-Bound' estimate of about 456 billion USD. The divergence is primarily due to the higher bound inclusion of energy efficiency investments.

[a] In SOD geographical breakdown will be presented according to IPCC regional classification, which requires accessing raw data.

As examined in more detail later in the Chapter (see Section 15.3) on current flows, renewable energy investment (mean USD 305 billion in 2017), was more than half the total mitigation, and the most important sub-sector (FS-UNEP Centre/BNEF 2019; IRENA 2019b). With falling or stagnant investments in Europe and other developed countries, much of the rising investments were taking place in developing countries (share of total global renewables investment rising from 32% to 63% between 2010 to 2017), with China alone accounting for 45% of global total and also other regions. Other reported developments were falling technology costs of solar renewables, increasing energy efficiency, early signs of sustainable transport investments, and rising green bonds labelled financing. The reported needs for mitigation financing to meet global temperature targets were the highest in developing countries (63% share of total), their gap in financing widest (1.1 trillion USD per year), and their costs of financing (interest rates spreads and maturities) three to five times higher because of lower credit ratings in global capital markets. Much (about 80%) of the recent progress in developing countries' mitigation climate financing and overall finance came from national and domestic financing sources, not cross-border financing or official public flows (Micale et al. 2018). Progress in climate finance within developed countries became more uncertain as some large countries sought to exit their climate commitments and increase their fossil fuel reliance. Reported mitigation climate investments within EU were stagnant or falling (1.2% of GDP, 2014 and 2018) and about the same as in North America, and one-third that in China among developing countries (EIB 2019). High-income developed countries, the main store of global wealth and financial assets (65–80%) (Lange et al. 2018), were neither investing adequately at home nor across borders in developing countries. Adaptation costs meanwhile, were rising. The fourth Adaption Gap Report 2018 in a series (UNEP 2018a) reported that while limiting global warming through mitigation would be the most critical factor in keeping the future adaptation challenge manageable, 'the adaptation efforts needed even under the 1.5°C global warming scenario far surpassed current levels and are set to affect the poor and vulnerable most, particularly in developing countries'. It reaffirmed earlier assessments that by 2030 the estimated costs of adaptation could be two to three times higher than the range cited in the Intergovernmental Panel on Climate Change (IPCC) (which had reported a value of 70 billion USD to 100 billion USD per year), and plausibly four to five times higher by 2050 (IPCC 2014).

The reported actual global public finance flows for adaptation in 2016 were estimated at 23 billion USD (falling from 26 billion USD in 2014). The costs of climate disasters have continued to rise, affecting all and developing countries most. Climate natural disasters – not all necessarily attributable to climate change – caused some 300 billion USD per year economic losses and well-being losses of about 520 billion USD per year (Hallegatte et al. 2017). Increasing climate risks were reported as negatively impacting the sovereign credit ratings and financing costs for developing countries (Buhr et al. 2018).

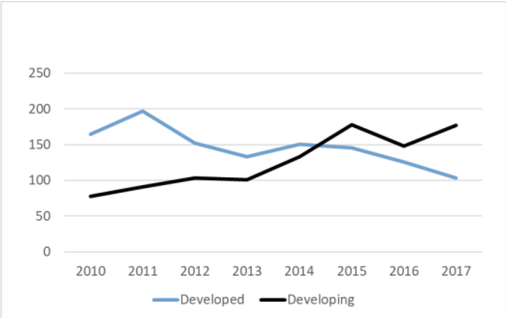

Figure 15.1 Renewable Energy Investment, by Region (billion USD)

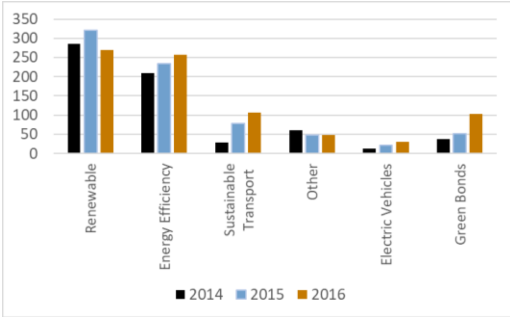

Figure 15.2 Trends of Climate Finance Flows, by Sub-Sectors (billion USD)

Source: FS-UNEP Centre/BNEF (2019) and IRENA (2019b)

As the rest of this chapter examines each of the above areas in more detail, it is worth noting that the total size of the reported mitigation gap at about 1.7 trillion USD per year and adaptation gap of about 200–500 billion USD per year, including loss and damage financing, together totalling about 2 trillion USD per year was about 2.5% of the world GDP (80 trillion USD) in 2018, and 0.5% of global financial assets (400 trillion USD) – a not insignificant sum but one that remained within the realm of financing possibilities. The potential returns to this investment could be high, generating jobs and growth with standard multiplier impacts (1.4–1.8 times the investment) from long-duration infrastructure-style capital assets.

And yet, there are serious current macroeconomic headwinds (see Section 15.5). The first is more unstable and slowing GDP growth in part because of worsening climate change impacts, especially in more vulnerable low-income regions. The second is rising fiscal costs of mitigation and adapting to rising climate shocks which are negatively impacting public debt and credit ratings at a time of significant general stresses on public finances, which are making increased carbon taxes increasingly politically costly. The third is rising financial and insurance sector stresses affecting both national and international financial institutions and their credit risks systematically. The fourth is the slowing global macroeconomic growth, and prospects for near-term recession, which are negatively impacting climate financing possibilities at the global and national levels in the 'near-term', when such stepped-up investments are especially important (see Special Report of Global Warming 1.5°C (IPCC 2018a)). During global real and financial cycle downturns, the perception of financial risks rises, causing financial institutions and savers to reallocate their investment to less risky or risk-free global assets (accounting in part for the recent observed 'flight to safety' tripling of financial assets 16.5 trillion USD to negative-interest earning assets over the past 18 months) – enough to have nearly closed the total climate financing gap in climate over a decade. These recent cascading headwinds mean that it is now nearly inconceivable that the required progress in closing the climate financing gap can happen – barring (unexpected) globally coordinated action. While a project-by-project, sector-by-sector, region-by-region and instrument-by-instrument approaches discussed in Section 15.6 to raising climate finances are important, macroeconomic constraints to finance will likely remain binding. Changing course, including behaviourally, will require political leadership, strengthening coalitions and innovative fiscal and monetary policy options for accelerated global actions across borders and within countries by willing governments and central banks, discussed in concluding Section 15.6.8 on pathways for the financial sector.

15.2 Financing needs

15.2.1 Definitions and qualitative assessment of financing needs

Qualitative Assessment for Financial Needs Qualitative Assessment for Financial Needs in the context of developing countries [Note to reviewers: This section to be further refined and developed]

Estimating financial needs

This section highlights climate financing needs in realising the goals of different sector under Paris and national voluntary agreements in developing country perspectives. It is quite a complicated process to quantify the exact financial needs to carry out the mitigation and adaptation projects and programs. Nevertheless, the State Flood Assessment report suggests that funding shortfall can be estimated by deducting available local funds and available non-local funds from anticipated cost (Lake et al. 2019). Whereas the anticipated cost is estimated based on reported and extrapolated costs to implement mitigation and adaptation activities for communities across the state. The locally available fund refers to the financial resources that communities expect to be able to contribute, at their discretion, to fund mitigation and adaptation activities. The gap between anticipated costs and the amount of locally available funds refers to the non-local funding needs which can be obtained from state, federal, or other international bodies needed by communities to aid their mitigation and adaptation activities.

A handful of literature focuses on approximate financial needs for climate change projects both in the developed and developing countries. In addition, there is little understanding in the context of developing countries perspectives on the role of public fund allocation in carrying out mitigation and adaptation projects. However, prior literature suggests that there are shortfalls funding to carry out adaptation projects, mitigation projects, and cross-cutting projects especially in developing countries. In addition, both mitigation and adaptation initiatives require long-term, stable sources of funding (Phelps et al. 2010). Both public and private sources of funding are required to carry out the climate change mitigation projects for curving the greenhouse gas concentrations and to strengthen the resilience of vulnerable countries to climate change. In developing countries, financial needs are significant, while the government fund is insufficient, as they heavily indebted per capita. Public debt often confines capacity of fiscal space to build resilience to climate change and eventually undermines debt sustainability and economic growth (Fuller et al. 2018). Debt for climate action poses new challenges for developing countries to build up the resilience to climate change.

Developing countries often urge the responsibilities of developed countries to offer necessary finance to developing countries who now suffer a disproportionate burden of the consequences. It is argued that most developed countries contribute less than they supposed to contribute, hence the concern raised by developing countries that climate finance is subject to be confounded (Padraig et al. 2018). One of the key outcomes of the Paris Agreement was a pledge to mobilise 100 billion USD per year by 2020 in new and additional funds to help developing countries avoid, or at least adapt to, the worst effects of climate change. However, the withdrawal of the US from the Paris Agreement has cast a shadow over the developed world's responsibilities to the developing world. Australia's decision to halt its own contributions to the Green Climate Fund (GCF) poses a new challenge.

Financial Needs in renewable energy

A sustainable source of investment is the main challenge for promoting renewable energies production, as many investors are sceptical in investing in renewable energy production due to high risk and less return. The current statistics show a downfall of gross investment in renewable energy worldwide, including early-stage and corporate-level funding as well as the financing of new capacity. Precisely, it dropped 11% in 2018 compared to 2017 (FS-UNEP Centre/BNEF 2018). A sustainable source of financing in renewable energy requires a better harmonisation between different types of finance and their willingness to invest in renewable energy projects. Till today, investment in fossil fuels in the power sector competes directly with the investment in renewable energy projects to generate electricity. Hence 'a major concern in the transition to low-carbon energy provision is how to obtain enough finance to steer investments into the RE direction' (Mazzucato and Semieniuk 2018).

Financial Needs in Small and medium-sized enterprises (SMEs)

Both developing and developed countries should recognise and engage SMEs, and particularly low-carbon technology SMEs, as prime economic players in the endeavour toward climate mitigation and sustainable development. SMEs account for around 45% of employment and up to 33% of GDP in emerging economies. Employment and GDP become even larger when informal SMEs are considered. SME itself generate precipitating impacts over the community once it grows its environmental pliability. SMEs focusing on green or low-carbon technologies often face high ratio of up-front to operating costs, which is considered as a detrimental factor. Such financing constraints to private capital have a negative 'impact on innovative low-carbon SMEs who have developed solutions to mitigate GHG [greenhouse gas] emissions' (Verdolini et al. 2018). In addition, green-technology based SMEs encounter a challenge in terms of the short run the return, their returns may accrue over a long-term horizon. Therefore, eco-efficient SMEs need to have access to finance with long (Lane 2017). More specifically, meeting environmental standards in textiles manufacturing, SMEs requires to purchase new energy-efficient equipment, for example, use costly non-toxic chemicals in their dyes. Agricultural producers, meanwhile, needs to invest in resource-efficient farming practices. These practices incur cost of money. A research focusing on 16 emerging countries projected that compliance with sustainability standards cost about 425,000 USD per firm, mainly due to increased spending on labour and capital (Maskus et al. 2005). SME owners usually face obstructions in securing bank loans which compelled them to get the loans from other alternative sources, including informal sector for carrying out their businesses. Around half of total formal SMEs lack access to formal credit whereas the total credit difference between formal and informal SMEs is 2.6 trillion USD globally. However, these costs are not one-time expenses. SMEs requires to spend money over time to maintain and document their compliance. Though the difference varies substantially across regions, Asia and Africa represent the highest difference.

Transport Sector

The transport sector accounts for about 23% of world CO_2 emissions among which global oil consumption consists of 60% and overall energy usage consists of 27%. Transport is the fastest-growing source of GHG emissions with demand for mobility increasing rampant particularly in developing countries. Obviously, the transport sector should be targeted with an aim to reduce GHG emissions thereby keeping climate warming at 2°C as agreed upon by the international community in 2015. For instance, Chinese commitment for fast adaption of smart transport, green freight transport, further development of public transport in their cities and priority of Indian Government towards low carbon infrastructure including energy-efficient railways and inland water transport as unanimously decided by the Intended Nationally determined Contribution (INDC) updated up to November 12th, sustainable transport sector includes investment of 5.3 billion USD in 34 countries contributing to the Rio+ pledge of 175 billion USD from multilateral development banks over 2012–2022 according to the estimate of the fiscal year 2015 only (Guislain 2015). Transport-related technical assistance and knowledge programs have been aimed to support climate change through Multi-Donor Trust Fund as intended by the World Bank.

Financial Needs in other sectors

The financial challenges are bigger in end-use sectors, for instance industry, transport and buildings. In 2015, about 220 billion USD was invested in more efficient appliances, lighting, cars and trucks as well as industrial motors. Such investments would require to be ten times higher by 2050, as they would also need to include other areas, such as renewable energy used for heat production in the buildings and industrial sectors, electric cars and trucks. This sharp rise in investment will require policy support to ensure affordability for consumers (IEA 2017). Such a profound transformation of the energy sector requires ambitious policy measures, including a swift removal of fossil-fuel subsidies, increasing 'CO_2 prices, extensive electricity market reforms to integrate large shares of renewables, and stringent low-carbon and energy efficiency mandates. Such policies should also ensure energy remains affordable to the billions of people currently without access to energy. More global technology collaboration would also be required to facilitate low-carbon technology development and deployment' (IEA 2017).

Qualitative assessment on financial needs

The UNFCCC (2016) stated that most climate finance in the total is mobilised and allocated domestically, both in developed and developing countries. Only a few developing countries domestic public finance surpasses the inflows of international public climate finance from bilateral and multilateral sources (Kissinger et al. 2019). Prior literature argues that the flows of international climate finance are insignificant to meet the demand from developing countries, as highlighted from most of the countries' Nationally Determined Contributions (NDCs).

Many risks posed by climate change arise in the long-term perspective, whereas investors are mostly assessed by their short-term performance and hence incentivised to follow shorter-term investment strategies. It is argued that the risks of climate change intend to encounter us in the future, but immediate actions require to mitigate them (Carney 2015). Although carbon tax has been imposed on carbon-intensive companies in many developed countries, nevertheless, the key problem that both investors and policymakers face is lack of data and metrics to quantify the precise exposure of companies to climate risks and their influence on the environment (Tate 2018). Without the asymmetric information, investors cannot make decisions to rebalance their portfolios, and regulators cannot design optimal policies. The financial stability board has, therefore, suggested establishing the national regulators framework for firms and asset managers to disclose their exposure to climate risks and how they plan to mitigate them.

The literature highlights that actions in five sectors including energy, transport, water and sanitation, and telecommunication can unlock investment growth and sustainable development that which is able to create over 65 million additional low carbon jobs, make available 2.8 trillion USD from carbon pricing revenues and removal of fossil fuel subsidies – all these while avoiding 700,000 premature deaths from air pollution (Evelyn 2018).

Given the scale of investment required for sustainable infrastructure and development, a generally significant scaling up of financing is required from all sources of domestic, public and international – including the links between them to make them stronger and to drive them up to scale. The pace of achieving the target of climate finance commitment has been slow. Hence the multilateral development banks have been moving more strongly. An enhanced partnership based on a new understanding of climate action is required as development banks can play a key role in moving from billions to trillions to finance the new global agenda.

However, in reality, new green initiatives that are rapidly emerging are often characterised by high reliance on funding from donors (e.g., Climate Neutral Now, Development Bank of Latin America, Clean Energy Finance Facility for the Caribbean and Central America, Canada International Development Agency, DFID - UK's Department For International Development, The Global Climate Change Alliance, Green Climate Fund, The GEF Small Grants Programme, International Finance

Corporation, International Climate Initiative, International Renewable Energy Agency, Japan International Cooperation Agency, The NAMA Facility, Pilot Auction Facility) which 'raises questions about whether some projects are overleveraged and overlooking long-term financial resilience' (Phelps et al. 2010). This is potentially problematic because diversified revenue is essential to sustainable conservation finance (Castro, 2003); in this case, excessive dependence on donors leads to higher exposure to significant financial risks, as over the long-term period donor support might be inconsistent. Diversification can include drawing on market, traditional donor, and philanthropic contributions. It may also rely on bundling other ecological services (notably water-related) with carbon for payment as ecosystem services, especially to gain resources for high opportunity cost areas (Phelps et al. 2010).

Climate finance flows have somewhat progressed as it raised about 472 billion USD in 2015 and 455 billion USD for 2016, obtained from the primarily private investment in renewables. This was followed by a drop in 2016 to 455 billion USD, caused by dropping renewable energy technology costs and fewer renewable energy capacity additions in some countries (Padraig et al. 2018).

Notably, The US-Aid Clean Energy Finance Facility for the Caribbean and Central America is an innovative, collaborative financing mechanism to facilitate renewable energy projects (UNFCCC 2016). Mitigation alone will cost developing countries 600 billion USD per year. The initial pledge in the Paris Agreement covered roughly 60–100 billion USD per year needed for adaptation measures as proposed by the IPCC. Thus, it's clear that the gap between what is needed and what is available grows deeper with each passing year.

Characterising financing needs on a project level

Understanding financing needs is crucial to identify appropriate funding sources, understand changes in funding flows compared to the business-as-usual scenario and to derive policy recommendations. Below the most important elements are illustrated:

Payback period: Capital intensity and resulting long payback periods represented a key challenge in financing of mitigation technologies in particularly after the financial crisis and restricted access to long-term debt thereafter. In addition, financial regulation burdened commercial loan provision for illiquid assets (see AR5 - IPCC 2014). Short-termism of capital markets led to financial innovations like YieldCos see creating tradable instruments to allow institutional investors to become involved in financing. Long term local currency financing remains a challenge in particular in less developed financial markets with lacking yield (TCX Fund 2014; Yescombe 2017) and consequently, long-term financing needs require additional attention from policymakers.

Payback profile: The payback profile of climate-related investments is heavily heterogeneous ranging from stable and predictable positive cash flows or stable and predictable savings generated by the financed asset (for example renewable energy and energy efficiency) to avoided extreme losses in case of extreme weather events with uncertainty about their timing and magnitude dominating the investment decisions (for example anticipatory adaptation). Implicit discount rates applied during the investment decision process vary depending on the payback profile with research in particularly covering the difference between financing of assets generating revenues versus costs (Jaffe et al. 2004; Schleich et al. 2016).

Financial viability and level of public goods produced: The increased deployment of renewable energy technologies over the past years was substantially driven by falling technology costs and the competitiveness of solar and wind power in selected markets without taking into account the climate effects (see annually reports FS-UNEP Centre/BNEF (2015, 2016, 2017, 2018, 2019) on global trends of renewable energy investments as well as global status reports on renewables (2017–2019) (REN21 2019). This reduced the dependency on regulatory support and consequently regulatory risks and created an attractive investment case for the private sector. Understanding the financial viability of investment categories will be crucial for policymakers when defining priority segments for private sector financing and allocating public funding. In addition, investment opportunities creating private goods, even on a country-level, will be easier to be financed with local funding. Compared to mitigation externalities, adaptation measures will in most cases materialise primarily in the respective country with a higher level of public spending being justified (UNEP FI and FS 2016; UNEP 2016).

Transaction sizes, pipelines and replicability and scalability: Transaction costs are a key concern for investors and can represent a massive challenge in early-stage markets with limited standardisation of business models and investment opportunities. Spreading initial transaction costs across a number of investment opportunities with a similar transaction structure will help to lower the burden on financial viability. In particular, for small transaction sizes as in rural electrification, the ability to aggregate financing needs is crucial. The important role of dedicated intermediaries bundling demand for financing has been demonstrated by securitisations of Pay-As-You-Go (PAYG) companies for example. Other aggregation vehicles and intermediaries might be necessary to facilitate supply of finance from global capital markets (Mathews and Kidney 2012). Sectors with limited pipelines of projects and still evolving business models might require a higher level of public support first.

Correlations to currently dominating asset classes: Institutional investors tend to manage portfolios based on asset allocation taking into the Markowitz modern portfolio theory. Diversification into higher-risk opportunities, in particular also in the international context, can be beneficial for the overall portfolio of investments if no or a negative correlation exists (Marinoni et al. 2011). Such uncorrelated assets might also be found in climate action offering opportunities for (international) institutional investor appetite.

Share of climate-related investment needs: The share of climate-related investment and the level of change in individual investments compared to business as usual will drive the need to address decision making processes of established investors and or the need to crowd in new investor groups and funding sources. Renewable energy technologies allowed new investor groups to enter the electricity markets and to invest alongside established utilities against the background of new technology with a new business model (IRENA 2019a). In contrast to that making infrastructure resilient is often 'only' an add-on component. OECD expects an additional cost of 0.6 trillion USD per year on top of the around 6.3 trillion USD per year of investment in infrastructure is required on average between 2016 and 2030 to meet development needs globally (OECD 2017) requiring a change of investment decision processes within established investor groups.

Link to direct mitigation/adaptation output: In particularly in the context of private sector mobilisation, significant investments into institutional capacity building within the public sector will be needed. Further discussion see financing gap section in 15.4 as well as in the section about private-public-partnerships in 15.3.4. Such activities often do not classify for Official development assistance (ODA) climate accounting given their only indirect contribution to mitigation and adaptation and therefore might not attract as much donor interest as other opportunities.

15.2.2 Quantitative assessment of financing needs

Introduction

Multiple stakeholders prepare and present quantitative funding needs assessments with methodologies applied to vary significantly. The differences relate to the scope of the assessments with regard to sectors, regions and time periods as well as top-down versus bottom-up approaches. In particular, for top-down approaches modelling assumptions are often heavily standardised with a strong focus on technology costs. Only limited global analysis is available on incremental costs and investments which reflects the reality of developing countries and can serve as a robust basis for negotiations about international public climate finance. The focus on investment costs does not allow a decent analysis of the need for international public funding to create viable investment cases on the one hand and the potential for private sector financing on the other hand (Clark et al. 2018). The yearly IRENA mapping on renewable energy auction results demonstrates the extremely broad ranges of LCOEs (equal to the agreed tariffs) for renewable energy which can be observed (IRENA 2019b). For example, in 2018, solar PV LCOEs for utility-scale projects came in between 0.04 and 0.35 USD/kWh with a global weighted average of 0.085 USD/kWh. Also, mostly rather standardised assumptions on soft costs, like balance-of-system (BOS) in energy generation, as well as financing costs, are applied not reflecting the reality in many developing countries. However, applying significantly standardised assumptions can consequently not provide robust insights for specific country groups.

While IAMs mostly discuss investment needs to achieve the Paris goals or other defined scenario outcomes, other methodologies focus on concrete or foreseen demand for financing assessing current pipelines or investment needs linked to current investment programs and/or commitments. This differentiation is crucial to be made in the context of the analysis on how to close financing gaps.

Using global scenarios assessed in Chapter 3 for assessing investment requirements

Tables below present the analysis of investment requirements in global mitigation pathways assessed in Chapter 3 for key energy sectors. These pathways explore the interactions of the energy, land-use and climate system and thus help to identify required transformations in the energy sector to reach specific long-term climate targets. The modelling of these scenarios is done with a variation of scenario assumptions along different dimensions (inter alia policy, socio-economic development and technology availability), as well as with different modelling tools which represent different assumptions about the structural functioning of the energy-economy-land-use systems (for further details see Annex C: Scenarios and modelling methods for details).

The presentation in the Table 15.2, Table 15.3, Table 15.4, Table 15.5 focuses on the near- (2023–2032) to medium-term (2023–2052) investment requirements and how these differ depending on temperature category, highlighting both clear requirements for increased investments, and a shift from fossil generation and extraction towards renewable technologies and efficiency with more restricted peak temperature limits. The substantial ranges within each of these categories reflect the existence of multiple pathways, differentiated by socio-economic assumptions, technology, et cetera. In order to understand the likely investment requirements on a finer resolution (within a country, for a specific technology), it, therefore, is necessary to open up these extra dimensions to understand how investment requirements depend on a set of specific circumstances and assumptions.

Table 15.2 Global average yearly investments from 2023–2032 for Electricity supply (including generation, transmission and distribution, and storage), and for fossil Fuel Extraction and Efficiency improvements (in billion USD2015)

Peak Temp. Range [°C]	**Electricity [billion USD]**	*of which fossil [billion USD]*	*Renewables [billion USD]*	*Solar [billion USD]*	*Wind [billion USD]*	**Extraction [billion USD]**	**Efficiency [billion USD]**
1.25–1.75	1532 (1115;2155) [102]	72 (39;107) [101]	1019 (555;1324) [79]	388 (179;651) [79]	302 (239;373) [79]	437 (239;578) [61]	304 (280;327) [8]
1.75–2.25	991 (688;1550) [103]	96 (58;133) [103]	593 (502;807) [73]	242 (133;276) [73]	215 (167;218) [73]	520 (442;762) [51]	245 (215;249) [3]

2.25–2.75	895 (732;1316) [16]	102 (99;209) [16]	593 (408;645) [11]	194 (109;242) [11]	149 (133;215) [11]	911 (592;933) [7]	NA [0]
2.75–3.25	992 (890;1187) [7]	207 (143;287) [7]	400 (392;584) [5]	166 (141;276) [5]	155 (131;161) [5]	982 (880;1042) [5]	261 (249;273) [2]
3.25–3.75	884 (553;1132) [13]	190 (100;260) [13]	309 (255;414) [12]	90 (64;174) [12]	106 (66;110) [12]	740 (657;996) [11]	227 (225;235) [7]
3.75–4.25	463 (455;540) [15]	153 (152;158) [15]	342 (312;372) [2]	126 (99;153) [2]	99 (94;104) [2]	698 (697;700) [14]	220 (220;220) [1]
4.25–4.75	1133 (1133;1153) [3]	227 (227;235) [3]	397 (397;397) [2]	174 (174;174) [2]	107 (107;107) [2]	NA [0]	NA [0]

Note: Scenarios are clustered into groups of peak temperature ranges (vertical axis). The numbers represent medians across all scenarios within one category, and rounded brackets indicate interquartile ranges, while the numbers in squared brackets indicate the number of scenarios.

Table 15.3 Global average yearly investments from 2023–2052 for Electricity supply (including generation, transmission and distribution, and storage), and for Fossil Fuel Extraction and Efficiency improvements (in billion USD2015)

Peak Temp. Range [°C]	**Electricity [billion USD]**	*of which fossil [billion USD]*	*Renewables [billion USD]*	*Solar [billion USD]*	*Wind [billion USD]*	**Extraction [billion USD]**	**Efficiency [billion USD]**
1.25–1.75	1575 (1392;2758) [102]	53 (35;93) [101]	1240 (697;1428) [79]	454 (261;791) [79]	376 (294;460) [79]	346 (217;499) [61]	465 (443;544) [8]
1.75–2.25	1261 (961;2509) [103]	94 (64;144) [103]	1098 (724;1318) [73]	350 (197;452) [73]	370 (225;461) [73]	484 (452;846) [51]	326 (262;348) [3]
2.25–2.75	1083 (898;2027) [16]	108 (85;170) [16]	625 (522;874) [11]	260 (162;300) [11]	256 (192;286) [11]	1002 (668;1173) [7]	NA [0]
2.75–3.25	1326 (1029;1637) [7]	209 (97;263) [7]	590 (480;881) [5]	331 (206;492) [5]	192 (188;261) [5]	1149 (1092;1371) [5]	310 (292;328) [2]
3.25–3.75	1022 (643;1610) [13]	144 (112;210) [13]	478 (315;717) [12]	128 (81;349) [12]	145 (77;203) [12]	1112 (728;1205) [11]	245 (241;261) [7]
3.75–4.25	518 (505;631) [15]	158 (152;159) [15]	541 (452;629) [2]	257 (183;331) [2]	169 (151;186) [2]	787 (784;790) [14]	236 (236;236) [1]
4.25–4.75	1610 (1583;1610) [3]	144 (144;165) [3]	714 (714;714) [2]	402 (402;402) [2]	202 (202;202) [2]	NA [0]	NA [0]

Note: Scenarios are clustered into groups of peak temperature ranges (vertical axis). The numbers represent medians across all scenarios within one category, and rounded brackets indicate interquartile ranges, while the numbers in squared brackets indicate the number of scenarios.

Table 15.4 Average yearly investments from 2023–2032 for Electricity Generation capacity, by aggregate regions (in billion USD)

	R5ASIA	R5LAM	R5MAF	R5OECD90+EU	R5REF

Peak Temp. Range [°C]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]
1.25–1.75	24 (16;30) [101]	507 (241;665) [65]	1 (0;7) [101]	79 (34;92) [65]	11 (8;26) [101]	86 (36;128) [65]	30 (14;38) [101]	323 (208;424) [65]	3 (0;9) [101]	29 (23;40) [65]
1.75–2.25	26 (22;39) [103]	251 (187;589) [45]	1 (1;7) [103]	66 (27;92) [45]	15 (10;28) [103]	34 (24;68) [45]	30 (17;39) [103]	235 (184;373) [45]	5 (3;14) [103]	15 (11;29) [45]
2.25–2.75	45 (36;65) [16]	227 (134;359) [6]	4 (2;11) [16]	62 (32;68) [6]	18 (12;29) [16]	38 (19;60) [6]	33 (29;47) [16]	199 (162;246) [6]	8 (4;21) [16]	13 (11;19) [6]
2.75–3.25	52 (36;77) [7]	153 (147;245) [5]	7 (1;12) [7]	48 (37;66) [5]	29 (20;39) [7]	23 (16;34) [5]	70 (30;72) [7]	194 (191;232) [5]	7 (7;35) [7]	7 (5;7) [5]
3.25–3.75	108 (37;118) [13]	112 (87;186) [11]	7 (3;17) [13]	25 (22;57) [11]	28 (15;31) [13]	15 (15;31) [11]	43 (40;70) [13]	120 (83;143) [11]	9 (7;13) [13]	5 (4;8) [11]
3.75–4.25	41 (41;46) [15]	144 (120;167) [2]	2 (2;3) [15]	40 (32;48) [2]	10 (10;11) [15]	22 (17;27) [2]	87 (79;89) [15]	130 (124;135) [2]	13 (13;13) [15]	8 (6;9) [2]
4.25–4.75	116 (116;124) [3]	187 (187;187) [2]	4 (4;5) [3]	56 (56;56) [2]	31 (30;31) [3]	31 (31;31) [2]	68 (67;68) [3]	117 (117;117) [2]	8 (8;9) [3]	5 (5;5) [2]

Note: The numbers represent medians across all scenarios within one category, and rounded brackets indicate interquartile ranges, while the numbers in squared brackets indicate the number of scenarios.

Table 15.5 Average yearly investments from 2023–2052 for Electricity Generation capacity, by aggregate regions (in billion USD)

Peak Temp. Range [°C]	R5ASIA		R5LAM		R5MAF		R5OECD90+EU		R5REF	
	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]	Fossil [billion USD]	Renewables [billion USD]
1.25–1.75	18 (11;26) [101]	649 (296;717) [65]	3 (0;7) [101]	84 (36;91) [65]	15 (8;25) [101]	157 (83;193) [65]	19 (12;42) [101]	325 (235;399) [65]	4 (1;10) [101]	33 (30;36) [65]
1.75–2.25	31 (25;37) [103]	599 (259;688) [45]	4 (1;9) [103]	86 (35;102) [45]	18 (13;34) [103]	155 (47;187) [45]	33 (20;51) [103]	342 (203;385) [45]	6 (3;14) [103]	32 (21;37) [45]
2.25–2.75	43 (34;47) [16]	341 (214;495) [6]	5 (2;13) [16]	57 (29;81) [6]	18 (16;33) [16]	59 (30;116) [6]	31 (29;58) [16]	229 (190;273) [6]	9 (5;17) [16]	19 (15;25) [6]
2.75–3.25	46 (42;56) [7]	303 (221;416) [5]	5 (2;14) [7]	64 (37;77) [5]	24 (20;39) [7]	70 (28;97) [5]	49 (25;65) [7]	198 (191;272) [5]	8 (5;37) [7]	12 (6;14) [5]
3.25–3.75	66 (43;105) [13]	147 (111;353) [11]	5 (2;18) [13]	37 (24;68) [11]	26 (21;34) [13]	26 (21;78) [11]	52 (43;57) [13]	154 (117;192) [11]	9 (6;14) [13]	10 (6;11) [11]
3.75–4.25	42 (42;56) [15]	254 (201;308) [2]	3 (3;3) [15]	47 (36;58) [2]	12 (12;16) [15]	53 (36;71) [2]	87 (79;88) [15]	175 (167;182) [2]	13 (13;13) [15]	11 (11;11) [2]
4.25–4.75	66 (66;78) [3]	358 (358;358) [2]	2 (2;2) [3]	68 (68;68) [2]	27 (27;31) [3]	87 (87;87) [2]	43 (43;45) [3]	190 (190;190) [2]	6 (6;8) [3]	10 (10;10) [2]

Note: The numbers represent medians across all scenarios within one category, and rounded brackets indicate interquartile ranges, while the numbers in squared brackets indicate the number of scenarios.

Quantitative analysis based on AR6 scenario database

Limiting peak temperature to levels of 1.5°C–2°C requires rapid decarbonisation of the global energy systems, with fastest relative emission reductions occurring in the power generation sector (Luderer et al. 2018; von Stechow et al. 2016). This requires very fast shifts of investment as infrastructures in the power sector generally have long lifetimes of a few decades. In the 1.5°C scenarios, investments into fossil power generation technologies (including those with carbon capture and storage (CCS)) decrease to less than 50 billion USD per year, from 127 in 2018 (IEA 2019a). At the same time, investments into non-biomass renewables increase to over 1 trillion USD per year in 2030, an increase by more than factor three over the values of around 250–300 billion USD per year that has been relatively stable over the last decade (IEA 2019a).

Roughly in line with investment patterns over the last nine years, solar technologies are projected to contribute to double roughly the absolute investments than wind turbines. Overall, electricity generation investments increase considerably, reflecting the higher relevance of capital expenditures in decarbonised electricity systems. The higher capital intensity of low-carbon power technologies can especially create obstacles for fast decarbonisation in countries with high-interest rates, which decrease the competitiveness of those technologies (Iyer et al. 2015; Hirth and Steckel 2016; Steckel and Jakob 2018). The regional pattern of power sector investments broadly mirrors the global picture. What is apparent however, is that the bulk of investment requirements corresponds to medium- and low-income countries in the regions R5ASIA, R5LAM, R5MAF and R5REF, as these not only need to replace existing fossil generation capacity but additionally still have growing energy demands. Global electricity demand is projected to increase by up to 75% from 2015 to 2030, with the bulk of this increase being located in low- and medium-income countries where demand today is still considerably lower than the global average.

Investments into fossil fuel extraction have declined from a level of close to 1 trillion USD per year in 2014 to 600 billion USD per year in each of the years between 2016 and 2018 (IEA 2019a). In scenarios without further strengthening of climate policy, in which peak temperatures reach 3°C and more, investments into fossil fuel extraction are projected to increase again to levels of over 1 trillion USD per year in 2030, caused by increasing energy demand especially in low- and medium-income countries. In scenarios that limit peak temperature to levels of 1.5°C–2°C, these investments stay at about today's level.

[Note to reviewers: Analysis of other sectors based on AR6 modelling database will be available after FOD only]

Financing needs relating to NDCs

Information on investment needs and financing options in NDCs is heavily heterogeneous. 122 out of 160 NDCs provide some information on finance with the need for predictable financing support being a major aspect flagged most developing countries NDCs (Zhang and Pan 2016). Approximately half of those include quantitative data on financial support needed with Zhang and Pan calculate a total demand of 4.6 trillion USD by 2030. Given that conditionality is not well defined across NDCs and cost estimate assumption varying heavily, the calculation of aggregated cost appears questionable (Pauw et al. 2019). 50 non-Annex I countries have included financial data for adaptation, accumulating to more than 50 billion USD per year for 2020–2030 (see NDC explorer by Pauw et al. (2016)). As NDCs do not yet come in at the level required reaching 1.5°C, financing needs remain below those resulting from IAM 2°C and 1.5°C scenarios.

Adaptation financing needs

Financing needs for adaptation are more difficult to be defined with most studies choosing a more narrow scope on primarily public sector projects ignoring household level investments as well as private sector adaptation (CPI 2019; UNEP 2018a). UNEP reports adaptation financing needs amounting to 140–300 billion USD per year by 2030 and 280–500 billion USD per year by 2050 (UNEP 2016) significantly exceeding the financial needs stated in NDCs. They also flag the high cost of adaptation in some of the world's poorest countries. Adaptation planning is an important (complementary or reinforcing) component of many developing countries NDCs (NAP Global Network 2017). Over 100 countries included adaptation component in their intended NDCs (INDCs) and approximately 25% of these referenced national adaptation plan (NAP) (GIZ 2017). While estimate of the amount of financing required for NAP processes is not available (NAP Global Network 2017), these NAPs, as formally agreed under the UNFCCC in 2010[1], iterative, continuous processes that have two important stages that require both operating and investment costs financing: developmental phase require or is more dependent on domestic sources of finances such as fiscal instruments (additional tax revenues, bond issue or debt conversion or redistribution of domestic resources from subsidy and subsidy reform. In some cases, developing countries are developing domestic climate funds as financial vehicles to support national and subnational adaptation planning process.

Analysis of funding needs derived in sectoral studies result [in broadly consistent numbers]. The IEA Sustainable Development Scenario presents total energy investment approximately amounts to 3.2 trillion USD each year from 2019 to 2040 on average, thereof some 45 billion USD per year between 2019 and 2030 to achieve universal access to electricity (IEA 2019b). In order to achieve the goals outlined in the Special Report on warming of 1.5°C, forestry actions that could achieve up to 5.8 $GtCO_2$ per year would cost 431 billion USD per year with a regional focus on Latin America followed by South-East Asia and Sub-Saharan Africa. Other studies have suggested similar ranges for the average cost of carbon sequestration in tropical countries (e.g. Griscom et al. 2017; Busch et al. 2019). Significant investments would be also required for ecosystem preservation across land and oceans, which could come in between 200–300 billion USD per year (Huwyler et al. 2016).

Bottom-up analysis and pipelines

Current pipelines and expected investment opportunities naturally remain below the amounts presented above but provide some snapshots on implementation progress. The International Finance Corporation (IFC) presented a portfolio of 23 trillion USD climate-related investment opportunities for 2016–2030 for 21 emerging countries with the building sector in East Asia Pacific accounting for approximately 50% of the portfolio (IFC 2016). Estimating the investment needs to achieve cities' current mitigation goals to 2030, IFC derives financing opportunities with a value of 29.4 trillion USD globally by 2030 in cities (IFC 2018), again driven by opportunities in the green buildings sector.

Further narrowing the scope with regard to readiness for implementation, concrete project pipelines can provide some indications. The Green Climate Fund's monthly pipeline report presents 357 projects requiring 53.8 billion USD of funding in November 2019 (Green Climate Fund 2019a).

National Adaption Plans

The second phase of the NAPs, the implementation phase generally will require more and higher levels of sustained financing which could come from bilateral grant-based technical assistance through budgetary support or basket funding for large projects/program or sector-wide approaches. Multilateral funding both under the UNFCCC and Non-UNFCCC also anticipate supporting NAP implementation. Those under the UNFCCC such as the GCF through its 3 million USD per country readiness and

[1] The NAP was established under the Cancun Adaptation Framework of the Cancun Agreements (Decision 1 CP.16, 2010) which focused on enabling effective adaptation planning in LDCs, and allow other developing countries to use the same modalities to support the formulation of NAPs (UNFCCC 2011). The NAP process has two-fold objectives: 1) 'to reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience' and 2) 'to facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes' (UNFCCC 2012). Related decision on adaptation planning and its implementation was included in the Paris agreement Article 7., para 5, (UNFCCC 2016).

preparatory support programme, the LDCF and the SCCF and the PPCR and ASAP are focused on supporting the preparatory process of the NAPs. But the Adaptation Fund will support the implementation of concrete projects up to 10 million USD per country. Other funding entities such as the MDBs and development banks also will support the implementation phase of NAPs particularly those involved incremental costs and co-benefits, which will include sectoral approach such as water, energy, infrastructures, food production (Fad et al. 2016). But, between 2015 and 2016, only about 3% of international public finance goes to adaptation action. (with 84% of development finance institutions and 13% government) (UNFCCC 2019a; Governance of Climate Change Finance to Enhance Gender Equality in Asia-Pacific 2019).

To date, the private sector has limited involvement in NAP and adaptation projects and planning but can be involved through public-private partnership (discussed in Section 15.3.4) and incentives by governments (NAP Global Network 2017; Koh et al. 2016; Schmidt-Traub and Sachs 2015; UNEP 2016; Druce et al. 2016). Innovative private financing mechanisms such as:

- Green bonds (Innovative Financing Initiative 2014; World Bank and PPIAF 2015; Hurley and Voituriez 2016; UNFCCC 2019a),
- Blue bonds (or water bonds), (Bonzon et al. 2014; Hurley and Voituriez 2016),
- Impact investing funds (Global Impact Investing Network),
- Guarantees (Hurley and Voituriez 2016), and
- Risk financing facilities

may also be important for the implementation of adaptation actions.

However, despite this optimism, the reality is that private financing account for very small percentage of adaptation financing. For example, adaptation financing is only about 2% of the share of green bond financing raised up to June 2019 (UNFCCC 2019a)[2]. Whereas it is about 10% of sovereign green bonds raised.

Resilience and disaster response needs

It is widely agreed that 'disasters are increasing and their costs are growing' (Watson et al. 2015); they are also a threat to sustainable development, poverty reduction, and SDGs (OECD and World Bank 2016; UN ESCAP 2017; UNISDR and WMO 2012; World Bank 2019). Between 1978 and 1997, the direct economic losses from disasters were valued between 895 billion USD2017 and 1,313 billion USD2017 and between 1998–2017 direct economic losses were valued at 2,908 billion USD2017 (Wallemacq and House 2018). Climate change and climate-related losses increased from 68% of losses in the 1978–1997 period to 77% of losses in the 1998–2017 period (Wallemacq and House 2018). The real cost to the global economy over the last twenty years is 520 billion USD per year and 26 million people impoverished (CRED and UNISDR 2018; World Bank 2019).

Disaster preparedness, disaster risk reduction and building resilience[3] are hence critical for sustainable development and allowing response to the effect for climate change. But financing for resilience is

[2] According to climate bonds initiative, total green bond finance raised in 2018 was 168.5 billion USD across 44 countries (UNFCCC 2019a).

[3] Disaster Risk Reduction is the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Definitions are from United Nations Office for Disaster Risk Reduction, UNISDR Terminology and Disaster Risk Reduction (ISDR 2009).

limited and difficult to access due to complex eligibility requirements and processes (OECD and World Bank 2016). What is available is often unpredictable, fragmented and focused on few projects or sectors and short term as opposed to programmatic and long-term (10–15 years) funding to build resilience (Watson et al. 2015; Kellett and Peters 2014; ISDR 2009, 2011). Disaster protection financing is focused on preparedness and is not equally available across extreme events (Watson et al. 2015). For example, it is not readily available for drought-prone countries (Watson et al. 2015).

Market-based mechanisms are available but not equally accessible to all developing countries, particularly SIDS and LDCs and such mechanisms can undermine debt sustainability (OECD and World Bank 2016). Many of these instruments as well as the very small literature on disaster financing focus on the transfer of risk through insurance and re-insurance products (Swiss Re 2008; Cummins and Mahul 2009; Watson et al. 2015; UNEP FI 2014a).

While resilience financing is mainly granted, concessional loans are increasing substantially and are key sources of financing for disaster and resilience, particularly for upper-middle-income countries (OECD and World Bank 2016). The combination of these trends can contribute to greater levels of indebtedness among many developing countries many of who are already at or approaching debt distress.

Countries need considerable and effective support in both responding to climate disasters and in building resilience, including enhancing enabling environment policy for climate and disaster resilience, enhancing information on resilience and information management systems and supporting the integration of climate and disaster risk into national planning and budgeting; and overall enhancement of capacity and coordination.

There will be need for actions to both mitigate risk and promote (physical, social and financial[4]) resilience by governments (to avoid the explicit and implicit contingent liabilities, loss of revenues and the opportunity costs of diverting funds from traditional development planning, as well as the fiscal transfer to subnational governments, the rehabilitation of damaged assets, livelihood support and stabilisation of the private sector); by businesses (SMEs, MSMEs – particularly in the agriculture sector, large firms and supply chain actors – who will suffer loss and damage to assets and loss of business income), by households, individuals and vulnerable populations and communities (who will suffer loss and damages to homes and assets, loss of employment, loss of markets and loss of livelihoods and experience increasing food insecurity) (Chatterjee 2019; World Bank 2019).

Addressing resilience in the context of climate-induced disasters will require risk-layering that seeks to match financing mechanisms such as budget reserves, contingent credit and risk transfer to the severity of the probability of the events (Chatterjee 2019). As discussed in the climate risk pooling approaches subsection (see Section 15.6.6), there are a wide variety of climate risk pooling instruments (catastrophe bonds, parametric insurance, traditional insurance, emergency loans/loans for managing different type of risk (from very extreme loss, medium-sized risk and low-to-medium-sized risk) which involve consideration of the return period relative to the relief/recovery/reconstruction.

In the case of resilience, the key tools may include taxes, budget reallocation, domestic credit, external contingent credit and mixing of different sources of international climate finance, both public and

[4] World Bank (2019) identifies three element of disaster resilience : 1) Physical resilience – reduce risk and prevent disaster through physical measures, including investments in high-quality and resilient infrastructures ; 2) Financial resilience – Pre-arrange predictable funding for post-disaster activities to protect the fiscal balance, subnational governments and households, and business ; and 3) help households and society cope with disaster shocks, through measures such as shock-responsive safety nets that can scale up following a disaster.

private. There is a wide range of tools and initiatives globally, regionally and nationally to support disasters and resilience (see box and tables below forthcoming). But the common consensus is that resilience financing remains fragmented and disconnected and not yet well suited to the purpose. Increasingly, climate finance is touted as an opportunity to finance disaster-risk-reduction (DRR), but much of this flow is directed towards resilience to extreme climate events. Watson et al. notes that between 2003 and 2014 of the 2 billion USD that flowed through dedicated climate change adaptation funds, only 369 million USD explicitly went to DRR activities, with most focused on early warning systems, coastal infrastructure, building resilience to climate change hazards, information systems and capacity building (Watson et al. 2015; Nakhooda et al. 2014a,b; Climate Funds Update 2014) they also noted that in 2014, 45% of adaptation finance included a DRR component.

For the private sector, insurance and reinsurance, including micro insurance, remains the dominant way to transfer risk. But this is currently an under-researched area (Watson et al. 2015).

Resilience will also require an emphasis on social protection to help to foster and ensure the enhancement of the resilience of households and individual to climate and weather-related disasters.

Financing climate-responsive social protection

Social protection systems that can be adaptive and scalable in response to climate change events require appropriate financing mechanisms. They can be linked with a number of the instruments already considered: reserve funds, insurance and catastrophe bonds, regional risk-sharing facilities, contingent credit, in addition to traditional international aid and disaster response. Hallegatte et al. (2017) recommend combining adaptive social protection with financial instruments in a consistent policy package, which includes financial instruments to deliver adequate liquidity and contingency plans for the disbursement of funds post-disaster.

[Note to reviewers: Boxes/tables to be developed for SOD]

- Box x.x. on resilience needs and initiatives both for extensive and intensive disasters
- Table x.x on data on development and climate finance for DRR and Resilience
- Table y.y on Risk financing, risk reduction and resilience measures and financing flows (including contingent lines of credit, catastrophe and weather risk transactions)

15.2.3 Loss and damage

There are finance needs related to residual risks, limits to adaptation, and loss and damage, in response to both extreme weather events and slow onset events (temperature rise, ocean acidification, land degradation, sea-level rise, salinisation, etc.) from climate change. Challenges for developing countries in financing loss and damage for extreme events include a need for rapid payouts; the increasing expense of risk financing as disasters become more frequent, intense and more costly; and designing adequate financial protection systems for reaching the most vulnerable. Limits to adaptation and slow onset events, leading to human displacement and irreversible and permanent loss, provide unique challenges for finance.

Given the variety of working definitions of loss and damage (Verheyen and Roderick 2007; Schinko et al. 2019; Thomas and Benjamin 2018), establishing boundaries around the category of loss and damage finance has been difficult. Moreover, there are important overlaps with adaptation finance and disaster risk reduction finance (broadly disaster risk management). Adaptation finance broadly focuses on building resilience of three broad types: reducing physical risk, reducing vulnerability, and increasing capacity for emergency response and disaster recovery (including financial capacity) (Levy 2018). 'Disaster risk reduction and risk financing contribute importantly to climate change adaptation by lessening exposure and vulnerability and enhancing resilience to the potential adverse impacts of climate extremes'(Linnerooth-Bayer and Hochrainer-Stigler 2015).

Financing needs

Actions to manage risks comprehensively include risk assessment, risk reduction, social protection, rehabilitation and recovery, and transformation. (Linnerooth-Bayer et al. 2019; Suarez and Linnerooth-Bayer 2011; World Bank 2017a; Ghesquiere and Mahul 2010; Roberts et al. 2016; Linnerooth-Bayer and Hochrainer-Stigler 2015; Surminski et al. 2016; Ranger et al. 2011; Schäfer et al. 2019; World Bank 2017b; Campillo et al. 2017; Suarez and Linnerooth-Bayer 2011; Mochizuki et al. 2018; Haque et al. 2019; Lashley and Warner 2013).

Loss and damage finance instruments and tools

Risk financing may be most viable for large and residual risks that cannot be reduced or managed otherwise (Surminski et al. 2014) a variety of instruments are needed; poorer and richer households have different needs and therefore require different instruments (Hallegatte et al. 2017).

Traditional risk financing includes solidarity finance (including humanitarian response), savings and credit, informal risk sharing, and insurance. Innovative risk financing includes index-based micro-insurance programs; public sector risk transfer; national insurance programs; catastrophe bonds; contingent credit; insuring donors that support governments; and sovereign insurance pools Linnerooth-Bayer and Hochrainer-Stigler (2015) as well as Koehler et al. (2014) differentiate between risk financing (ex-ante) and loss financing (ex-post).

In their review of financial protection tools, Campillo et al. (2017) include savings or reserve funds; insurance mechanisms; catastrophe bonds; post-disaster credit/contingent credit; ex-ante social protection/social safety nets; humanitarian relief and compensation payments; and remittances.

Risk-retention and risk transfer instruments are extremely limited in their suitability to protect the poor and help them recover from climate-related loss and damage. *Social protection* instruments can play key roles, including both traditional instruments such as cash transfers or work programs as well as dedicated climate-related instruments such as adaptive social protection (Hallegatte et al. 2017). Social safety nets can be used to channel sovereign-level financing from catastrophe risk pools to direct beneficiaries (World Bank 2017a; Costella et al. 2017).

Comprehensive climate risk management

'[Comprehensive climate risk management's] overall remit is to anticipate, avoid, prevent, and finance risks as well as absorb remaining impacts'(Mechler and Schinko 2016). Comprehensive climate risk management layers approaches to risk assessment, disaster risk reduction practices, financial protection, relief, recovery, and reconstruction. These layered approaches may combine various financial instruments: Contingency funds, contingent loans and grants, and risk transfer solutions. Different instruments address different risks and different funding needs. The combination of instruments will also need to evolve as climate change alters a country's risk profile (World Bank 2017b). Financial protection strategies should include a mix of financial instruments, directed to reducing the protection gap, advancing financial protection against climate and disaster risks, and scaling up of catastrophe risk pools (World Bank 2017a; Campillo et al. 2017; Linnerooth-Bayer and Hochrainer-Stigler 2015). Comprehensive sovereign risk financing strategies can be designed by layering instruments that can address the range of risks (relative to frequency and severity) that a country may experience. (Ghesquiere and Mahul 2010; Mechler et al. 2014; World Bank Group 2017; Campillo et al. 2017).

Evidence on the scale of financing required for disaster/catastrophe risk finance (including risk pooling and contingency finance)

Using economic IAMs, Markandya and González-Eguino (2019) estimate total residual damage in non-Annex I regions to range from 116–435 billion USD in 2020, rising to 290–580 billion USD in 2030 and 1.13–1.74 trillion USD in 2050. They note the relationship between adaptation expenditures and loss and damage suffered, and that even if adaptation is undertaken, there is a significant amount of loss and damage not eliminated. Estimates are significantly higher if tipping points are considered in the analysis.

Gaps and limits to loss and damage/risk financing

Thomas and Benjamin (2018) find a lack of data in SIDS countries relating to loss and damage and gaps in financial assessments of loss and damage, which are most significant with respect to slow onset events. Such gaps in data and assessment make it difficult to identify gaps in loss and damage finance overall. Roberts et al. (2016) look at shortfalls with respect to slow onset, high-certainty events, noting the large gap between funding available and funding needed, and suggesting that greater attention is needed to the question of how funding raised can support efforts to address loss and damage from slow onset events, such as sea-level rise and desertification. The potential limits on individual, government and donor financing mean that a risk layer 'beyond adaptation' cannot be ruled out, especially for highly vulnerable countries facing more extreme losses. Even today, many highly exposed developing countries cannot finance their risks at the higher layers (UNISDR 2013) as cited by Linnerooth-Bayer and Hochrainer-Stigler (2015).

15.2.4 Prioritisation of financing needs

The prioritisation of financing needs in the climate finance literature is discussed at multiple levels: Global, multilateral, regional, national, local and sectoral as well as across the thematic areas of adaptation, mitigation, loss and damage, disaster risk management (Schweikert et al. 2018; Saunders 2019; OECD et al. 2018; Fridahl and Linnér 2016; Halimanjaya 2015; Micale et al. 2018; AGF 2010; AMCEN 2011; Drunen et al. 2009; World Bank 2010). Sometimes, country-based, thematic-based and sector-based prioritisation discussions are intertwined with sustainable development concerns (Franks et al. 2018; Steckel et al. 2017; AMCEN 2011).

Prioritising needs is fundamentally about three important factors: Desirability, viability and sustainability (World Bank 2018a). In the context of climate finance, these three are very much inter-related to the well-discussed emphasis on 'ambition' and 'transformation' which are linked to the Paris Agreement of 2015 and it three objectives outlined in article 2[5]. Most discussion on prioritisation needs at the global level is focused on article 2.1c; but for many developing countries, 2.1b has strong currency. It leads to prioritisation of system-level resilience to shock and adaptation. In this context, 'transformative' is about promoting resilience and decreasing climate disaster risks. Prioritising resilience includes assessment and measures to address social safety nets, infrastructure, and early warning systems for monitoring extreme weather events. Whereas prioritisation of 2.1c is about putting countries on a path to deep carbonisation with a focus on renewable energy, energy efficiency, abatement per tonne and policy-related matters such as (fossil fuel and bio-energy) subsidy reform.

[5] PA article 2: para 1(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; (b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

In this discussion on prioritisation, vulnerable countries are limited by a high level of poverty, low (institutional and technological) capacity and limited access to capital markets and information and barriers asymmetry. These binding constraints can undermine the ability to appraise and assess a menu of options for effective and efficient climate action. The result may limit risk perception and may encourage biases or short-term choice making that results in maladaptation. Furthermore, effective prioritisation of needs is related to the time frame in which the decision/actions are expected to occur, short-tern (2030) or long-run (2050) as well as careful assessment of the barriers, challenges and constraints to implementation of select menu of options.

At the general level, prioritisation of financing needs, as discussed in the climate finance literature, includes addressing adaptation (climate resilience and adaptability, especially of vulnerable population), whether it is treated at purely sectoral or in an integrated and cross-sectoral process (for more discussion on this see Roberts (2010), Parry et al. (2009) and Sanchez-Rodriguez (2009)) and mitigation (scaling down GHGs emission and related actions) and loss and damage issues due to climate-related extreme weather events and their aftermaths. This includes making effective responses to climate disasters, re-creating agriculture, ensuring food and water security and health of humans and other species are resilient and stabilising the eco-systems (Government of Ghana 2016). It also involves action undertaken to reduce relative total climate risk (Haas et al. 2009) (i.e. both current climate risk and the additional future risk) that climate change may present in the context of temperature goal, whether 2°C or 1.5°C. Additionally, 'needs' are relevant to the prevalence of impacts of climate-related events and are underpinned by the need to tackle underlying social injustices and inequalities (CSO Equity Review 2009; Biagini et al. 2014; Ribot 2011).

'Prioritisation' in both the practice and academic aspects of the climate finance literature is also undertaken in the context of the discussion of the flow of, or, the availability of financing or effort and with regard to country-based, thematic based and sector-based prioritisation. The prioritisation of climate finance for adaptation, despite the rhetoric of climate finance providers have not shifted significantly since 2009, adaptation still receives less than 20% of total climate finance flows at global level (with the exception of bilateral climate finance flows at 'slightly more than 19%' (OECD 2019a) and 'vulnerable countries' still continue to receive only a small proportion of climate finance flow, including for adaptation (Climate Funds Update 2014). Total public climate finance reported by developed countries was 13.3 billion USD (19%) for adaptation, 5.5 billion USD (8%) for cross-cutting activities and 52.4 billion USD (73%) for mitigation (OECD 2019a). The same report highlights that the share of adaptation in public climate finance in 2016–2017 is significantly higher for LDCs (45%) and SIDS (43%) than for all developing countries (22%). But what is needed according to UNEP (2018a) is 140–300 billion USD per year between 2010–2030 (UNEP 2016; UNEP 2018a). This assumes 2°C. The mitigation investment gap is about 400 billion USD per year until 2030 (Elzen et al. 2017). Loss and damage due to climate change is estimated to be 300–700 billion USD by 2030 (Barnett et al. 2016) and is estimated to require at least 300 billion USD per year by 2030 and 1.2 trillion USD per year by 2060 (Parry et al. 2009). Estimates of loss and damages varies. Prospective annual financial loss for developing countries is estimated as high as 4 trillion USD per year after 2030. DARA and the Climate Vulnerable Forum estimate that LDCs will face the largest damages proportionate to the size of their economies (CSO Equity Review 2009).

In the area of adaptation, as noted by the Global Commission on Adaptation, 'the economic case for resilience is strong, and there are strong demands for increased resources to strengthen the resilience of […] economies'. And, yet as the authors of the report noted 'money is not flowing at the volume needed' (The Global Commission on Adaptation 2019). At the same time, it is important to note that countries such as Fiji and Kenya have developed innovating financing mechanism such as special climate-related taxes and climate risk layer instruments in order to make more effective their priorities in both the areas of adaptation and mitigation.

In 2017, Fiji introduced its Environment and Climate Adaptation Levy (ECAL), a 10% tax on such items as luxury cars and yacht charters, and a 10% income tax on the rich. More than 255 million FJUSD (about 117 million USD) has been collected and spent on renewable energy, reforestation, agricultural research, disaster relief, upgraded bridges, rural roads, and many other projects to protect the country's natural environment, reduce its carbon footprint, and improve its ability to adapt to the impacts of climate change (The Global Commission on Adaptation 2019).

Kenya has multiple instruments. It established the National Drought Emergency Fund, acquired a 200 million USD contingent credit line for emergencies, and implemented the Kenya Livestock Insurance Programme (KLIP), an index-based program that is subsidised by the government (The Global Commission on Adaptation 2019).

Ultimately, prioritisation of financing needs must permeate from global level actors, both public and private, to national, city and locality and micro-level actions on the ground.

At the global level of the UNFCCC, the Conference of the Parties (COP) has made explicit decisions targeting to particularly vulnerable groups of countries and has recognised the need to take into account indigenous peoples and women's gender equality and women's empowerment perspectives. In its decisions regarding finance, it has also focused attention on the balance between adaptation and mitigation in the distribution and flow of climate finance. Prioritisation of needs within the private sector is less discussed. But, increasingly, there are focused efforts to seek to develop within the financial sector portfolios that are more resilient to climate-related risks in the long. Within this sector, Climate finance is referred to 'financial investments directed toward mitigating climate change effects and adapting to negative consequences' and is viewed as an opportunity to develop portfolios that are more resilient to climate-related risks in the long term (Blue Orchard 2019).

Corresponding to these directives and independent work on parallel track in the landscape of practice of finance, there are also a few frameworks and a wide range of tools, instruments and mechanisms for garnering information about the prioritisation of financing needs at each of these levels (Government of Ghana 2016b; OECD 2019; ACT 2017). By far, the thematic area of adaptation is the most widely discussed in the regional and national level literature (Government of Ghana 2016).

15.2.4.1 Global directives and efforts at prioritising needs

Since 2010, there has been significant push under UNFCCC to focus on prioritisation in the context of financing climate change. The Cancun agreement took note 'the collective commitment by developed countries to provide new and additional resources, including forestry and investments through international institutions, approaching 30 billion USD for the period 2010–2012, with a balanced allocation between adaptation and mitigation; funding for adaptation will be prioritised for the most vulnerable developing countries, such as the least developed countries, small island developing States and Africa' (para 95, UNFCCC 2010). In paragraph 97, the COP decided that parties shall (take) into account the urgent and immediate needs of developing countries that are particularly vulnerable to the adverse effects of climate change.

The 2015 Paris agreement re-affirmed this prioritising trend. Article 9 (4) states that 'the provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation, taking into account country-driven strategies, and the priorities and needs of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints, such as the least developed countries and small island developing States, considering the need for public and grant-based resources for adaptation' (UNFCCC 2019b). And as noted above, it also introduced new prioritisation parameter (2.1c) in terms of ambition and transformation around which finance should be aligned.

Following these directives, the finance mechanisms of the Convention, bilateral and multilateral funding entities have all to different degree pay focused attention to prioritising streams of financing to (a) to encourage private sector finance to be aligned with the achievement of the long term goal of 2°C and 1.5°C and (b) support developing countries development of country programmes that prioritise their adaptation and mitigation financing needs (Readiness programmes) as well as implement those programmes.

Targeting to the Paris Agreement lead to a focus 2.1c on prioritising financing needs in terms of renewable energy followed by energy efficiency and sustainable transport. For example, the World Bank in its Climate Change Action Plan 2016–2020 (World Bank 2016) it has identified 'six high-impact areas' that it wants to support (World Bank 2016), including:

(i) renewable energy and energy efficiency;
(ii) sustainable mobility (for example, the transport sector. Focus is on building on climate adaptation of the transport sector);
(iii) sustainable and resilient cities;
(iv) climate-smart land use, water, and food security; and
(v) green competitiveness…

In developed countries, parliaments, ministries of environment and treasuries are also focusing on prioritising different dimensions of adaptation and or mitigation in alignment with meeting their NDCs commitments under the Paris Agreement and to address the impacts of extreme weather events on their peoples and economics. Since almost none include adaptation as a component of their NDCs, reliance will be on their adaptation planning tools such as, for example, UK's NAP, 2018–2023 and the EU adaptation strategy. Additionally, global governance institutions such as the IMF and the World Bank have introduced programs that are prioritising climate risk and climate finance to manage those risks. See for example, the joint International Monetary Fund/World Bank Financial Stability Assessment Programs (FSAPs) - which is focused on supporting countries in integrating comprehensive disaster finance strategies into their macro-fiscal frameworks (IMF 2019).

15.2.4.2 Multilateral, regional and bilateral level prioritising of financing needs

(a) Selected multilateral climate funds and the prioritisation of financing needs

Of the twenty-three funds listed in the Climate Funds Update database, four are focused on adaptation (ASF, AF, PPCR, MDG achievement funds - each with their own edibility criteria; Klein and Möhner 2011); five engaged with REDD and mitigation action (the Amazon fund, Biocarbon funds, the Congo basin Forest Fund and the forest carbon partnership Fund-CF and the FIP; Klein and Möhner 2011). And the remaining funds focus on mitigation general fund. Climate funds such as the Global Climate Change Alliance, the Pilot Project on Climate Resilience and the Adaptation Fund (AF) were all designed to make decisions on country prioritisation and allocate funds based on levels of vulnerability, but they all have their own standards for doing so (Klein and Möhner 2011).

The Green Climate Fund through its board decisions is committed to 'deliver a 50:50 balance between mitigation and adaptation allocations in its portfolio, and ensure that at least 50% of adaptation funding goes to particularly vulnerable countries, including LDCs, SIDS and African States' (Green Climate Fund 2019b). Prioritisation of needs is based on the Fund's eight results areas covering four adaptation and four mitigation objectives. Countries then align their country programming requests to these results areas.

The Adaptation Fund prioritises developing countries who are Parties to the Kyoto Protocol and those particularly vulnerable to the adverse effects of climate change. This includes: low-lying coastal and other small island countries, and countries with fragile mountainous ecosystems, arid and semi-arid areas, and areas susceptible to floods, drought and desertification. The AF also support those LDCs that are unable to access the Least Developed Countries Fund (LDCF) will also be given priority to AF funds. The AF' project guideline, Annexe I gives the strategic priorities, policies and guidelines of the AF and how it encourages and facilitates prioritisation at the national level.

According to the AF documents, country allocation also takes into account the strategic priorities, policies and guidelines of the AF (UNFCCC 2009), specifically:

- Level of vulnerability to climate change;
- Level of urgency and risks arising from delay of action;
- Ensuring access to the fund in a balanced and equitable manner;
- Lessons learned in project and programme design and implementation to be captured;
- Securing regional co-benefits to the extent possible, where applicable;
- Potential for maximising multi-sectoral or cross-sectoral benefits;
- Adaptive capacity to the effects of climate change;
- Potential for learning lessons in project and programme design and implementation.

The Climate Investment Funds (CIF) programmes also support countries prioritisation of their financing needs, which ostensibly should be based on countries' National Adaptation Programs of Action and other relevant countries strategies. The Pilot Program for Climate Resilience (PPCR), which is the CIF's primary adaptation funding aspect gives priority to highly vulnerable Least Developed Countries eligible for MDB concessional funds, including the Small Island Developing States. (In 2017, the PPCR reported that 44 PPCR projects in 15 countries supported over 39 million people, about 50% women, who are expected to benefit from enhanced climate resilience (Climate Investment Funds 2017). The CIFs like the Bank and the MDBs have a focus on transformational change/potential focusing on low-carbon and climate resilient development with sustainable development co-benefits (World Bank 2018b).

(b) Selected Multilateral Development Banks and prioritising financing needs

Most all MDBs have portfolios that are dominated by mitigation finance, except for the African Development Bank where there is a balance between financing adaptation and financing mitigation (AfDB 2018). The EIB seeks to 'support regions that have less accurate data to develop climate-resilient planning and less financial capacity to invest in climate change mitigation and adaptation, (EIB 2019; Blue Orchard 2019).

15.2.4.3 Framework, tools and instrument for national, local and micro-level prioritisation of financing needs

There is also a rich and growing literature, tools and frameworks geared at helping countries to prioritised their financing needs in terms of sectoral approach. Most countries draw up upon the IPCC key priority sector for adaptation as well as mitigation and are further guided by the priorities of the climate funds and their respective results areas for both adaptation and mitigation. To date, climate funds have no explicit mandate with regard to loss and damage.

Frameworks include the Bellagio Framework for Adaptation, The Nairobi Adaptation Framework under the UNFCCC, the GCF's 8 results areas (four for adaptation and four for mitigation). Most all of these draw from or rely for implementation on the NAPs and the Guidebook for NAPs process created by the UNFCCC's LDC Expert Group.

Institutions that are relevant for supporting prioritization around NDCs and NAMAs, LEDS and LCDS include the NDC partnership, UNDP, UNEP and the World Bank. UNDP and UNEP and other institutions have evolved multiple tools and frameworks to support countries in prioritization of needs. These frameworks help facilitate dialogue between key stakeholders, donors and funds. Tools and method for enabling prioritisation of climate change financing needs build on or, are geared around the below non-exhaustive set of analytical tools, including project based and price-based approaches:

- Multi-voting technique
- Multi-criteria analysis
- MCAL Clinical project prioritisation
- PEST analysis for the private sector
- OECD DAC criteria for assessing development impacts
- Criteria based matrix
- Development Impact Assessment Visual tool

Other quantitative tools such as cost benefits or cost-effectiveness analysis – exploring the implication of climate risk management for adaptation decision making – as noted by Li et al. (2014) are mostly applied to investment project-based appraisals. Economic analysis including cross-sector and general equilibrium effects of sectoral and national adaptation policy (Li et al. 2014).

a.) National prioritisation of need

At the national (and to a certain extent) sectoral levels, prioritisation financing need is based on long term goals and a strategy around increasing climate resiliency and decreasing climate risk in the context of enhancing sustainable development. This is the launchpad for identifying sectoral priorities. National prioritisation includes agriculture and food security, sustainable forest and resource management, resilient infrastructure and build environment, climate and health, water resources these points to the strategic areas and policy actions that may be needed to generate the action. Countries involved in the GCF Readiness and support programme have up to 1 million USD per year available for supporting the national designated authority to design processes and mechanism, including stakeholder consultations for 'no objections procedures' for vetting proposal submitted to the Fund. The same processes are expected to generate country programmes with investment/funding pipe-lines. Additionally, countries have a one-time access of up to 3 million USD to prepare national adaptation plans and undertake related adaptation planning. Programming for financing must conform to the GCF eight result areas four for adaptation and four for mitigation.

The first and general level in priorisation is the national climate change policy and plans which identified key priorities areas and sectors to be developed. These generally are the basis for instruments such as NAPs, LCDS/LEDS and ultimately INDCs that operate at the more granular level. But as noted above, increasingly, prioritisation around financing country programme and country-level investment plans/strategies are driven by initatives such as the readiness programme of the GCF. The GCF's result areas are linked to impact potential, transformational potential, sustainable development potential and include gender and sustainable development impacts in the context of country ownership and efficiency and effectiveness.

At the micro-level, as highlighted by (Blue Orchard 2019; GCA 2019), for both mitigation and adaptation, micro-level actors such as farmers may prioritise financing needs in terms of the need real-time weather data, for instance temperature, wind direction, rainfall and humidity and real-time access to crop advisory and farming practices through mobile phones, especially digital weather information for time-sensitive decision-making (Blue Orchard 2019).

b.) Adaptation and Mitigation

Adaptation, though rhetorically promoted, still lags behind mitigation in terms of finance, though it would seem to be the most prioritised at national and local levels. The literature on prioritisation effort for adaptation is much richer than for mitigation even though across NDCs, mitigation is much more prioritised, particularly in the NDCs of developed countries.

Adaptation prioritising in the literature aims at increasing resilience and tend to circulate around the following four key areas health, food water security, ecosystem services, infrastructure and built environment and livelihood (including attention to gender and vulnerable groups (The Global Commission on Adaptation 2019). Within this broad frame countries fine-tune according to national context (Government of Ghana 2016). For example, Ghana priorised agriculture and food security, sustainable forest resource management, resilient infrastructure and build environment and gender and the vulnerable (Government of Ghana 2016).

Mitigation, like adaptation, also pivots around four key areas: Energy generation and access, Forest and land-use, Building in cities industry and transport. Here again, Ghana is an illustrative case refining down to AFOLU, Energy, Industry and Transport.

c.) Prioritisation of needs with the explicit involvement of the private sector

The GCF has a private sector facility, and the CIFs argue that they engage with the private sector. The private sector needs are for climate-related risks (expressed in terms of transition and physical risks), and enabling policy environment with predictability and stability. They also require data and standardisation of climate risks models for scenario and analysis and stress testing (Blue Orchard 2019). Transition risks arise from sudden assets adjustment and restore of the coordination of market participants' expectations about climate policies' implementation impact (Swiss Sustainable Finance 2019; TCFD 2017). Transition risk includes policies risk: unanticipated introduction of new carbon pricing mechanism, subsidies and tariffs. What is needed is early introduction of change and stable in implementation to minimise transition risks (other aspects of transition risks include legal risk (litigation claims regarding the outcome of failure to mitigate climate change impacts or insufficient disclosure); technologies risk: new technology for renewable energy and energy efficiency for low carbon economy. Negative externalities such as unemployment, redundancy and stranded assets.

Market risk

Lower demand for carbon-intensive production and rising cost of high carbon supplies. Reputational risk: management of value- and supply chains and negative value judgement on some sectors and industries.

Physical risks

Damage done to physical assets, natural capital and or human lives from extreme weather events (EWE). This includes acute risk (cyclone or flood) and chronic risk (long term changes such as SLR rising. Physical risk impacts production capacity, damage assets and property, safety of employees, increased insurance cost (TCFD 2017).

'START BOX 15.2. HERE'

Box 15.2 Risk

Financial risk or the potential for adverse consequences, associated with climate change is generally classified in three categories (Bank of England 2015) including physical risk (risk of assets damaged by climate-related events, for instance, storms and floods), liability risk (risk of legal parties seeking reparations from other parties for climate-related damages) and transition risk (risk imposed by a market or policy transition towards a low-carbon economy).

Transition risk is more specifically defined as the risk '[…] associated with changes in climate change-related policy and regulation, the rapid development of low carbon technology, changing investor preferences, the occurrence of physical events and significant developments in climate science' (Bank of England 2015). Transition risk can impact the credit risk of companies, as some companies in the oil and gas sector have already exhibited and are expected to face in the future (S&P Trucost 2018; Moodys 2017) and investment portfolio returns and value-at-risk (Mercer 2015; Dietz et al. 2016). However, more information is needed for banks to assess the credit impact of transition risk (UNEP FI 2018). See Section 15.6.3 for further discussion on potential impacts of transition and physical risk. The combination of physical risk from climate change and transition risk implies that while a low-carbon transition that is insufficiently rapid to achieve climate targets could exacerbate physical risks of climate change, a very rapid transition could exacerbate systemic transition risks (Bank of England 2018).

Liability risk can result from policy and regulatory developments. Legal risk developments have been increasing via legal cases for climate-related damage against oil companies, and shareholder cases against companies for not disclosing climate risk (Phillips 2017). The current legal risk may not be very high, but as data and awareness increase, this could grow (Petkov et al. 2016). Regulatory developments (see Section 15.3.4) could also increase the risk for legal recourse for causing climate damage or failing to disclose climate risk.

Physical risk in the form of financial damage from climate-related events including heat stress, flooding, drought, sea-level rise and extreme weather events have already resulted in increasing costs and are expected to increase in the future (see Section 15.2 links to WGI and WGII). Increased operational costs from disrupted production from climate change are already being experienced but may not be reflected in corporate adaptation strategies (Goldstein et al. 2019). Extreme weather events can exacerbate inflationary challenges in developing countries (Heinen et al. 2019). To assess physical impacts in the next 10 to 20 years, the choice of scenario does not make much difference, given the GHG emissions already locked-in to the atmosphere, however, physical impacts around mid-century or later are more dependent on policy changes (Clapp et al. 2017). Physical risk is a function of the probability of a climate-related hazard occurring, the vulnerability and the exposure of the asset, portfolio, or financial system to the potential negative consequences.

'END BOX 15.2. HERE'

15.3 Current flows, commitments and initiatives

15.3.1 Definitions of relevant financial flows

Measures of financial flows and stocks provide complementary and interrelated insights into trends over time: the accumulation of flows, measured per unit of time, results in stocks, observed at a given point in time (UN and ECB 2015; IMF 2009). Figure 15.3 and Figure 15.4 attempts to provide aggregate level reference points of relevance to the remainder of this chapter.

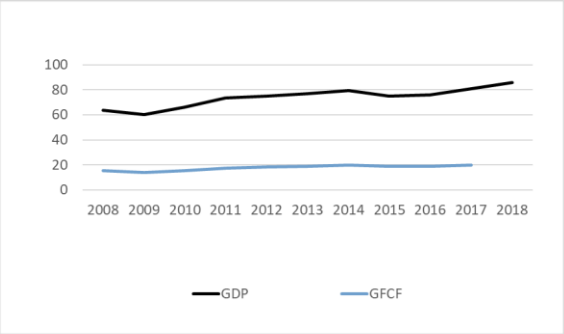

Figure 15.3 Financial flows: orders of magnitude (current USD trillion)

Sources: World Bank Data (2019a,b) for annual gross flows.

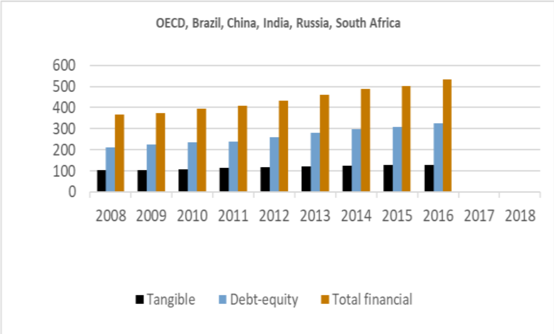

Figure 15.4 Financial stocks: orders of magnitude (trillion USD current)

Sources: OECD.Stat (2019a,b) for stocks of assets.

Note: Geographical breakdown according to IPCC classification will be added to the extent possible.

On the flows side, gross-fixed capital formation, which covers tangible and intangible assets, is widely referred to as a good proxy for investment flows in the real economy. GFCF notably captures investments in infrastructure, which is estimated to be directly responsible for over 60% of GHG emissions over its lifetime (New Climate Economy 2016). GDP, in addition to investments, notably also includes flows of operating expenses and consumption, which have a well-documented and very significant direct and indirect climate footprint (Dubois et al. 2019). One the stock side, the growing gap between the values of tangible financial assets illustrates the financialisation of economies at domestic and international levels. This remains an uneven process between developed countries, most of which have deep capital markets, and developing countries, where local capital market development remains partial or elusive (see Section 15.6.4).

From the perspective of climate change action, these reference points make it possible to highlight both the relatively small size of current climate finance flows (see Section 15.3.3.1) and the scale of investment flows and stocks that more broadly have to be made consistent with climate goals (see Section 15.3.3.2).

Climate finance is a subset of environmental finance, in turn, a subset of sustainable finance, as illustrated in Figure 15.5. In practice, each of these concepts is characterised by a lack of internationally standardised definition and scope. There is broad consensus that climate finance refers to that 'whose expected effect is to reduce net GHG emissions and/or enhance resilience to the impacts of climate variability and projected climate change' (UNFCCC 2018). However, as was already the case at the time of AR5, there remains a very significant room for interpretation and context-specific considerations.

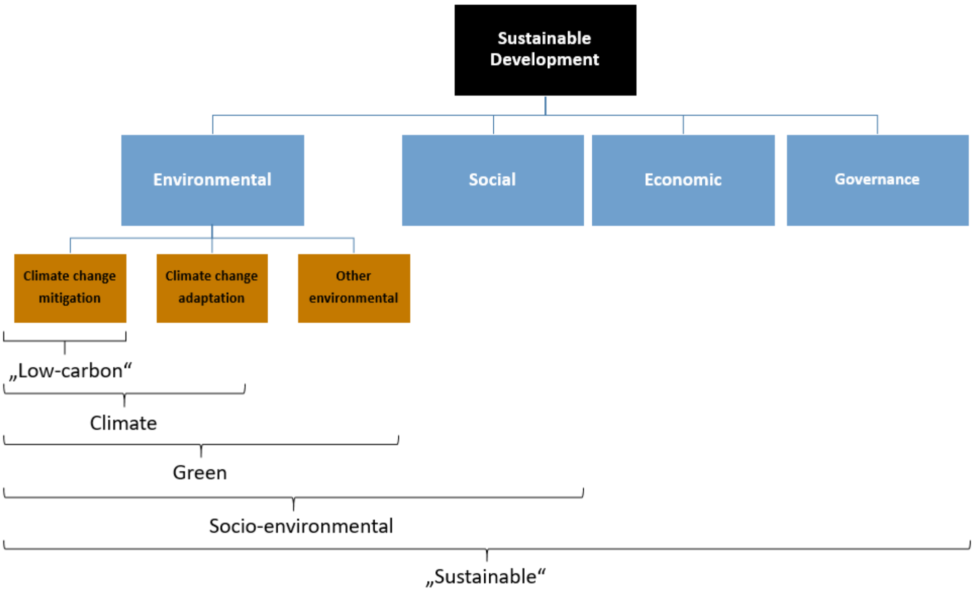

Figure 15.5 Climate finance in the broader context of sustainable finance

Source: UNEP Inquiry (2016).

In practice, specifying the scope of climate finance requires defining two terms: what qualifies as ‘finance’ and as ‘climate’ respectively. The scope of what finance to consider relates in particular to issues of only considering investments versus also operating expenses (see Section 15.2 for a discussion of investment versus cost), stocks versus flows, gross versus net, a selection of versus all financial instruments, domestic versus cross-border, or public versus private. In terms of what may be considered as ‘climate’, a key difference relates to measuring climate-specific finance or climate-related finance, which typically result in very different accounting boundaries (the latter systematically capturing total project costs). In many cases, labelling investments and underlying financing as ‘climate’ will also depend on the context of implementation such as priorities and activities listed in NDCs (UNFCCC 2019c).

Hence, rather than opposing these different options, the choice of one or the other depends on the desired scope of measurement, which in turn depends on the policy objective. This is illustrated by the increasingly diverse body of grey literature analyses at the levels of domestic finance flows (e.g. Hainaut and Cochran 2018; UNDP 2015), international flows (e.g. Joint-MDBs 2019; OECD 2016), global flows (e.g. UNFCCC 2018; CPI 2019) or looking at the financial system (e.g. UNEP 2016) or specific financial instruments such as bonds (e.g. Climate Bond Initiative 2018). Under the UNFCC, the specific modalities to account for financial resources provided and mobilised for climate action in developing countries have, since AR5, continued to be characterised by chronic issues, although the Paris Agreement’s ‘enhanced transparency framework’ may lead to improvements (Weikmans and Roberts 2019a). These aspects are further discussed in **Error! Reference source not found.**.

Beyond the relevance of accurately measuring levels of climate finance, the Paris Agreement provides a broad policy environment and momentum for a more systemic change in investment and financing strategies and patterns. Article 2.1c, which calls for ‘making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development’, positions finance as one of the Agreement’s three overarching goals. This is a recognition that the mitigation and resilience goals cannot be achieved without finance, and the financial system as a whole, being aligned in the Paris Agreement (UNFCCC 2015).

Assessing the climate consistency of finance implies looking at all financing activities, whether they target, contribute to, undermine or have no particular impact on climate objectives. It also requires monitoring public interventions that directly or indirectly support these (Pauw et al. 2019a). Attempts to conceptualise the alignment of finance with climate objectives suggest the use of shades of browns and greens to categorise activities based on their negative, neutral (‘do no harm”) or positive contributions, (e.g. Cochran and Pauthier 2019; Natixis 2019; CICERO 2015). Hence, since AR5, in addition to measuring and analysing climate finance per se, an increasing focus has been placed on monitoring investments and financing for fossil fuel as well as other activities that may be incompatible with mitigation pathways (see Section 15.3.3).

The consistency of finance with climate mitigation may in practice be assessed based on multiple reference points including: national targets and pathways under the UNFCCC, institutional-level targets, sectoral and global scenarios, as well as taxonomies of activities. Hence, measuring progress towards consistency implies compiling, though not aggregating, a wide range of indicators across the financial value chain, for instance both on financial markets and in the ‘real economy’ (Jachnik et al. 2019).

15.3.2 Conceptual mapping of actors and instruments

15.3.2.1 Overview of financial actors and instruments

Finance for climate action is often embedded in the more general structure of investment and financing activities. Different actors typically make use of a range of financial instruments depending on their position in the financial value chain (intermediary, direct investor), their mandate (e.g. commercial, developmental), their scope of activity (local, national, international), as well as their risk appetite.

Table 15.6 From sources of finance to economic activities

Source	Actor	Instrument	Project Initiator	
Taxes and levies Earnings and savings Capital markets	Governments Public institutions Commercial financial institutions Corporates Institutional investors Philanthropies Households	Grants Debt Equity Guarantees Insurances	Public authorities Corporations Small and medium-sized enterprises Households	*Climate-relevant sectors of the economy, notably:* *Agriculture* *Buildings* *Energy* *Industry* *Transport*

Source: Adapted from Hainaut et al. (2019), CPI (2019), CICERO and Climate Policy Initiative (2015).

Actors and instruments active in investing and financing activities with climate change mitigation and adaptation benefits vary greatly depending on, inter alia, different sectors (see finance sections of sector-specific chapters) and geographies. Hence, the increasing climate focus of certain actors (e.g. institutional investors, philanthropies) and the emerging use of certain instruments (e.g. green bonds) since AR5 needs to be nuanced. Notably, equity investors typically have a home bias due to a combination of reasons relating in particular to information and familiarity (Lindblom et al. 2018).

15.3.2.2 International climate finance architecture

As depicted by Climate Funds Update (Heinrich Böll Foundation and Overseas Development Institute), the architecture of international public climate finance is ‘complex and always evolving. Funds flow through multilateral channels – both within and outside the UNFCCC Financial Mechanism – as well as through bilateral and regional initiatives and channels. A growing number of recipient countries are also setting up national climate change funds that receive funding from multiple contributor countries in an effort to coordinate and align contributor interests with national priorities’. Figure 15.6 illustrates the complexity that results from the multiplication of sources and channels of international climate finance over the years (Climate Funds Update 2018).

The operationalisation of the GCF has notably attracted particular attention since AR5. The literature on the GCF focuses on three aspects: how it should raise funds; the use of these funds towards numerous developing countries; and the balance of such use between mitigation and adaptation activities (Cui and Huang 2018). Chapter 14 provides a further assessment of the financial mechanisms of the UNFCCC, notably the progress made and challenges faced by GCF.

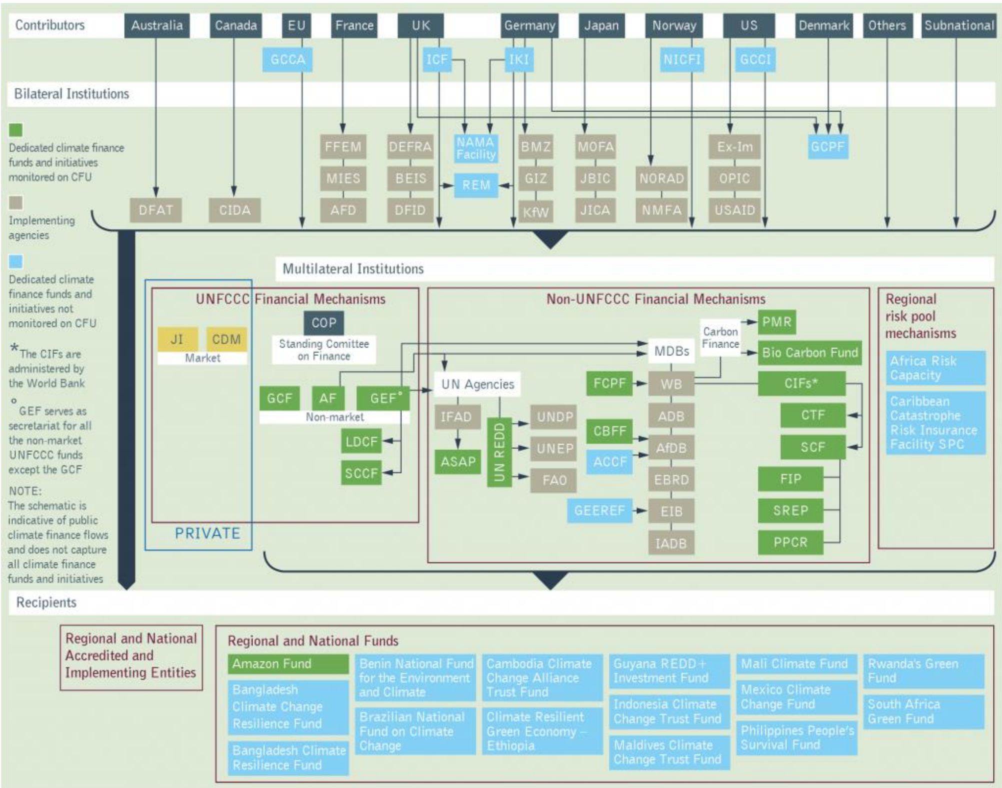

Figure 15.6 Overview of the architecture of international climate finance

Source: Climate Funds Update (2018).

There is evidence that such complexity implies significant transaction costs (Brunner and Enting 2014), in part due to bureaucracy and intra-governmental factors (Peterson and Skovgaard 2019), which are most often not accounted for in assessments of climate finance. On the ground, activities by international providers operating in the same countries may overlap in certain sectors, with limited coordination and duplication of efforts, both on the bilateral and multilateral sides (Ahluwalia et al. 2016). Further, the above view does not capture emerging providers of development co-operation, both bilateral (Benn and Luijkx 2017) and multilateral (Asian Infrastructure Investment Bank). These necessarily further interplay with (Gallagher et al. 2018) compete with or run in parallel to (Humphrey and Michaelowa 2019) financing provided by traditional donor countries and institutions.

National development banks are assessed to have the potential to play an important role beyond tradition capital provision, towards de-risking projects to mobilise additional capital, playing educational role to enable financial sector learning, and producing track records to crowd-in private finance (OECD 2019b; Geddes et al. 2018; Smallridge et al. 2013).

15.3.3 Assessment of current financial flows

15.3.3.1 Climate finance flows

The measurement of climate finance flows continues to face the same definitional and reliability issues than AR5 (IPCC 2014) and 1.5°C reports (IPCC 2018b), despite progress made (more sources, greater frequency, and some definitional improvements) by a range of data providers and collators. Based on available estimates, flows of annual global climate finance are on an upward trend since AR5, reaching a high-bound estimate of 681 billion USD in 2016 (UNFCCC 2018). Latest available estimates, however, indicate a likely drop in 2018 (CPI 2019). Current climate finance remains small (3%) compared to the GFCF reference point introduced in Section 15.3.1, as well as significantly below estimates of needs presented in Section 15.2. Direct comparisons are here, however, not possible due to inconsistencies in terms of scope and coverage.

[Note to reviewers: Data by sector and region to come]

Table 15.7 Available estimates of global climate finance

Source		2011	2012	2013	2014	2015	2016	2017	2018	2019
SCF Biennial Assessments	Total high	n/a	n/a	687	584	680	681	tbc	tbc	n/a
	Total low	n/a	n/a	339	392	472	456	tbc	tbc	n/a
CPI Global Landscape	Total	364	359	342	388	472	455	612	546	tbc
	OECD[a]	53%	49%	50%	n/a	46%		39%		tbc
	Non-OECD	47%	51%	50%	n/a	54%		61%		tbc

Note: Given the variations in numbers reported by different entities, changes in data, definitions and methodologies over time, there is low confidence attached to the aggregate numbers presented here. The higher bound reported in the SCF's Biennial Assessment reports includes estimates from the International Energy Agency on energy efficiency investments, which are excluded from the lower bound and CPI's estimates.

[a] In SOD geographical breakdown will be presented according to IPCC regional classification, which requires accessing raw data.

Source: UNFCCC (2018, 2014) and CPI (2019)

At an aggregate level, in both developed and developing countries, the vast majority of tracked climate finance is sourced from domestic or national markets rather than cross-border financing (CPI 2019). This indicates that the general home bias of finance and investment holds for climate finance as well. It also reinforces the point that national policies and settings remain crucial, along with the development of local capital markets, including towards the issuance of local bonds (Section 15.6.4).

The increasing share of developing countries' in total tracked climate finance since 2011 is due in particular to a sharp increase in China and, to a lesser extent, India as well as other developing countries. While increased climate finance in developing countries is a positive trend, such finance is heavily concentrated in a few countries, in particular, emerging economies (BNEF 2019; CPI 2019).

On the other hand, the plateauing of climate finance in developed countries is a matter of serious concern given that economic circumstances are, in most cases, relatively more amenable to greater financing, savings and affordability than in developing countries.

Mitigation, continue to represent the lion's share of climate finance and in particular renewable energy and energy efficiency, for instance between 70–80% combined depending on the year (UNFCCC 2018; CPI 2019). While falling technology costs in certain sectors (e.g. solar energy) has had a negative impact on the year-on-year trend that can be observed in terms of volumes of climate finance, capacity additions on the ground kept rising (BNEF 2019; CPI 2019). However, such cost reduction should, in principle, free up investment and financing capacities for potential use in other climate-related activities. Adaptation remains underfunded compared to rapidly rising needs (see Section 15.2). Tracking adaptation finance, however, continues to pose significant challenges in terms of data and methods. Notably, the mainstreaming of resilience into investments and business decisions (Averchenkova et al. 2016; Agrawala et al. 2011) makes it difficult to identify relevant activities within financial datasets.

Significant gaps remain to track climate finance comprehensively at a global level. Available estimates are heavily skewed towards investments in renewable energy and, where available, energy efficiency and transport. Other sectors remain more difficult to track, such as agriculture and land use, as well as adaptation altogether (UNFCCC 2018; CPI 2019).

In contrast to international public climate finance, domestic public finance data remains very partial, although an increasing number of countries are running climate and green budgeting exercises. Data on private and commercial finance remains very patchy, particularly for corporate investments and bilateral loans provided by commercial banks (Jachnik et al. 2019).

Further, as individual source of aggregate reporting (UNFCCC 2018a; FS-UNEP Centre/BNEF 2019; CPI 2019) tend to rely on the same main data sources (notably the BNEF commercial database for renewable energy investments) as well as to cross-check numbers against similar other sources, there is a potential for 'group-think' and bias. Finally, data gaps as well as varying definitions of what qualifies as 'climate' (both from the perspective of mitigation and resilience) not only pose a measurement challenge but also result in a lack of clarity for decision-making by investors and financiers wanting to pursue opportunities that would lead to climate mitigation benefits (Section 15.6.3).

In terms of finance provided and mobilised by developed countries for climate action in developing countries, significant variations remain in possible accounting methodologies (see **Error! Reference source not found.**). There is, however, a consensus on a need to further scale up public finance and improve its effectiveness in mobilising private finance (OECD 2019a), as well as to further prioritise adaptation financing, in particular towards the most vulnerable countries (Oxfam 2018).

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Box 15.3 Measuring progress towards the USD 100 billion p.a. by 2020 goal: Issues of method

In 2009, at COP15, Parties to the UNFCCC agreed the following: 'In the context of meaningful mitigation actions and transparency on implementation, developed countries commit to a goal of mobilizing jointly 100 billion USD per year by 2020 to address the needs of developing countries. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance' (UNFCCC 2010). The scope of this goal is narrower than total (inter-)national-level climate finance flows (Section 15.3.3.1) and needs (Section 15.2).

Nevertheless, in addition to supporting climate action in developing countries, the fulfilment of the 100 billion USD goal represents an important trust-building element in the international climate negotiations process, including towards unlocking increased climate ambition and action. However, as the exact parameters for what and how to count were not defined at the same time than the goal was set, there remain different interpretations on how to account for progress.

These different interpretations relate mainly to the type and proportion of activities that may qualify as 'climate' on the one hand, and to how to account for different types of finance (and financial instruments) on the other hand. As an example, there are different points at which financing can be measured, for instance, pledges, commitments, disbursements. There can be significant lags between these different points in time; for instance, disbursements may be spread over time for individual projects or milestones of large projects. Further, the choice of point of measurement can have an impact on the characteristics of the finance tracked, for instance, geographical origin, labelling as public or private.

As a result, reporting by developed country Parties to the UNFCCC on climate finance provided and mobilised, as part of their Biennial Reports, demonstrates variations. The issue of a lack of standards is well known (Jachnik et al. 2015; Stadelmann et al. 2013; Clapp et al. 2012), and continues to be controversial (Weikmans and Roberts 2019). The enhanced transparency framework under the Paris Agreement may, however, lead to improvements and more consensus in the way climate finance is accounted for and reported under the UNFCCC.

In the meantime, available estimates specifically aimed at assessing progress towards the 100 billion USD goal remain rare; for instance, the UNFCCC SCF Biennial Assessments do not directly address this point (UNFCCC 2018). Dedicated OECD reports account for gross flows of climate finance on the basis of analysing data reported by developed country parties to the UNFCCC, data reported by DAC members as well by as multilateral development banks and funds to the OECD DAC statistical system, as well as complementary data on climate-related export credits (OECD 2015a, 2019a).

OECD estimates include four components: developed countries bilateral public climate finance, multilateral public climate finance attributed to developed countries, developed countries bilateral climate-related export credits, and private finance mobilised attributed to developed countries. For 2017, the OECD estimate was as follows: A total of 71.2 billion USD, out of which 54.5 billion USD of public finance, 2.1 billion USD of export credits and 14.5 billion USD of private finance mobilised. Mitigation represented 73% of the total, adaptation 19% and cross-cutting activities 8%. The low share of adaptation may in part due to a low level of obligation and precision global adaptation rules and commitments (Hall and Persson 2018). Further, providers of international climate finance may have more incentive to support mitigation over adaptation as mitigation benefits are global, while the benefits of adaptation are local (Abadie et al. 2013). Reports by Oxfam provide a complementary view, which, building on OECD estimates and underlying data sources, translates gross flows of bilateral and multilateral public climate finance in grant equivalent terms (Oxfam 2016, 2018). Based on annual averages for 2013–2014 and 2015–2016, Oxfam estimates indicate that grant equivalence represents between 27% (low bound) and 52% (high bound) of gross public climate finance.

There are also potential alternative methodological options to those used by the OECD. One of them relates to using different reference points for attributing shares of climate finance from multilateral institutions to developed countries. Sensitivity analysis by the OECD for 2013–2014 estimates indicates a variation of plus or minus 24% depending on the method, with OECD estimates almost exactly in the middle of these lower and upper bounds (OECD 2019b).

A further point of method that attracts much attention relates to how to account for and attribute private finance mobilised. OECD estimates for 2016 and 2017, compared to estimates for 2013 and 2014, rely on improved granularity of data collection and further methodological developments work (OECD 2019c). There are here no alternative estimates of mobilised private finance for climate action in developing countries, except those put forwards by MDBs in their joint climate finance reporting (African Development Bank; Asian Development Bank; European Bank for Reconstruction and Development; European Investment Bank; Inter-American Development Bank Group; the Islamic Development Bank; World Bank Group; 2019). MDB estimates of mobilised private finance and the underlying methodology (World Bank 2018a) however, neither correspond to the geographical scope of the USD 100 billion goal, nor address the issue of attribution to the extent required.

In conclusion, notwithstanding methodological discussions under the UNFCCC, there is still some distance from the 100 billion USD per year commitment being achieved, including in terms of further prioritising adaptation. While the scope of the commitment corresponds to only a fraction of the larger sums needed (Section 15.2), its fulfilment can both contribute significantly to climate action in developing countries as well as to trust-building in international climate negotiations. Combined with further clarity on geographical and sectoral gaps, this can, in turn, facilitate the implementation of better-coordinated and cooperative arrangements for mobilising funds (Peake and Ekins 2017).

'END BOX 15.3. HERE'

15.3.3.2 Broader investment and financial flows and stocks

Since AR5, the range of active actors and financial instruments aimed at climate and broader sustainability issues has grown. Financial markets (see financial stocks estimates in Section 15.3.1) have witnessed a proliferation of environmental, social and governance (ESG) indices as well as sustainability labelling, for instance green, sustainable, blue, ESG. The degree to which they are climate relevant depends on underlying criteria and how they are applied.

A tangible and noticeable development has been the significant growth in the issuance of labelled green bond, which exceeded 160 billion USD in 2017–2018, up from 37–51 billion USD in 2014–2015 (Climate Bond Initiative 2019). Development finance institutions played a pioneering role in this market. Since 2007, 43% of green bonds have been issued by multilateral and bilateral development institutions to finance climate action in developing countries, in addition to some bonds issued by institutions located in emerging markets such as the city of Johannesburg in South Africa, Yes Bank in India, and Nafin development finance institute in Mexico (Clapp and Pillay 2017). Green sukuks, Islamic finance instruments, were first issued in Malaysia in 2017, followed by Indonesia. Commercial, financial institutions and corporates (e.g. in real estate, retail, manufacturing, energy utilities) now represent the largest volumes (Climate Bond Initiative 2019), although this remains tied to the development of local capital markets (Section 15.6.4).

Despite this significant growth, green bonds remain below 1% of the global bond market. Further, green bonds are often used to refinance existing climate projects and thus do not necessarily result in finance for new climate projects and additional GHG reductions. They may, however, contribute to capacity building within issuing institutions on climate change (Schneeweiss 2019).

Available assessments indicate that many investors' portfolios (financial assets) indirectly support a temperature increase well above 2°C, for example (2° Investing Initiative 2017). The currently mixed evidence about the financial performance of green financial products, which is in turn due to underpricing of climate-related externalities and risks, may explain this (see Section 15.6.3). The demand for financial products aligned with the objectives of the Paris Agreement is, however, likely to rise as an increasing number of financial institutions, institutional investors and asset managers announce climate-related pledges. Such pledges typically consist in committing to allocate a defined volume or age of funds to activities with identified climate benefits or to divest from or stop financing fossil fuel-related activities, notably coal.

While an upscaling of pledges by the financial sector could result in avoided emission (Glomsrød and Wei 2018) there is contested evidence about the impact of divestment. Arguments in support of it relate to indirect effects such as the stigmatisation of the industry, bringing climate change into the discourse of fiduciary duty and building a network of influence. Criticisms include the close to absence of impact in terms of GHG emission reductions, and the potential diversion of attention from for the systemic nature of the problem, which requires coherent policies and co-ordinated climate action (Braungardt, van den Bergh, and Dunlop, 2019; Bergman 2018; Ayling and Gunningham 2017). Further, the divestments from and commitments to stop financing fossil fuels may not be impactful as substitute investors and financiers are available. Active shareholding could be an alternative to divestment, but there have been to date limited environmental shareholder activism (Flammer et al. 2019) and even more limited climate-related shareholder resolutions (2° Investing Initiative 2019).

As further developed in Section 15.6.2, the level of ambition and coherence of public policy and finance at national and international level are, in many cases, still insufficient to set the right incentives for a more rapid scaling up climate finance (UNEP 2018c), including in terms of misaligned policies in non-climate policy areas such as trade and financial regulation (OECD 2015b). While public financial institutions are progressively withdrawing from fossil fuel-related activities, public direct and indirect financial support for fossil fuel-related production and consumption remain very significant in many parts of the world (Climate Transparency 2018; Coady et al. 2017; Bast et al. 2015). OECD inventory (direct budgetary transfers, revenue forgone, risk transfers, or induced transfers) shows that progress in reducing support slowed down among OECD and G20 economies in 2017. OECD (2018) and IEA (2019b) estimates indicate that fossil-fuel subsidies for consumption are on the rise in several developing economies. The combined OECD-IEA global estimate for 2017, including subsidies in 76 economies, rose to 340 billion USD, a 5% increase compared to 2016. Given the scale of historical support to fossil fuel industry production and consumption, this greatly reduces the efficiency of public instruments and incentives aimed at redirecting investments and financing towards climate beneficial activities. As a result, the demand for fossil fuels, especially in the energy production and transport sectors, remains high, and the risk-return profile of fossil fuel-related investments it still positive in many instances (Hanif et al. 2019). Political economy constraints of fossil fuel subsidy reform remains a major hurdle for climate action (Röttgers and Anderson 2018; Schwanitz et al. 2014).

Data on ‘brown’ investments and financing on the ground remain very partial and difficult to access, as relevant actors have little incentive and no obligations to disclose such information compared to reporting on communicating about their ‘green’ activities. A growing number of investors/financiers are assessing climate-related risks with the aim to both disclose information about their current level of exposure, as well as to inform their future decisions (TCFD 2017). Reporting to date is, however, inconsistent across geographies and jurisdictions (CDSB 2018; Perera et al. 2019). Further, risk-related assessments and disclosure have not resulted in more transparency about the underlying volumes of remaining investments/financing to climate detrimental activities. Consequently, there is currently not enough evidence in order to conclude whether such risk assessments result in increased climate mitigation and resilience on the ground.

Available estimates of ‘brown finance’ indicate that recent investments in and financing for climate-misaligned activities have not necessarily decreased, for example in the energy system (IEA 2019a), or in terms of financing and underwriting provided by commercial banks (Rainforest Action Network

2018). Global investment in oil and gas and coal mining had been falling until 2016, accompanying a large fall in oil prices from their previous peak levels. They have, however, increased again recently (shale oil and coal) and remained larger in aggregate than the total reported low carbon energy mitigation financing worldwide (IEA 2019a). Given the long lifespan of most tangible assets (infrastructure, equipment), the GHG emissions locked in by such investments are at odds with emission pathways to reach the Paris Agreement temperature goal.

'BOX 15.4. STARTS HERE'

Box 15.4 Behavioural failures

Empirical evidence from behavioural economics and psychology demonstrates that people's judgements and decisions systematically deviate from the basic principles of logic and probability (Shafir and LeBoeuf 2002). Rather than maximizing utility functions people often seem to rely on intuitive strategies and heuristics. While these prove to be reasonably effective in everyday decisions (Gigerenzer and Gaissmaier 2011), they can also cause severe biases in human decision making (Kahneman et al. 1991).

Individual psychological factors: Perception and reflection of risk in investment decisions: The difference between risky and ambiguous choices – where the probabilities for certain outcomes are known for the former but unknown / not well defined for the latter – was illustrated by the Ellsberg paradox (Ellsberg 1961). Decisions under risk seem to activate different neural networks, then ambiguous decisions, indicating their different physiological nature (Krain et al. 2006). Whereas people generally seem to be averse to risk, their aversion to ambiguity is usually stronger (Platt and Huettel 2008).

Choosing adaptation means to proactively adapt to future events whose probabilities are often unknown and therefore ambiguous. When the probabilities of events are unknown, people usually remain inactive and rely on the status quo (Kahneman et al. 1991; Samuelson and Zeckhauser 1988).

Self-efficacy: A large body of evidence from psychological science suggests that behaviour results from the perception of one's own abilities (Bandura 1977). According to a recent meta-analysis (Van Valkengoed and Steg 2019), one of the strongest factors that relate to climate behaviour is self-efficacy, for instance 'people's beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives' (Bandura 1993). Thus, the more people believe that they are able to prevent climate change, the more likely they are to adapt their behaviour. Moreover, the more they believe that specific behaviours protect them from climate-related hazards such as floods, hurricanes, or droughts, the more likely they are to behave in this way (Van Valkengoed and Steg 2019).

Construal effects: Many of the positive effects of climate action lie in the future. Climate change initiatives, therefore, require that individuals sacrifice immediate benefits for the sake of a distant goal. While future events are construed in an abstract and distant way, the presentation of present events is vivid and concrete, which leads people to prefer smaller, immediate rewards over larger delayed rewards (Green and Myerson 2004; Trope and Liberman 2003). Recent work in cognitive and personality psychology points to the malleability of intertemporal preferences. Lempert et al. (2016) argue that intertemporal preferences can be altered by framing (the way decision alternatives are presented), incidental affective states (e.g. sad mood) and prospection (mental representations of possible future events). Calluso, Tosoni, Fortunato, and Committeri (2017) provide support for the notion that intertemporal choices are heavily dependent on contextual factors including perceived social norms.

Availability bias: When making judgements, people consciously or unconsciously rely on initially available pieces of information (Tversky and Kahneman 1974). Bias occurs when future information is evaluated on the basis of an unrelated anchor of information. For example, the availability bias might manifest in the observation that some people seem to rely on less relevant, but available information (such as the perception of warm days) instead of more reliable but less accessible data (such as global climate change patterns) when forming decisions (Zaval et al. 2014). One specific policy recommendation is, therefore, to avoid too cognitively loaded descriptions of climate-related policies but instead rely on memorable experiences, relevant stories and metaphors which are more likely to be recalled by private sector actors when decisions to invest in adaption are formed (Van der Linden et al. 2015).

Affectivity: Bosman, Kräussl, and Mirgorodskaya (2017) investigated how different formulations of news influence the expectations and beliefs of financial investors. Study participants were randomly assigned to two different conditions (positive vs negative news frames) and asked to assess the stock price performance of real listed companies. Participants in the positive news frame seemed to predict higher stock prices for the listed companies, felt more positive about the economic outlook and perceived stock markets as safer compared to participants in the negative news frame.

In a recent study, researchers exposed study participants to brief media articles which were either framed in terms of 'war against climate change' or 'race against climate change' and manipulated whether the emission reduction goals were either relatively near or distant in the future. Participants who were exposed to the 'war frame' perceived a higher urgency and risk of climate change and reported a higher willingness to increase conservation behaviour related to climate change compared to participants who were exposed to the 'race frame' (Flusberg et al. 2017). Thus, metaphors may trigger emotional responses which in turn are known to influence reasoning about risk (Loewenstein and Lerner 2003).

Personality traits: In addition to the cognitive processes mentioned above, several personality traits appear to exist that influence the perception of climate change (Brick and Lewis 2016). People differ, for example, in how intensively they try to approach positive results and avoid negative ones. Higgins (Higgins 1997, 1998) suggested two different orientations: A dispositional promotion focus that identifies people who focus on progress and goal achievement, and a prevention focus that identifies people who focus on safety, non-failure, and protection. In the context of investment decisions, research suggests that different financial products be associated with self-regulatory orientations. Contrary to standard financial decision theory - which assumes that investors' goals and targets are exogenous and that rational investors should select the portfolio which maximizes their utility in view of their attitude towards risk (Markowitz 1952). Zhou and Pham (2004) provide empirical evidence that some financial products (e.g. individual stocks and trading accounts) are related to the achievement of gains (promotion focus) whereas other financial products (e.g. mutual funds and retirement accounts) are related to the avoidance of loss (prevention focus). The theory of self-regulation (promotion vs prevention focus) can, therefore, lead to a better understanding of the willingness of private sector investors to participate or not in climate change action. It may be that some investors aim to reduce the risks of climate change in day-to-day business operations (prevention focus), while other investors aim to exploit new opportunities (promotion focus).

Another individual factor which may be of value in designing effective policies is gender. Eagly (2009) argued that beliefs about gender roles insinuate that women are more communal (e.g. concerned with others, unselfish, friendly) while men are thought of to be more agentic (e.g. dominant, assertive, competitive). While both men and women display prosocial behaviour, they can be assumed to do so in different contexts: Prosocial behaviours are more common in men if they have a collective emphasis, facilitate gaining status, or imply higher status (Eagly 2009 p.646), whereas women are more likely to act prosocially in order to care for someone else, i.e. when there is a relational focus. Whether prosocial behaviour leads to investment decisions in the context of climate action that takes into account global equity considerations and the current aspect of common goods besides individual financial returns warrants future research.

Social factors contributing to climate action: In addition to individual factors, social aspects such as norms and culture do affect people's motivation to get engaged in climate change action and in particular to adapt to climate change (Cialdini and Goldstein 2004; Fehr and Schurtenberger 2018; Van Valkengoed and Steg 2019). Individuals orient their behaviour towards social norms, for instance the behaviour of others (Cialdini and Goldstein 2004; Fehr and Schurtenberger 2018). These social forces can outperform individual factors. For example, while the lack of self-efficacy is a major barrier to accelerated action against climate change at the individual level, it can be compensated by the perception of others who adapt their behaviour. These others can serve as role models and thus increase the self-efficacy of bystanders; besides, bystanders might simply adapt their behaviour so as not to exclude themselves from the majority. Social norms are embedded in cultural settings. Empirical evidence suggests that current policies partly overlook cultural factors in the analysis of responses to climate change. A deeper understanding of cultural dimensions is therefore important to better understand the documented differences in reactions across populations to the same climate-related risks (Adger et al. 2013).

'BOX 15.4. ENDS HERE'

15.3.4 The public-private and mobilization narrative and current initiatives

The need to mobilize private sector capital in order to meet the financing needs related to climate as well as SDGs has been increasingly in the focus of international negotiations as well as cooperation with many relevant institutions, think tanks and governments presenting targets concepts for implementation, also against the background of a number of commitments made by private-sector financial institutions conditional to risk-mitigation, co-financing or other kinds of support by the public sector research (e.g. G20 IFA WG 2017).

Private sector investments can happen at various levels depending on the level of remaining risk allocation to the public sector as well as the level of due diligence and structuring, project management and aggregation being provided by the public sector. The following figure 15.7 illustrates selected options for mobilizing private capital - from project-specific leverage to financing through financial intermediaries and development banks, leveraging through refinancing via green bonds and securitisations and their impact on attractiveness for various financial sector players.

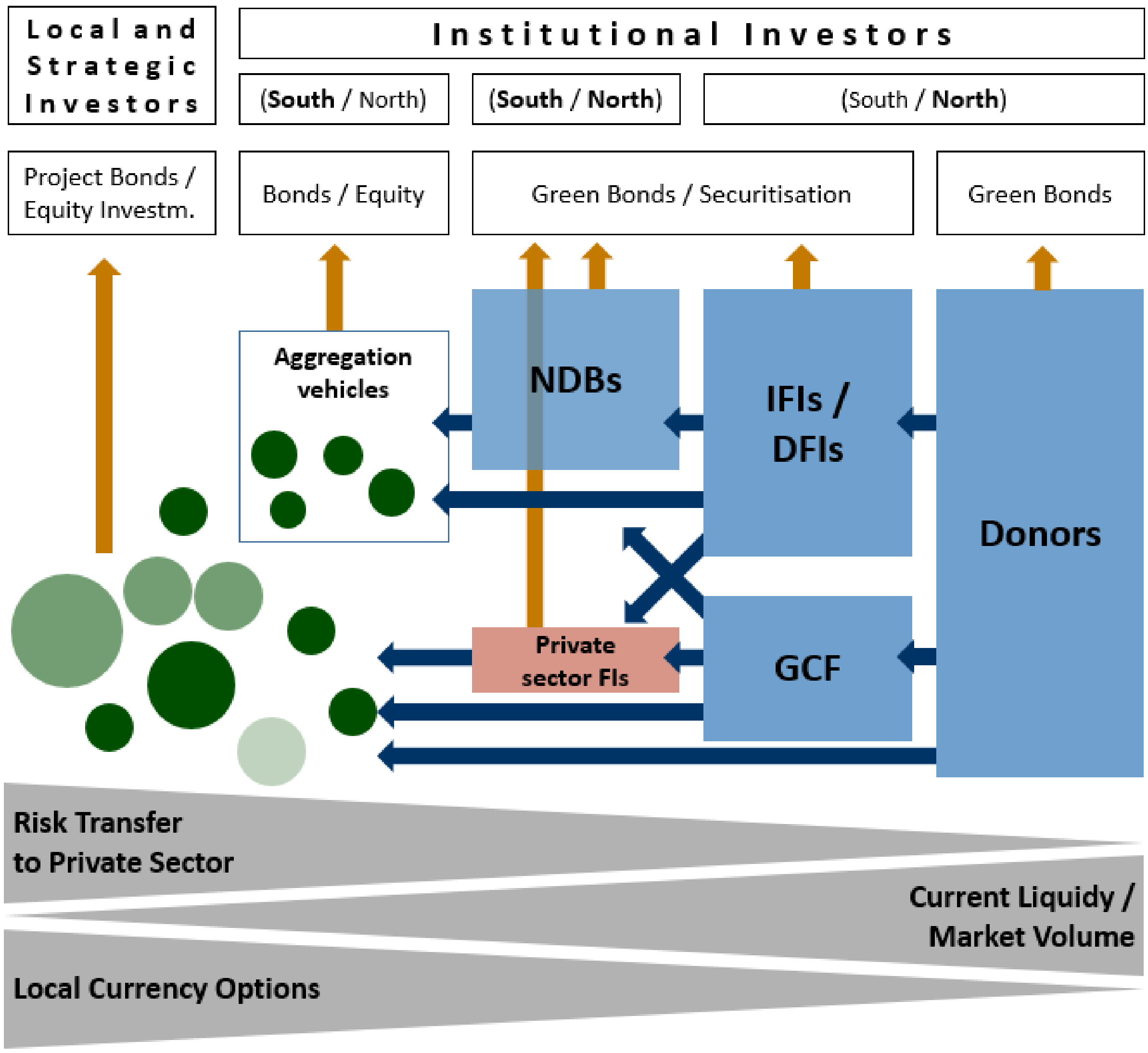

Figure 15.7 Focus and strategy of efficient private sector mobilization

Note: Bold indicate dominating funding sources.

Source: Own drawing.

NDBs	National Development Banks
IFIs	International Financial Institutions
DFIs	Domestic Financial Institutions
GCF	Green Climate Fund
FIs	Financial Intermediaries

Financing provided by development finance institutions and development banks aims to address market failures and barriers related to limited access to capital as well as provides direct and indirect subsidisation (by accepting higher risk, longer loan tenors and/or lower pricing). In principle, the subsidy component can be separated from the financing component in all transaction structures, for example concessional loans could be replaced by commercial financing in combination with public sector guarantees and subsidies. This is reflected in the World Bank's CASCADE approach (Cordella 2018).

Given the high level of required subsidisation, many development and climate projects in developing and emerging countries have traditionally been supported with concessional loans by DFIs/IFIs, combining both elements described above. With an increasing number of sectors becoming viable and increasing complaints of private sector players with regard to crowding-out (Bahal et al. 2018), a stronger separation and crowding-in of commercial financing at the project/asset level is targeted. The combination of the financing and subsidisation element at the project/asset level has traditionally shifted private sector involvement to a higher level (refinancing of DFIs/IFIs on capital markets if at all). MDBs and IFIs have been crucial for opening and scaling the green bond market in early years and still represent a substantial share of issuances (Climate Bond Initiative 2019) which is hardly recognized as private sector involvement in the current debate.

Initiatives and approaches mentioned above foster the trend towards mobilizing the private finance sector closer to the project level requiring a change in the use of public support instruments. Public support to improve enabling conditions, develop and implement targeted policies, build capacities, demonstrate technologies, et cetera may not mobilise large volumes of private finance in the very short term, but of critical importance for scaling up climate investments over time. Such type of support is particularly critical in countries, sectors and technologies, which the private/commercial investors and financiers consider as too risky for the time being.

Different public finance instruments play different roles along the technology/project development lifecycle as well as to contribute to mitigating risks of different nature depending on the context and country (Taghizadeh-Hesary and Yoshino 2019), notably:

- Public grants and subsidies to fund early stages, development and demonstration costs towards attracting later stage private/commercial investment and financing
- Fund-level or direct equity investments and debt provision in riskier tranches to attract commercial/private co-financing (OECD 2019c)
- Programme- and project-level guarantees for de-risking otherwise commercially-viable projects (Green Growth Action Alliance 2013)

Direct and indirect financial support provided by climate-related policies can contribute significantly to improving the risk-return profile of mitigation projects (Haščič et al. 2015).

While the primary reason stated for an increased private sector involvement in climate finance is the scale of financing needs combined with a restricted access to funding of the public sector, the following aspects tend to be additional drivers for (perceived) advantages of an increased focus of private sector involvement in particular from local sources.

Access to local currency finance: Avoiding hard currency debt poses a significant risk to many partner countries, especially given the high levels of investment needed to achieve the SDGs with the Paris targets and the accompanying increase in the capital intensity of the economies raising the importance even more. Access to local currency finance in many partner countries is primarily possible through local sources of finance. In the private sector, local pension funds, insurance companies and family offices are potential and not to be underestimated sources of funding. The nominal higher financing costs in local currency must be carefully converted to hard currency basis before comparisons can be made and often do not come in at higher levels in real terms.

Reduction of risk premiums for country risks: The international private sector often sets high prices on country and political risks and is driven by a strong home bias. Investments without mitigating these risks are hardly possible in some countries. Local investors often assess these risks differently or have other options to control and mitigate them. This can lead to a reduction in risk premiums and thus lower financing costs (references see intro section on home bias).

Implicit stabilization effects: Retroactive changes in the regulatory framework and/or breaches of contract by investors are particularly likely when governments feel that originally negotiated transaction conditions are leading to an unfair distribution of costs and profits and, notably, that international investors benefit from contracts, for instance such returns flow away from the partner countries. The involvement of local sources of funding, especially those based on broad participation, such as pension funds reduce these concerns and can thereby stabilize contract structures. In addition, long-term contractual arrangements could provide for stability also in a time of changing political preferences (Hodge et al. 2018).

The aspect of increased efficiency in financing, a key pillar of classical public–private partnership (PPP) research, is rarely stated in these strategies. Drivers of an efficient private sector involvement are stronger incentives to have projects delivered on time and to the allocated budget as well as competition for and in markets (Hodge et al. 2018). Besides these potential efficiency gains, economically viable projects – independent of the implementation structure - should be able to attract funding. Higher indebtedness in case of a purely public financed project would be justified by higher returns and consequently GDP in future.

It remains key that the private sector mobilization in the context of international cooperation needs to go hand in hand with institutional capacity building as well as strong sectoral development in the host country with research underlining that a strong, knowledgeable public partner with the ability to manage the private sector is a dominating success factor for public private cooperation (Hodge et al. 2018; World Economic Forum 2013; Yescombe 2017).

In this context selected non-governmental organizations stated critique on the strong trend towards private sector involvement in climate finance as they are concerned by the argument of lacking public creditworthiness being used rather than focus put on increasing public sector income and fiscal stability.

Limited comparative research is available on the efficiency of mobilization of the private sector at the various levels and/or the theory of change attached to the different approaches as applied in classical PPP. Also, transparency on current flows and private involvement at the various levels is limited with no differentiation being made in reporting (e.g. GCF co-financing reporting). So far limited prioritization and agreement on prioritization on sectors and/or project categories being ready and/or preferred for direct private sector involvement which might become a challenge in the coming years (Sudmant et al. 2017b,a).

Selected authors also flag the risk of an overemphasize on private sector finance and the reduced focus on increased public sector funding to accelerate climate action. Shortfalls in public sector funding might not be picked up by the private sector as hoped (Clark et al. 2018).

15.4 Considerations on financing gaps and drivers

15.4.1 Definition of finance gaps and dimensions to be considered

The analysis of financial flows is used to measure implementation action and mitigation impact on the one hand (FS-UNEP Centre/BNEF 2019) as a prerequisite of climate action on the other hand, in particular in the context of research papers on barriers for climate action. Finance gap usually discussed as a demand-side challenge with very rare discussions on challenges to deploy funds (e.g. Ramlee and Berma 2013).

With most analysis focusing on accumulated investment needs until 2030 or 2050, the term ‘funding gap’ requires a clear and robust definition taking into the different time horizons in the context of needs, demand and supply of financial flows for climate action. Current flows come in significantly below (average and accumulated) future needs using the numbers presented in the previous sections. This could result in a significant gap in future if funding cannot be scaled up substantially which is discussed below as ‘Potential future financing gaps based on current flows’. Due to highly heterogeneous financing data in NDCs and resulting questions marks behind the accumulated numbers on financing needs we refrain from performing a comparable analysis against current flows.

The following quantitative analysis can and does not differentiate between financing gaps driven by barriers within or outside the financial sector while these considerations are crucial for the interpretation of results. Assuming investment needs derived from integrated assessment models as presented above represent the efficient allocations, any undersupply of finance would represent inefficiency in the sense of broader economic literature. The UNEP Adaptation Finance report (UNEP 2018a) defines a barrier as ‘a friction that prevents socially optimal investments from being commercially attractive’ (UNEP FI and FS 2016). As already discussed and noted in AR5 (i.e. Low-Carbon-Policy-Risks, lack of long-term capital, cross-border currency fluctuation, and pre-investment costs), barriers within the financial sector are in particular relevant for private sector funding and comprise:

- Short-termism, for instance the focus on short-term financial returns (e.g. Robins and McDaniels 2016)
- Information gaps (incomplete/asymmetric information) and high perceived risks for mitigation relevant technologies and/or regions (e.g. Clark et al. 2018)
- Lack of carbon pricing effects (e.g. Best and Burke 2018)
- Home bias and resulting limited balancing for regional mismatches between current capital distribution and needs distribution (e.g. Boissinot et al. 2016)
- (Perceived) high opportunity and transaction costs resulting from limited visibility of future pipelines and policy interventions as well as small/medium-sized financing tickets (missing middle) (e.g. Grubler et al. 2016)

In addition, barriers outside the financial sector will have to be addressed to close future financing gaps. The mix and dominance of individual barriers might vary significantly across sectors and regions and is analysed below.

The interpretation of results needs to be performed, taking into account the qualitative needs assessment in Section 15.2.1 as well as the outlook for increased deployment of funds in future. In particular, the current share of and ability to attract commercial funding will be crucial to assess the necessity for (international) public funding.

The scale-up of commercial finance will be heavily dependent on the relative attractiveness of climate investments compared to other investment opportunities. With some institutions having announced climate finance commitments and/or targets (see also **Error! Reference source not found.** Measuring progress towards the USD 100 billion per year by 2020 goal: issues of method), the actual asset allocation including sectoral and regional focus will respond to tangible and financially viable investment opportunities available in the short-term. Robust long-term pathways to create such conditions for a significant private sector involvement do rarely exist and expectations on private sector involvement in some critical sectors/regions might be too high (Clark et al. 2018).

15.4.2 Gaps identified with regard to volumes, instruments, regions, sectors

Analysis and interpretation of results

[Note to reviewers: Data from IAM database will be available for SOD only, dummy data only]

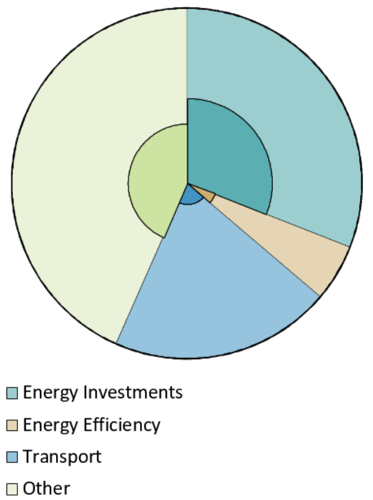

Figure 15.8 Investment Needs p.a. and Climate Finance Flows, by Sector

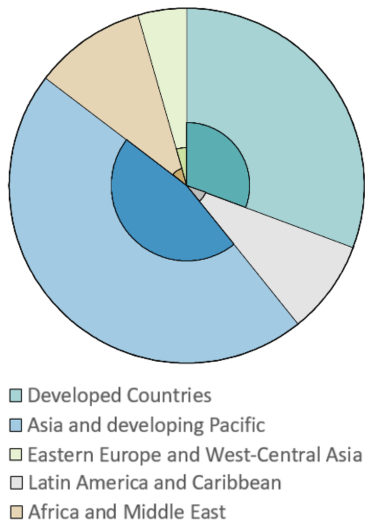

Figure 15.9 Investment Needs p.a. and Climate Finance Flows, by Region

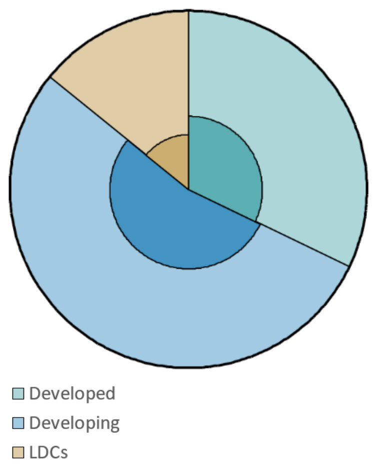

Figure 15.10 Investment Needs p.a. and Climate Finance Flows, by Type of Economy

Note: Dummy data – final numbers on financing needs based on AR6 IAM database not yet available. Lighter coloured pie chart indicates financing needs numbers. Darker coloured chart indicates current finance flows.

Source: Own calculations / illustrations.

The renewable energy sector attracted by far the highest level of funding in absolute and relative terms with business models in generation being proven and rapidly falling technology costs driving the competitiveness of solar and wind even without taking account the mitigation component (IRENA 2019b; FS-UNEP Centre/BNEF 2019). This investment activity comes in in line with the first generation of NDCs and their heavy focus on mitigation opportunities in the renewable energy sector (Schletz et al. 2017; Pauw et al. 2016). Still, current investment levels come in substantially below the required average investments needed. However, comparing total investments in energy including fossil-fuel related investments – approximately 1.8 trillion USD in 2018 – the gaps decreases significantly underlining the required shift of existing capital investment (McCollum et al. 2018; Granoff et al. 2016) rather than the need to massively increase sector allocations.

Ensuring access to the heavily regulated electricity markets is a key driver for an accelerated private sector engagement (IFC 2016; REN21 2019; FS-UNEP Centre/BNEF 2018) with phasing out of support schemes and regulatory uncertainty being a major driver for reduced investment volumes in various regional markets in the past years (FS-UNEP Centre/BNEF 2015, 2016, 2017, 2018, 2019). Strategic investors and corporate investments by utilities dominate the investment activity in developed countries and countries in transition (BNEF 2019) based on the competitiveness of renewable energy sources. Reasonable auction results based on a substantial private-sector competition for investments have also been achieved in selected developing countries driven by rather standardized contract structures and the increased availability of risk mitigation instruments addressing political/regulatory risks and home bias constraints (IRENA 2019b; FS-UNEP Centre/BNEF 2019). DFI climate portfolios tend to be driven by concessional loans for RE generation assets with equity often being provided by (semi-) commercial investors (see Section on current flows in 15.3.3 which will have to change to accelerate renewable energy investment activity.

Changing electricity market structures, including a potential higher share of market pricing, will change business models (Pahle et al. 2016). Also, investments in transmission will have to be scaled up massively. These effects will have a significant impact on transaction structures and involved investor types.

Financing of land-based mitigation options is less than 1 billion USD per year representing only 2.5% of climate mitigation funding, significantly below the potential proportional contribution (CPI 2015). Taking into account the specifics of land-based mitigation (in particular long investment horizons, strong dependency on monetization of mitigation effects, strong public sector involvement) a significant scale-up of commercial funding to the sector can hardly be expected (Clark et al. 2018).

Concerning NAPs, the second phase of implementation will require more and higher levels of sustained financing. Funding channels through bilateral grant based technical assistance through budgetary support or basket funding for large projects/program or sector wide approaches or multilater funding under (Non-)UNFCCC[6] are also anticipate supporting NAP implementation - particularly those involved incremental costs and co-benefits, which will include sectoral approach such as water, energy, infrastructures, food production (Fad et al. 2016).. But, between 2015 and 2016, only about 3% of international public finance goes to adaptation action. (with 84% of development finance institutions and 13% government (UNFCCC 2019a; Governance of Climate Change Finance to Enhance Gender Equality in Asia-Pacific 2019). To date, the private sector has limited involvement in NAP and adaptation projects and planning but can be involved though public private partnership and incentives by governments (NAP Global Network 2017; Koh et al. 2016; Schmidt-Traub and Sachs 2015; UNEP 2016; Druce et al. 2016). Innovative private financing mechanisms such as green bonds (Innovative Financing Initiative 2014; World Bank and PPIAF 2015; Hurley and Voituriez 2016; UNFCCC 2019a); blue bonds (or water bonds), (Bonzon et al. 2014; Hurley and Voituriez 2016); impact investing funds (Global Impact Investing Network); guarantees (Hurley and Voituriez 2016) and risk financing facilities (African Risk Capacity 2016) may also be important for the implementation of adaptation actions.

However, despite this optimism, the reality is that private financing account for very small percentage of adaptation financing. For example, adaptation financing is only about 2% of the share of green bond financing raised up to June 2019 (UNFCCC 2019a). Whereas it is about 10% of sovereign green bonds raised.

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[Note to reviewers: Analysis of transport sector and others to come after FOD only]

[Note to reviewers: Analysis of gaps by region and dev status to come after FOD only – hart below should present an indication of aspects to be covered in the analysis]

[6] Those under the UNFCCC such as the GCF through its 3 million USD per country readiness and preparatory support programme, the LDCF and the SCCF and the PPCR and ASAP are focused on supporting the preparatory process of the NAPs. But the Adaptation Fund will support the implementation of concrete projects up to 10 million USD per country.

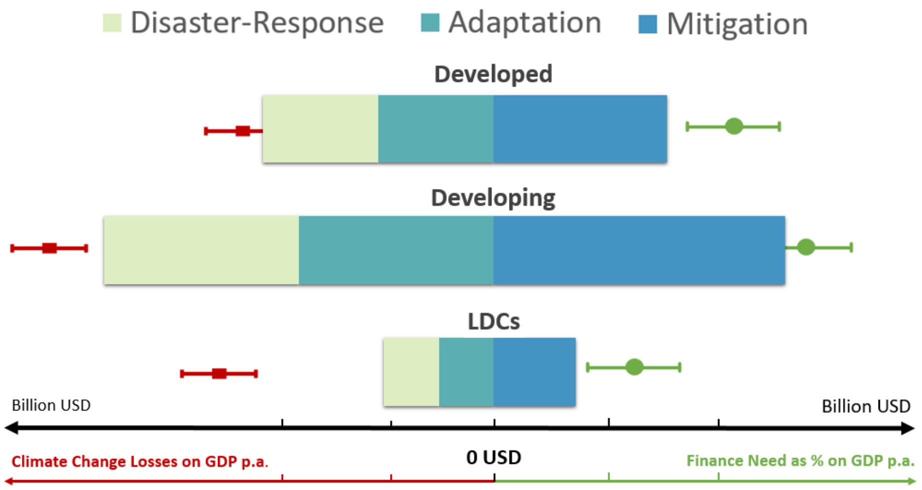

Figure 15.11 Financing needs, by type of economy and GDP p.a. in relation to climate finance and climate change losses

Note: Dummy data – final numbers on financing needs based on AR6 IAM database not yet available. Red square represents the percentage share of climate change losses on GDP p.a., by type of economy, including standard deviation. Green dot represents the percentage share of current finance flows on GDP p.a., by type of economy.

Source: Own calculations / illustrations.

Regionally, the current focus of the global climate investment needs, policies and opportunities tends to be on the big four (China, USA, EU-28 and India) and the G-20 generally (UNEP Emissions Gap Report 2019). But attention must accelerate on low-income Africa. This large continent currently contributes very little to global emissions, but its rapidly rising energy demands and renewable energy potential versus its growing reliance on fossil fuels and 'cheap' biomass (especially charcoal use and deforestation) amid fast-rising urbanization makes it imperative that institutional investors and policy-makers recognize the very large 'leap-frog' potential for the renewable energy transition as well as risks of lock-in effects in infrastructure more general in Africa that is critical to hold the global temperatures rise to well below 2°C in the longer-term (2020–2050). Overlooking this transition opportunity, rivaling China, India, US and Europe, would be costly. Policies centered around the accelerated development of local capital markets for energy transitions - with support from external grants, supra-national guarantees and recognition of carbon remediation assets - are crucial options here, as in other low-income countries and regional settings.

Soft costs / Institutional capacity

Most funding needs assessments focus on technology costs and ignore the cascade of financing needs as outlined above. International grant funding or national budget allocations for soft costs like the creation of a regulatory environment can be prerequisite for the supply of commercial financing for the deployment of technologies. Such critical funding needs might represent a small share of overall investment needs but current (relatively small) gaps in funding of policy reforms can hinder/delay deployment of large volumes of funding in later years. The role, as well as the approximate volumes of such required timely international grant funding or national budget allocations, appear underestimated in research. The numbers available for the creation of an enabling environment for medium-sized RE projects in Uganda (GET FiT Uganda) are illustrative only and cannot be transferred as assumptions to other countries without taking into account potentially varying starting points in terms of institutional readiness, pipelines as well as the general business environment. GET FiT Uganda supported 170 MWp of medium-scale RE capacity triggering investments of 453 million USD (GET FiT Uganda 2018), international results-based incremental cost support amounted to 92 million USD and project preparation, technical assistance, as well as implementation support, required 8 million USD excluding support from national agencies.

There is strong evidence of the correlation between institutional capacity of countries and international climate finance flows towards those economies (Adenle et al. 2017; Stender et al. 2019). Also, most of the developing countries NDCs are conditional upon international support for capacity building (Pauw et al. 2019). The Climate Technology Centre and Network (CTCN) was created as an operational arm of the UNFCCC Technology Mechanism with the mandate to respond to requests from developing countries. Initial evaluations of the mechanism underpin its importance and value for developing countries but stress long lead times and predictability of future international public funding to maintain operations as key challenges (DANIDA 2018; UNFCCC 2017). While limited pipelines, limited absorptive capacities as well as restricted institutional capacity of countries being often stated as challenge for an accelerated deployment of funding (Adenle et al. 2017), the question remains on the role of international public climate finance to address this gap and whether a concrete current financing gap exists for patient institutional capacity building. While current short-term, mostly project-related capacity building often fails to meet needs but alternative, well-structured patient interventions and funding could play an important role (Saldanha 2006; Hope 2011) accepting other barriers than funding playing a role as well. One reason why international public climate funding is not sufficiently directed to such needs might be the complexity in measuring intangible, direct outcomes like improved institutional capacity (Clark et al. 2018).

Lock-in effects

The delayed deployment of climate funding and consequently limited alignment of investment activity with the Paris Agreement will result in significant carbon lock-ins and stranded assets. This holds true for all major sectors, but in particular for transport and urban infrastructure. Chapter 8 highlights the significant urban infrastructure, which will be built in the next two decades, especially in the Global South. A delay of alignment of related investment activity with Paris and the SDGs will have massive negative and in the mid-term hardly reversible effects on mitigation potentials.

15.5 Macroeconomic considerations

Four key aspects of the current global macroeconomy, each slightly different, point in a cascading fashion towards a deteriorating environment for stepped-up climate financing over the next crucial decade (2020–2030). Globally coordinated actions by central banks and by willing clubs of sovereigns are now crucial to deal with these large macroeconomic headwinds.

The argument is often made that there is enough climate financing available if the right projects and enabling policy actions (‘bankable projects’) presented themselves (Cuntz 2017; Meltzer 2018). Some significant gains in climate financing at the sectoral and microeconomic level are indeed happening in specific segments, such as solar energy financing and labelled green bond financing (although how much of such labelled financing is incremental to unlabelled financing that might have happened anyway remains unanswered) (Tolliver et al. 2019). But these increments remain in aggregate small compared to the size of the shifts and gaps in climate financing required in the coming decade. The reason is global macroeconomic headwinds, which explain why the sum of climate finances (as measured by many different entities) all show a relative stagnation since 2016 and limited cross-border flows in particular (Yeo 2019).

The first headwind is more unstable and slowing GDP growth at individual country levels and in aggregate because of worsening climate change impact (Donadelli et al. 2019; Kahn et al. 2019). As each warmer year keeps producing more negative impacts – arising from greater and rising variability and intensity of rainfall, floods, droughts, fires and storms – the negative consequences have become more macroeconomically significant, and worst for the most climate-vulnerable developing countries (two-thirds of world population and one half of world income). Paradoxically, while these effects should raise the social returns to invest more in climate, a standard public policy argument, these macroeconomic shocks work in the opposite direction for private decisions (Cherif and Hasanov 2018). With some climate tipping points being reached in the near term (see relevant Section in WGI) the uncertainty with regard to the economic viability and growth prospects of selected macroeconomically critical sectors increases significantly (see relevant Section in WGII). Taking into account considerations on general behavioural failures, this creates a barrier for pro-active and accelerated mitigation and adaptation action.

The second headwind is rising public fiscal costs of mitigation and adapting to rising climate shocks affecting many countries, which are negatively impacting public indebtedness and country credit ratings significantly at a time of significant stresses on public finances (Benali et al. 2018; Kling et al. 2018). Every climate shock and slowing growth puts greater pressures on public finances to offset these impacts. Crucially, the negative consequences are typically much greater at the lower end of income distributions everywhere (Aggarwal 2019; Acevedo et al. 2018). As a result, the 'standard prescription ' of raising broadly-based carbon taxes (often accompanied perversely by countries cutting taxes for the better off to attempt to stimulate falling growth) and cutting back fossil fuel subsidies to raise resources are facing unexpected and serious political backlash, often leading to roll-backs of such fiscal measures in high-income and low-income countries alike and raising fiscal costs to deal with and compensate for the adverse consequences of climate change for households at the lower-income ends of income distribution. In addition, in particular vulnerable countries face an increase in cost of sovereign debt. (Buhr et al. 2018). Buhr et al. (2018) calculate the additional financing costs of Climate Vulnerable Forum countries of 40 billion USD on government debt over the past 10 years and 62 billion USD for the next 10 years. Including private sector financing costs the amount increases to 146–168 billion USD over the next decade.

The third headwind is rising financial and insurance sector risks and stresses (distinct from real 'physical' climate risks above) arising from the impacts of climate change systematically affecting both national and international financial institutions and raising their credit risks (Dafermos et al. 2018a; Rudebusch 2019). Policies to make these risks more transparent in some countries, while desirable, may paradoxically be making this more complex. Central banks are beginning to take notice which is helpful (Carney 2019). But it is also the case that, even if at greater risk from stranded assets in the future, the large-scale financing of fossil fuel projects by the same large global financial institutions under scrutiny has started to rise significantly since 2016, paradoxically because of perceived lower private risks and higher private returns in these investments, than in alternative but perceived more risky low carbon investments.

The fourth headwind is the current sharply slowing global macroeconomic growth, and prospects for near-term recession, and hence rising financial risk, both from secular stagnation and cyclical reasons (independent of ongoing climate change), which are negatively impacting climate financing possibilities generally at the global and national levels in the 'near-term', (meaning the next several crucial years) when such stepped-up investments are especially important for a low-carbon transition globally. The reason? During prospective global real and financial cycle downturns (Jordà et al. 2019), which tend to last a relatively long time, the perception of general financial risks rises sharply, causing financial institutions and savers to reallocate their financing assets to risk-free global assets (accounting in large part for the observed astonishing 'flight to safety' tripling of financial assets to about 16.5

trillion USD to negative-interest earning 'safer' assets over the past year) in world debt markets – enough to have nearly closed the total financing gap in climate over a decade.

How big are these macroeconomic headwind consequences when taken together? Very large. With a global low carbon transition expected to require some additional reallocation or increase of global savings equivalent to 2.7% of world GDP in climate mitigation and adaptation, which while not absolutely large relative to the size of the financial system stock of assets, is now inconceivable given the current cascading macroeconomic headwinds described above to allow anywhere near this to happen – barring some (unexpected and unlikely) globally coordinated action. While a project-by-project, sector-by-sector, and instrument-by-instrument approach to raising climate finances is thus important and useful, ultimately macroeconomic drivers of finance remain crucial.

The evidence is that globally coordinated macroeconomic actions are falling apart politically as countries shift their attention to within border non-climate perceived 'real' immediate priorities (growth and jobs) where climate is not nearly as important. Attention must turn to revive the scope for such coordinated action. The choices or options towards the latter are some combinations of four well-known possible elements:

(a) global central banks acting in unison to include climate finance as an intrinsic part of their monetary policy stimulus ('green QE') and policy tools, which are as yet almost entirely missing in practice in the policy landscape;

(b) large governments running coordinated fiscal deficits to explicitly expedite the financing of low carbon investments as a significant counter-cyclical addition to its fiscal tools, again which is talked about (in terms of the so-called 'sustainable infrastructure drive') but as yet unobserved;

(c) introducing new actions, including regulatory, to take some of the risks off-the-table from financial players investing specifically in climate mitigation, investment and insurance;

(d) including the provision of larger sovereign guarantees to such private finance backed by explicit and transparent recognition of the 'social value of mitigation actions' or SVMAs, as fiscally superior (because of many times bigger 'multipliers' of such fiscal action to catalyse private investment than direct public investment) instrument to closing the gap between private returns to climate investments and the bigger social value of such investments (Article 108, UNFCCC) (Krogstrup and Oman 2019), again largely still missing as a significant policy direction despite much talk; and

(e) facilitating through sovereign guarantees and other risk-reducing actions above to incentivize much larger flows of cross-border climate financing which is especially crucial for such investments to happen in developing regions, where as much as two-thirds of collective investment may need to happen, and where the role of multilateral, regional and global institutions such as the IMF (including the expansion in availability of climate SDRs) could be important.

There is urgency now for such macroeconomic options and actions, especially at the G20 and similar (central banks coordination forums) or possibly new forums of smaller significant 'clubs' of countries, institutions and regions. Indeed, central banks have started to pay increasing attention to such policy choices (especially given the marked absence of fiscal coordination) (Carney and Bank 2019; Jordà et al. 2019). They would also more sustainably stimulate global growth. Which if any of these options will prove feasible, however, in the current context will be a test of the political possibilities towards better global collective action (versus relying primarily on individual actions at the country or project-institution levels) for faster feasible climate action— as the world economy continues to slow inexorably from both secular stagnation reasons (including demographic slowing in rich countries that continue to remain the primary source of global savings) and a long financial down cycle which the world is currently facing. What action or which participants will collectively bell the proverbial cat remains the key question.

15.6 Approaches to address financing gaps

15.6.1 Considerations on availability and effectiveness of public sector funding

As described in the previous sections, debt levels have significantly increased over the past years with current and expected climate change impacts further burdening debt sustainability. Consequently, a debate has started about the appropriateness of the use of debt instruments in the context of international climate cooperation. Major challenges exist with regard to a robust calculation of indebtedness levels, in particular, the effect of climate change on the future GDP on the one hand and the appropriate use of debt instruments in particular in the context of adaptation and disaster response on the other hand.

With long-term economic impacts of climate change being in the focus of the modelling community, the volatility of GDP in the short term driven by shocks is more difficult to analyse and requires country-specific deep-dives. IPCC scenario data is often not sufficient to perform such analysis with additional assumptions being (Acevedo 2016). For debt sustainability analysis, these more short-term impacts are, however, a crucial driver with transparency being limited to the significance of climate-related revision of estimates. Moody's takes into account the effects of both long-term climate trends as well as short-term shocks (Lafakis et al. 2019). IMF considers a 20-year time horizon with effect for the next 5 years and the period beyond 5 years being forecasted separately. A bottom-up approach is taken with country teams being responsible for the development of forecasts with a non-standardized approach regarding climate change impacts (IEA 2019b). The limited transparency resulting from this approach might result in a continued overestimation of future GDP as happened in the past increasing the vulnerability of highly indebted countries (Guzman 2016). While climate change considerations have already impacted country ratings and debt sustainability assessments (and financing costs), it is unclear whether current GDP forecasts are conservative enough. The review of the IMF debt sustainability framework leads to a stronger focus on vulnerability rather than only income thresholds when deciding upon eligibility for debt relief and/or concessional resources (Mitchell 2015), which could become a mitigation factor for the challenge described before.

With public funds becoming scarcer (see also Section 15.5 on Macroeconomic considerations), a preference for loan rather than grant instruments could emerge in international climate cooperation requiring robust debt sustainability analysis as well as loan structures ensuring efficient debt restructuring and debt relief in events of extreme shocks and imminent over-indebtedness and sovereign debt default. In this context, the Commonwealth Secretariat flagged that the diversification of the lender portfolio made debt restructuring more difficult with more and more heterogeneous stakeholders being involved (Mitchell 2015). This is a side effect of a stronger use of capital markets, which need to be carefully considered in the context of sovereign bond issuances. The use of debt-for-nature and debt-for-climate-swaps is still very limited and not mainstreamed but offers significant potential if used correctly (Warland and Michaelowa Zurich 2015) although donor countries appear more reluctant to engage in debt relief given own resource constraints (Mitchell 2015). At the same time, the limitation of the use of debt-based instruments as a response to climate-related disasters and counter-cyclical loans might be necessary (Griffith-Jones and Tyson 2010).

Efficient allocations of public funding against the background of gaps identified

[Note to reviewers: This section will be written once the needs data from the AR6 database is more stable]

'START BOX 15.5 HERE'

Box 15.5 The role of enabling environments for decreasing-economic cost of renewable energy

A widely used indicator for the relative attractiveness of renewable energy but also development of price levels is the levelised cost of energy (LCOE). It is applied by a wide range of public and private stakeholders when tracking progress with regard to cost degression (Aldersey-Williams and Rubert 2019). LCOE calculation methodologies vary but in principle, consider project-level costs only (NEA 1989). Besides other weaknesses, the LCOE concept usually does not consider societal costs resulting from de-risking instruments and/or other public interventions/support and therefore caution has to be applied when using the LCOE as single and only indicator for the success of enabling environments. The yearly IRENA mapping on renewable energy auction results demonstrates the extremely broad ranges of LCOEs (equal to the agreed tariffs) for renewable energy which can be observed (IRENA 2019b). For example, in 2018, solar PV LCOEs for utility-scale projects came in between 0.04 USD/kWh and 0.35 USD/kWh with a global weighted average of 0.085 USD/kWh. However, comparative analysis taking into account societal costs are hardly available driven by challenges in the context of the quantification of public support.

The GET FiT concept argued that the mitigation of political and regulatory risk by sovereign and international guarantees is cost-efficient in developing countries illustrating the estimated impact of such risk-mitigation instruments on equity and debt financing costs and consequently required feed-in tariff levels (Deutsche Bank Climate Change Advisors 2011). The impact of financing costs on cost of renewable energy generation is well researched with significant differences across countries and technologies being observed with major drivers being the regulatory framework as well as the availability and type of public support instruments (Geddes et al. 2018; Steffen 2019). With a focus on developing countries and based on a case study in Thailand, Huenteler et al. (2016) demonstrate the significant effect of regulatory environments but also local learning and skilled workforce on cost of renewables. The effect of those exceeds the one of global technology learning curves.

Egli, Steffen and Schmidt (2018) identify macroeconomic conditions (general interest rate) and experience effects within the renewable energy finance industry as key drivers in developed countries with a stable regulatory environment contributing 5% (photovoltaic) and 24% (wind) to the observed reductions in LCOEs in the German market with a relatively stable regulatory environment. They conclude that 'extant studies may overestimate technological learning and that increases in the general interest rate may increase renewable energies' LCOEs, casting doubt on the efficacy of plans to phase out policy support' (Egli et al. 2018). A rising general interest rate level could heavily impact LCOEs – for Germany, a rise of interest rates to pre-financial crisis levels in five years could increase LCOEs of solar and wind by 11–25% respectively (Schmidt et al. 2019).

END BOX 15.5. HERE'

Cooperative solutions in large-scale north-south climate finance clubs

Climate action above all faces a global 'commons' problem, that is not easily amenable to independent local (national) actions alone, leading to the tragedy of the global commons without international coordination and cooperation. The 2015 Paris Agreement (UNFCCC 2015) is a hybrid of collective action (international commitments and monitoring), but with voluntary and nationally determined actions, provided or conditional upon financing availability for most developing countries. Fragmented moderate national actions lead to clearly unsustainable climate outcomes, but the possibility of 'staged accession' with regional leadership among a few large players (front-runner coalitions such as EU and China or 'climate clubs') does better, although still falling short of averting a rise in temperatures of above a 'safe' 2°C and higher costs of mitigation actions than if coordinated globally (Kriegler et al. 2015). Country actions most often proceed unilaterally for domestic political and economic reasons (McGrath and Bernauer 2017), but do worse when faced with free-riding (McGrath and Bernauer, 2017; Reingewertz, 2017).

There is a problem, however, when we turn to climate finance. Discussing Theory of Change (TOC) options for climate finance (see Section 15.6.7), as if national borders do not matter and that climate finance, wherever sourced globally, and in whatever form raised, finds its way seamlessly to needs and opportunities across national borders. In turns out that finance in general, and climate finance, has a particularly large 'home bias'. Over 80% of climate finance is reported to originate and stay within borders, and even higher for private climate flows (over 90%) (Boissinot et al. 2016). There are multiple reasons for such 'home bias' in finance - national policy support, differences in regulatory standards, exchange rate, political and governance risks, information market failures and credit rating home bias - which we examine in Section 15.6. There is evidence that trade and investment integration, as in EU, reduces the extent of this home bias (De Marco and Macchiavelli 2016; Fuchs et al. 2017; Martínez-San Román et al. 2016; Darvas and Schoenmaker 2017; Gehring and Schneider 2018), but recent trends towards 'trade and investment disintegration', globally or regionally, would make matters worse. Moreover, even in case of supranational institutions (EU budgets, MDBs, development finance institutions), the nationality of decision-makers appear to shift allocations towards 'home' countries (Gehring and Schneider 2018; Novosad and Werker 2019; Ege and Bauer 2017) and strategic choices. Such extensive home bias means that even if national actions are announced and intended to be implemented unilaterally and voluntarily, the ability to implement them requires access to climate finance which are constrained by the relative ability of financial and capital markets at home to provide such financing, and access to global capital markets that requires supporting institutional policies in source countries. 'Enabling' public policies and actions locally (cities, states, countries and regions), to reduce investment risks and boost domestic climate capital markets financing, and to enlarge the pool of external climate financing sources with policy support from source capital countries thus matter at a general level.

The particular context, however, is that the biggest problem in climate finance is likely to be in developing countries, even in the presence of such enabling policies and quite apart from any other considerations such as equity and climate justice (Klinsky et al. 2017) or questions about the equitable allocations of future 'climate budgets' (Gignac and Matthews 2015). The differentiation between developed and developing countries matter most on financing. Most developed countries have already achieved very high levels of incomes, have the largest pool of capital stock and financial capital (which can be more easily redeployed within these countries given the 'home bias' of financial markets), the most well-developed financial markets and the highest sovereign credit-ratings, in addition to starting with very high levels of per capita carbon consumption - factors that should allow the fastest adjustment to low carbon investments and transition in these countries from domestic policies alone. Whether this is happening at a fast-enough rate there is a different question, relatively unconstrained by access to well-developed financial markets and public resources.

The financial and economic circumstances are the opposite for virtually all developing countries, even within a heterogeneity of circumstances across countries. The dilemma, however, is that the fastest rates of the expected increase in future carbon emissions are in developing countries. The biggest problem of climate finance globally is thus likely to be the constraints to climate financing because of the opportunity costs and relative under-development of capital markets and financing constraints (and costs) at home in developing countries, and the relative availability or absence of adequate financing policy support internationally from developed countries. The Paris Agreement and commitment by developed countries to support the climate financing needs of developing countries thus continue to matter a great deal.

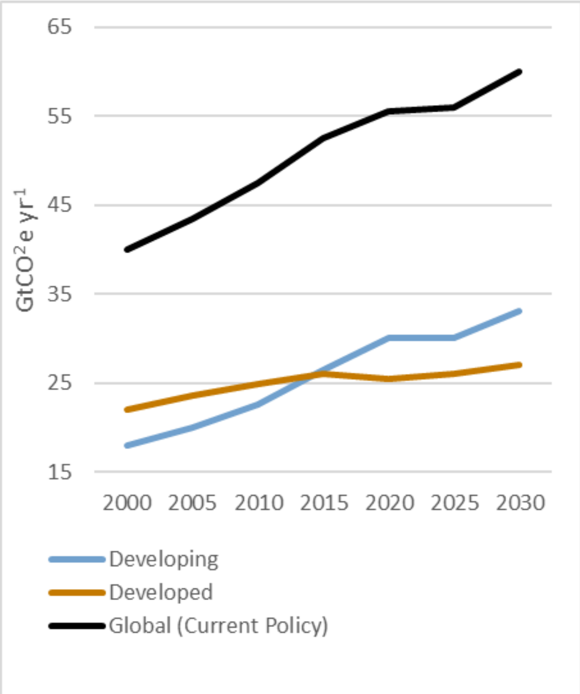

Figure 15.12 GtCO₂eq p.a., by Scenario

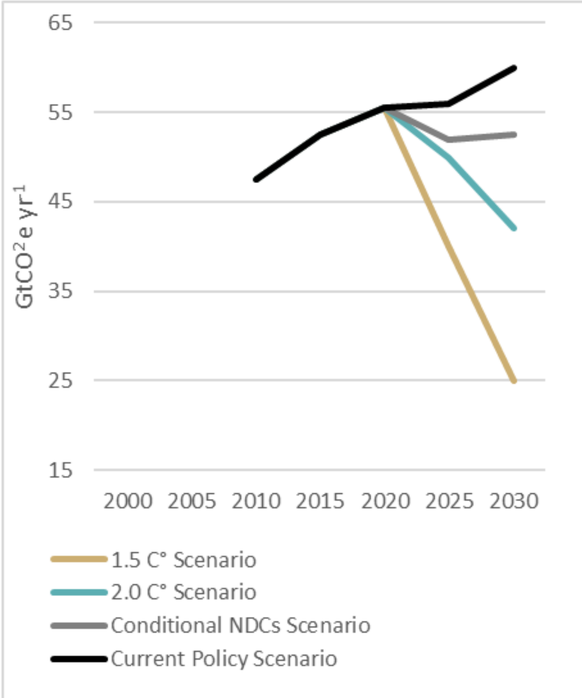

Figure 15.13 GtCO₂eq p.a., by Region

Note: Geographical breakdown as well as scenarios will be updated in line with IPCC classification. Charts only for illustration.

Source: Visually derived from UNEP Emissions Gap Report 2019. Data is not verified – only for illustration. For deeper discussion see UNEP (2019)

If it is assumed then that there is a role for substantial international or global coordination to accelerate public and publicly supported or mobilized private climate finance flows to developing countries for some combination of all the previous reasons that have been discussed so far (the reason clearly why finance was added as a third goal in the 2015 Paris Agreement), then group strategic behaviour, and its dynamics between nation-states become paramount. One useful analytic tool in this regard is game theory (DeCanio and Fremstad 2013) to inform choices about factors and conditions that might lead to successful outcomes on climate finance (or failures).

There are two contrasting models. One is a competitive 'game' where nation-states primarily focus rationally about their own self-interests and then making decisions on how to behave (cooperate or free-ride on the actions of others). Fortunately, this need not always be the case (Kopec 2017). Still, in a competitive climate finance coordination 'game', individual nation-states will always want to minimize their individual financial contributions to the group goal while hoping that others will contribute more - leading inevitably to a prisoner's dilemma where the group outcome (total climate finance contribution of all members) will be far less than a more socially optimal possibility where everyone would contribute more and the sum of the efforts would be of greater benefit to all in terms of a global public good such as global warming. All that is needed to arrive at this outcome are two assumptions: that nation-states value their individual self-interest more than the collective one in terms of financial contributions, and second that the group cannot exercise any costs of non-compliance by any member to freeride or 'cheat' on their obligations.

In a cooperative game, with repeated interactions, the picture changes. Here the challenge is the collective action problem that not all members are necessarily equally committed to the group outcome (raising the maximum possible climate finance for developing countries given their circumstances) for a variety of possible reasons (limited public finances, political costs at home, other), and therefore, to prevent the consequences of freeriding by some (which if allowed to happen, may attract more 'defectors' or free-riders over time and lead to less than socially optimal outcomes), deterrence rules have to be devised. The twin problems with deterrence in a global climate outcome game are that: (a.) it is not possible to exclude any member from the benefits; and (b.) it is difficult or even impossible to enforce these rules, as in the case of the competitive game. What is possible in climate finance is, however, smaller initial coalitions or clubs (Nordhaus 2015; Michaelowa 2015) with more cohesive and cooperative group selection of 'like-minded' members (Stua 2017), with greater specific deterrence measures tied to access to climate finance benefits (Urpelainen 2012) and (pre-) commitment rules of membership (Sasaki et al. 2015) so that exit becomes costly (costs of leaving are greater than the costs of staying). Over time, the benefits of membership in this smaller climate finance group - faster access to climate finance, lower costs of financing, and reciprocal spillovers of higher growth and economic benefits of higher investments rates in climate investments in developing countries to source capital developed countries - may induce the membership to grow, so long as these benefits are demonstrable and the rules of membership are consolidated.

The key questions then are the initial membership selection (Ostrom 2015, 2007, 2010) on which members and how many would bring greatest value to the group (the 'Shapley' value in game-theoretic terms (Shapley 1953) which depends on attributes (of the contribution a member makes to the group), the rules of club membership (such as up-front financial commitments or pre-commitments clearly specified), and the costs of exit (cannot access preferential terms of financing or its derivatives). These are in fact also reasons that multi-lateral development banks (MDBs) came into existence and have operated successfully in expanding areas of development financing, which now includes climate finance as key goals. However, the MDBs have multiple financing objectives not necessarily restricted to climate (diffusion), and have inherited their own priorities and governance structures which may not be fully compatible with the narrower goal of accelerating climate finance dramatically, and its membership has become so broad that it may be difficult to establish new rules of the game - calling for a smaller, more cohesive climate finance North-South club and specific instruments, such as the large-scale use of multi-sovereign guarantees (Dasgupta et al. 2019), and using 'shadow' price for social value of carbon mitigation action (SVMA) to determine the value of such guarantees (Pottier 2018) especially given the time-inconsistency and uncertainty problems with future carbon prices which can be mitigated with project guarantees (Chiappinelli and Neuhoff 2017) and while higher explicit prices are important, 'carbon pricing by itself may not be sufficient to induce change at the pace and on the scale required' (High-Level Commission of Carbon Prices 2017).

15.6.2 Enabling environments

The concept of enabling environment is not clearly defined; therefore, several different definitions exist. One is government policies that focus on 'creating and maintaining an overall macroeconomic environment' (UNCTAD 1998). Another interprets an 'enabling environment' as the wider context within which development processes take place, for instance the role of societal norms, rules, regulations, and systems. This environment may either be supportive (enabling) or constraining (Bolger 2000).

A major part of the finance ecosystem is the provision of a stable and enabling policy environment that not only provides financial support but also sets a regulatory and tax regime that incentivizes long horizon green private investment, and facilitates optimal (from investor and environmental perspectives) exits from investment (Owen et al. 2018). Governments can provide information, fund research and development, and form public-private partnerships to encourage resilience building, particularly where outcomes are public goods (Watson and Kellett 2016). Furthermore, awareness that finance can create directions is an important point to heed when designing policies. To map the effects that policies have on the direction and not just the amount of financial funds before implementing policies, will help prevent surprises and lock-ins later (Mazzucato and Semieniuk 2018).

Alleviating risk burden of investments, such as financial and policy uncertainties, would encourage clean energy investments. Policy de-risking measures, such as robust policy design and better transparency, as well as financial de-risking measures, such as green bonds and guarantees, in both domestic and international level, enhance the attractiveness of clean energy investments (Steckel and Jakob 2018).

A potential approach would be to increase the use of guarantees to de-risk investments (Bowman and Minas 2019). Four types of interventions have been implemented by financial regulators and central banks in dealing with climate-related risks: 'First, they can develop methodologies and tools that would promote a better understanding of these risks and their economic and financial implications. Second, investors can be encouraged or required to disclose their exposure to climate-related risks. Third, these risks can be explicitly taken into account in setting financial regulations. Fourth, central banks can take into account climate-related risks in their policy toolkit' (Campiglio et al. 2018) (e.g. monetary policy).

A combination of factors such as financial, economic, institutional and transition barriers slows down clean technology innovation and overall technological transition. The government should nurture green finance development from an early stage by laying out the green credit rules and long-term price mechanisms, which could reduce the green project risks (Peng et al. 2018a). Thus, the role of government is crucial for creating an enabling environment for climate finance. Policy reform to accurately value natural resources and environmental degradation, providing subsidies to incentivize private investments, making concrete financial information using existing projects and investments, bridging finance gaps by improving cost effectiveness of projects and ensuring project transparency are fundamental roles of government that enhances the trust of private investors (Clark et al. 2018).

In addition, governments can help streamline the bankable infrastructure projects. It is estimated that project preparation can be about 5–10% of total infrastructure costs. Government agencies need to build the capacity in projects preparation and planning, including the negotiation and project evaluation procedures (Meltzer 2016). 'Climate finance could be used to develop these skills and capacities' (Meltzer 2016). Furthermore, subsidizing pilot projects, instead of full projects, can expand the set of socially beneficial and climate-related investments (Kotchen and Costello 2018).

Enabling the private sector to invest in green projects would be necessary, but the role of the public sector is often overlooked. The public sector is capable of handling higher risks so more direct financing of green projects would be needed creating markets and leading the private sector (Mazzucato and Semieniuk 2017). Further discussion on private-public-partnerships see Section 15.3.4.

The government can reduce the risks of financing green projects by improving the rate of returns, which could be achieved by establishing green credit guarantee schemes (GCGSs) or considering tax returns (Taghizadeh-Hesary and Yoshino 2019). Similarly, Peng et al. (2018b) examines the green financing conditions of China, and suggests the following to improve the rate of return for green investments: improve green finance policies, laws and regulations; develop information exchange channels; reform the financial institutions; reduce the rate of return for non-green projects; and strengthen the international cooperation in building green financial system.

Generally, external financing is largely from three different sources: bank lending; market debt; and market equity. Among these, bank lending is the most common source of external finance for firms, especially for small and medium enterprises and in emerging markets (Eickmeier et al. 2014). For climate financing, the role of market debt (in the form of green bonds) have been expanding (Campiglio 2016). Further discussion on green bonds see Section 15.6.3.

Central banks' quantitative easing (QE) is created as temporary cyclical tools, but it is now being examined as a tool for enabling climate investments. When large quantities of asset are bought by the central banks, it could signal the market participants that this asset category is more liquid and less risky than others. Thus, this green QE program 'would have the benefit of providing large amounts of additional liquidity to companies interested' in green projects (Campiglio et al. 2018). However, green QE program by itself would not be an effective measure (Dafermos et al. 2018). It is suggested that other green fiscal policies, green finance policies, and regulatory interventions should be implemented to compliment the green finance measures.

Additional monetary policies and macroprudential financial regulation may need to be considered to facilitate the expected role of carbon pricing on boosting low-carbon investments. The commercial banks may not respond to the price signal and allocate credits to low-carbon investments due to the existence of market failure (Campiglio 2016).

Efficient Financial Markets and Financial Regulation

An influential efficient financial markets hypothesis (Fama 1970, 1997, 1991) proceeds from the assumption that in well-developed financial markets, available information at any point of time is already well captured in capital markets with many participants, that any new information (say, effects of fossil-fuels on global warming and its downsides) is rapidly absorbed by market participants and changing prices; therefore, public interventions can do little to improve the working of such financial markets and are not generally justified.

The efficient financial markets hypothesis is perhaps the most extensively tested model of capital markets (Malkiel 2003). It was widely believed to be correct earlier but is now increasingly discredited (Sewell 2011), especially by repeated episodes of very large and continuing global financial crashes and crises, and other widely noted anomalies (or irrationalities). But the jury is still out on whether a weaker form of the efficient markets hypothesis still applies (that given enough time, investors cannot do better than the market, even if the latter makes short-term errors). Specifically turning to climate future, the rational markets hypothesis would argue that given enough time and information becoming credibly available, the market for climate finance would adjust on its own and start to increasingly provide the incentives for the scale and needs of climate finance. It is arguable from this point of view that as a cascade of more credible scientific information has been accumulating about the effects of global warming, it is being accompanied by rising levels of climate finance, such as global green bonds, while banks and institutional investors are also progressively rebalancing their investment portfolios away from fossil-fuels and towards rising portfolios of low-carbon investments over time.

However, the efficient markets hypothesis is only reliable in a weak form and almost certainly wrong in the extreme form (Fama 1991). In the meantime, the world runs the risk of sharp adjustments, crises and irreversible 'tipping points' (Lontzek et al. 2015) that could be sufficiently dangerous to destabilize long-term climate outcomes. That leads to the policy prescription towards financial regulatory agencies requiring greater and swifter disclosure of information about rising climate risks faced by financial institutions in projects and portfolios and central bank attention to systemic climate risk problems as one possible route of policy action (Zenghelis and Stern 2016; Carney 2015; (Dietz et al. 2016; Campiglio et al. 2018). The reality is that in practice, market adjustment has so far been weak (Hahn et al. 2015): disclosure requirements of risks and information in private settings remain mostly voluntary and difficult to implement (Monasterolo et al. 2017; Battiston et al. 2017a), credit rating systems have paradoxically raised costs of borrowing for poor countries for climate and non-climate financing (Buhr et al. 2018) but done little to alter the ground conditions for climate investment to shift decisively towards low-carbon investments in developed country markets, where there is no real differentiation except labelling and terminology as yet between green bond markets and overall bond markets (Ehlers and Packer 2017), the absolute volume of green bond markets (nearing 1 trillion USD cumulative) although rising remains small relative to the overall size of global bond markets (about 80 trillion USD), and there is as yet no significant rating changes evident for fossil-fuel companies and oil majors, other than coal, despite significantly rising risks of 'stranded assets' in fossil fuel sectors (Griffin et al. 2015; Silver 2017; Diaz-Rainey et al. 2017).

Nevertheless, financial markets are innovating in search of solutions. They appear to be increasingly internalizing the increased scientific information now available on climate change risks, and the impacts already becoming evident on the ground. As a result, many more instruments of what is best termed as 'financial engineering' are being deployed to enable larger-scale long-lived low-carbon investments at individual project levels, as also at a more 'macro' level of sectors, cities and states (Yuen et al. 2015; C40 Cities Climate Leadership Group et al. 2016). These include securitizing renewable energy to spread the risks beyond the reach of single investors, non-recourse project financing to protect sponsoring companies from debt risks (including establishing bankruptcy-protected companies), bundling construction financing, debt financing (bank term loans and bond market private placements), mezzanine financing (mezzanine debt, leasing, tax equity), pool financing (inverted leases, asset-backed securities (ABS), equity inflows through Real Estate Investment Trusts (REITs), master limited partnership (MLPs), yield cost (contracted cash-flows to secure debt), and the use of government guarantees to secure offtake risks and to generally de-risk projects and lower the cost of capital. Recognizing and dealing with stranded fossil-fuel assets is also a key area of growing concern that financial institutions are beginning to grapple with. Larger institutions with more patient capital (pensions, insurance) are also increasingly beginning to enter the financing of projects and green bond markets. The combined influence of these factors is that the size of innovative project innovation has grown rapidly, financing in effect the very rapid increases in clean energy, solar and wind projects, and starting to enter other sectors, especially the financing of transport and energy in cities in both developed and developing countries. But the scale has not been nearly enough to bridge the overall financing needs and gaps. The scarcity of 'bankable' or implementable projects of scale is also sometimes mentioned.

The situation in developing countries is inherently more challenging because domestic financial markets are not well developed, and there are large currency, political, governance and other risks for cross-border private flows. The case for efficient financial markets in developing countries, which are expected to account for nearly two-thirds of financing needs for climate mitigation investments, is worse (Abbasi and Riaz 2016; Hong et al. 2019) because of weaker financial institutions (Hamid et al. 2017), heightened credit rationing behaviour (Bond et al. 2015), high-risk aversion since most developing country markets are rated as junk or below investment grade or just barely above investment grade (barring exceptions of high savings countries, such as China with high costs of ratings changes (Hanusch et al. 2016), limited long-term financial instruments and underdeveloped domestic capital markets, absence of significant domestic bond markets for investments other than sovereign borrowing, inadequate term and tenor of financing, and other related financial constraints which make the efficient markets thesis practically inapplicable and unviable for most countries and circumstances, except a few. More generally, the development of local capital markets and robust domestic financial systems is a priority but takes a very long period of institutional change and can be expected to work only in a limited number of fast-growing and high savings middle-income countries and regions. More pro-active interventions, such as publicly organized and supported low-carbon infrastructures through resurrected national development banks may therefore be justified (Mazzucato and Penna 2016).

High investment risks tend to obstruct low-carbon investments, especially in LDCs and developing countries. It is important to implement effective de-risking measures to reduce investment risks, but lacking research and data availability hinders designing de-risking measures (Dietz et al. 2016). Also, the traditional risk financing mechanisms, such as solidarity and insurance, does not appropriately cover the long-term trend in weather-related disasters or climate change adaptation that can incur losses and damages on long-term investments. Especially in developing countries, traditional risk financing mechanisms often fail to cover extreme losses and climate adaptation, and the risks bearers with low financial resilience suffer severely from losses and are forced to give up their productive assets. In addition to the traditional risk financing, innovative risk financing mechanisms, such as index-based micro-insurance programs, catastrophe bonds and contingent credits, for disaster-risk management and climate change adaptation can be beneficial to enhancing financial resilience of risk bearers, especially the most vulnerable communities and their governments (Linnerooth-Bayer and Hochrainer-Stigler 2015).

The financial market may follow the adaptive market hypothesis, instead of efficient market hypothesis. For example, the UK energy system satisfied the conditions for adaptive markets hypothesis that is based on evolutionary economics theory. The theory considers 'institutional and structural constraints, behavioural routines, and fundamental uncertainties.' In this sense, the range of climate policies for low-carbon investments may not be limited to providing subsidy and market mechanisms for supporting a rational return but expanded to changing agents' behaviours and overcoming structural constraints (Hall et al. 2017).

Markets: Public Theory, Finance, and Creative Destruction

The extension of the case for public policy support to supporting new markets and the role of new entrepreneurship and finance has a long tradition, going back to Schumpeter (1934). The logic as applied increasingly in climate finance is that investments are not just about progressively enlarging the space of low-carbon investments but replacing one system (fossil fuels energy system) rapidly by another (low-carbon energy system), establishing a wave of 'creative destruction'. Normally, this might be expected to proceed without public policy intervention over a longer time when profit opportunities in older technologies are exhausted and replaced by newer ones. But the scale and urgency of change might force options of change to occur faster, supported by state policy because excessive financialization may be impeding the establishment of new investments (Jerneck 2017), the presence of strong complementarities between Schumpeterian (technological) and Keynesian (demand-related) policies (Dosi et al. 2017) and to avoid the lock-in damages of long-lasting infrastructure investments using fossil-fuel technologies (Stern 2018).

A literature review of the policy-induced technological choices for low-climate investment conducted for the European Commission (Mercure et al. 2016), concludes that all surveyed branches of macro-innovation theory (under different models) could be grouped into two principal classes: 'equilibrium – optimisation' theories that treat innovators as rational perfectly informed agents and reaching equilibrium under market price signals; and the other 'non-equilibrium' theory where market choices are shaped by history and institutional forces and the role of public policy is to intervene in processes, given a historical context, to promote a better outcome or new economic trajectory. One implication of the latter is that new technologies might not find their way to the market without price or regulatory policies to reduce uncertainty on expected economic returns. However, the review suggests that more evidence is needed (for use in simulation models) about 'the conditions under which policies that promote low-carbon, capital-intensive investment in the place of conventional, less capital-intensive alternatives would divert financial resources and displace investment elsewhere (significantly) in the economy' and whether the pool of financial resources available is large enough. A key issue is the perception of risk by investors and financial institutions and modelling the financial sector more adequately (in the simulation models). Some reviews of the role of the financial system in other studies suggest that a systemic approach using multiple instruments (cutting subsidies to fossil fuels, supporting clean energy innovation and diffusion, levelling the institutional playing field and making risks transparent) is key to redirecting private investment (Polzin 2017), whereas others suggest that a bigger systemic push may be needed (Kern and Rogge 2016), in particular, the role of 'institutional innovation intermediaries' (Polzin et al. 2016).

The Schumpeterian three-stage process of invention, innovation and diffusion was unpacked for eight core countries in the European wind-sector Grafström and Lindman (2017) and suggests that public R&D support did not necessarily induce significant effects on invention (patents), there were large cross-border knowledge spillovers (impact of international patents) indicating that openness to trade was important, capacity expansion had positive effects on learning-by-doing on innovation over time, and that feed-in-tariffs (FITs), in particular, had positive impacts on technology diffusion. The FITs program - long-term (10 to 25 years) power purchase contracts with guaranteed grid-access and cost-based prices - more generally has been associated with rapid increase in early renewables capacity expansion across the world (in over 50 countries) by reducing market risks in financing and stability in project revenues (Menanteau et al. 2003; Jacobsson et al. 2009), but with later rapidly rising fiscal costs of subsidies and rapid gains in technology driving generation close to grid-parity, has now increasingly halted or switched to alternative designs of more cost-effective public support, with greater differentiation (location, size, technology), performance-based systems, progressive cost-reductions given technology changes and increasingly, reverse auctions instead of baseline FITs (Shrimali et al. 2016). More complex policy questions are also now becoming evident on the design of public risk-reduction innovation and diffusion support as the size of renewables electricity generation expands, such as the policy-lobbying effect of traditional fossil-fuels energy producers (Aguirre and Ibikunle 2014), storage options and costs (including meeting peak demands with more rapid demand-sensitive fossil-fuels such as gas turbines as a complement), scarcity pricing, electricity grid-interconnectivity across borders, factors driving decline in costs by scaled production and adoption of new technologies in major global manufacturing centres (Lam et al. 2018), innovation and technology transfer in global value chains (Zhang and Gallagher 2016), and equilibrating the marginal social cost of different sources of renewable energy (rather than a predominant capacity expansion target as goal in a first phase).

Outside of renewable energy, scattered but numerous examples are available on the role of innovative public policy to spur and create new markets and technologies. They range from the success of the city lighting scheme with LEDs and bulk public procurement to lower prices in India (2014–2018) and earlier energy-efficient lighting with standardisation and quality assurance, direct procurement, stakeholder 'involvement' and 'demonstrations' in Sweden (1991–2000) (Arent and Zinaman 2017), working with financial markets, corporates and inducting new entrepreneurs, to energy efficiency schemes at the city and state levels in the USA, again working with private sector and financial players, and many other examples in Europe, Latin America, Africa and North America. The pro-active role of the state in such energy transitions was invariably a key, as in the retirement of all coal-fired power plants in Ontario, Canada between 2007 to 2014 (Sovacool 2016; Kern and Rogge 2016). However, too early an exit and design problems that did not take into account market acceptability and financing issues are known to have caused premature collapses of public policy interventions in creating new markets, such as energy-efficient retrofitting in housing in the UK (Rosenow and Eyre 2016) and low or negative returns in reality versus engineering estimates in weatherization programs in US (Fowlie et al. 2018), while political economy changes brought a decline in offshore wind opportunities in Norway.

Government guarantees are an important financial instrument that plays an important role in expanding climate finance, especially from the private sector, by reducing the risk profile of the investment opportunities. Sustainable infrastructure requiring long-term investment in developing countries can be largely benefited from government guarantees. By reducing the risks of private investments and by allowing leverage effects, government guarantee allows more effective use of scarce public finance. Providing guarantees can reduce various types of risks, such as developers' risks, counterparty risks and political risks, which are critical for decision-making of private investors. Investment guarantees, which is issued by governments or development banks, encourage oversea investments usually by covering political risks (IIGCC 2015).

Different types of government guarantees mitigate the various types of risks surrounding investment opportunities. For example, government guarantees, such as loan guarantees or investment guarantees, are the direct instruments for reducing the risk profile of the private sector investment (Climate Action Network 2013). First-loss piece or guarantee schemes lead sharing of resources and risk-taking among a group of participants. Risk-sharing allows participants to increase the amount and number of resources and participants, to leverage scarce public finance to maximize the impacts, and to take shared and common approaches among financial actors (UNEP 2011).

Support of Climate Action via Carbon Pricing/Taxes/Emission Trading Systems

The second strand of literature and evidence suggests that futures markets as regards climate are incomplete because they do not price in externalities, by definition (Scholtens 2017). They are incomplete because there are no futures markets of states of the climate world that might otherwise predict and lead to asymptotically rising prices of carbon to price in progressively higher risks (lack of perfect foresight), technical inertia of long-term infrastructure investments (Waisman et al. 2012) and the future climate risks, in any case, cannot itself be diversified (there is only one planet). As a result, low-carbon investments do not take place to socially and economically optimal levels, and the correct market signals would involve setting carbon prices high enough or equivalent trading in reduced carbon emissions by regulatory action to induce sufficient and faster shift towards low-carbon investments (Aghion et al. 2016).

The trouble with setting such explicit carbon prices is that they often depend on modelled estimates of the marginal cost of emissions damages and discount rates of the future which together can produce a large range of uncertainty as well as uncertainty of credibility of rival information sources (Aliakbari and McKitrick 2018). The solution then goes to set a path of varying emissions taxes and exemptions and trading mechanisms (cap and trade mechanisms) to reduce such uncertainty, dependent on how strong the consensus is within and across countries on climate forecasts and costs. Setting carbon taxes at global levels sufficiently high suffer additionally from problems of consumer, producer and political resistance to new taxes (Carattini et al. 2019), together with redistribution consequences because energy taxes are inherently regressive (the poor spend more on energy as a share of their incomes). It is possible to set different carbon taxes in different countries at different levels (Bataille et al. 2018) given differences in development objectives, multiple market failures and limited scope for international transfers, but the problems of resistance to taxes and redistribution concerns within countries remain. Emission trading systems (ETS) are vulnerable to well-known problems, either in setting exemptions too high to begin with or carbon taxes too low because of distributive consequences and effects emanating from inadequate domestic demand, market power of dominant firms (Hintermann 2011; Hintermann et al. 2016), 'limited financial involvement, incomplete regulatory infrastructure, and excessive government intervention' (Lo 2016) as evident from the poor performance of the EU ETS and those in China (Lo 2016). A review suggests that while carbon taxes and emissions trading systems (ETSs) to limit emissions of greenhouse gases (GHGs) are becoming increasingly common, with ETSs operating in 55 jurisdictions while 18 jurisdictions collected a carbon tax, the results so far have been mixed. Emissions reductions achieved by existing carbon taxes have been small in most jurisdictions due to the low tax rates, the modest changes in tax rates and inelastic demands for fossil fuels, and existing taxes yielded virtually no insight into the relationship between changes to the tax rate and changes to emissions - although one study estimated that the presence of carbon taxes (versus those who did not) raised the share of solar and wind electricity use in total by 2.4–5.2% respectively (Best and Burke 2018). Carbon taxes also impact GDP negatively (not accounting for welfare gains from lower carbon emissions), lower exports and competitiveness, and are accompanied by significant emission leakages through shift in production and trade to lower tax jurisdictions (Timilsina 2018). In similar vein, the ETSs have accumulated banks of surplus allowances and while most have implemented measures to reduce these banks (Haites et al. 2018), success has remained elusive.

Paradoxically, the use of carbon taxes and emission trading systems is of late rising faster in developing countries - six developing countries (Mexico, Chile, Colombia, India[7], China and South Africa) have added carbon taxes or ETS since 2011, while only 3 developed countries have done so (Japan, UK, France and Portugal have joined while Australia has dropped) have done so, in part due to the strong influence of MDBs who are encouraging carbon taxes and ETSs as the principal way forward and their absent influence in developed country jurisdictions.

Role of domestic funding sources

In sub-Saharan Africa, LSE production has been increased through the deployment of mini-grid and solar home systems in rural communities. In the transport sector, cities (such as Lagos, Kaduna, Enugu in Nigeria) are developing holistic and urban resilience strategies to reduce reliance on cars by developing public transport infrastructure including bus transit and light rail systems.

However, challenges and constraints to the involvement of sub-nationals in climate policy design and implementation include lack the autonomy to take unilateral policy action, limited institutional capacity and financial resources; and the haphazard nature of sub-national governance collaboration and cooperation at national or regional level. This is huge challenges with regard to data acquisition and collation at national level – crucial to understanding a nation's vulnerability to climate change and for planning.

It is therefore clear, that the government cannot be the only actor in contributing to a shift to a low-carbon economy, it, however, plays a very important role in creating the legal and policy environment that prioritises climate change mitigation and adaptation. This brings to fore the need to bridge the climate finance gap through the adoption of a stakeholder cum grassroots approach that enlists the support of everyone in tackling climate change**.**

Public investment through the federal, state and local governments forms the country's capital stock by allocating resources to the basic physical infrastructure (such as roads, bridges, rail lines, airports, and water distribution), innovative activity (basic research), green investments (clean power sources and weatherization), and education (both primary and advanced, as well as job training) which are expected to lead to increased productivity and better standard of living (Bivens 2012).

Investments in education, health financing, and green investments are worth hundreds of billions of dollars of prospective public investment that brings very high rates of social return.

15.6.3 Address knowledge gaps with regard to climate risk analysis and transparency

The framing of climate risk as a financial risk (not just as an ethical issue) can be broken down into transition and physical risk components (see Box on Risk in section 15.2). The TCFD recommendations framed both transition and physical risks as components of financial risk (TCFD 2017).

Transition risk, stranded assets, and systemic risk

[7] India has a coal cess (2010 onwards), as well as an ETS style PAT (Performance, Achieve and Trade) system since 2009 for 1,000 largest corporations:

Fossil fuel reserve and resource estimates exceed in equivalent quantity of CO_2 with virtual certainty the carbon budget available to reach a 1.5°C and 2°C targets (McGlade and Ekins 2015; Meinshausen et al. 2009; Millar et al. 2017). This suggests that less than the whole quantity of fossil fuels currently valued (either currently extracted, waiting for extraction as reserves or assets on company balance sheets) can yield economic return if the carbon budget is respected. When they are valued on balance sheets, the devaluation of fossil fuel assets imply financial losses to some parties, public or private (Coffin and Grant 2019).

Stranded fossil fuel assets are fossil-related assets (fuel or equipment) that become unproductive. Global estimates of potential stranded fossil fuel assets are at least 1 trillion of stranded fossil fuel assets, based on ongoing low-carbon technology trends and without any new climate policies implemented (cumulated to 2035 with 10% discount rate applied; 8 trillion USD without discounting (Mercure et al. 2018a). With new climate policies worldwide to achieve the 2°C target with 75% likelihood, this could increase to over 4 trillion USD (until 2035, 10% discount rate; 12 trillion USD without discounting). Other estimates indicate 8–15 trillion USD (until 2050, 5% discount rate, Bauer et al., 2015) and 185 trillion USD (cumulated to year 2115 using combined social and private discount rate; (Linquiti and Cogswell 2016) However the geographical distribution of potential stranded fossil fuel assets (also called ‘unburnable carbon’) is not even across the world due to differences in production costs (McGlade and Ekins 2015).

A carbon bubble is a hypothetical situation in which the supply capacity in the fossil fuel extraction and transformation sectors far exceeds the expected demand for fossil fuels, leading to an oversupply of fuels and a build-up of financial risk resulting from devaluation of fuel, extraction and transformation assets and of the equity of their owners (Coffin and Grant 2019). Since the volume of fossil fuels traded on financial markets is comparable to or exceeds the carbon budget, a correction in the value of fossil fuel-related assets (e.g. oil and gas reserves, extraction sites and equipment, fossil fuel transformation and transportation equipment) could take place, suddenly or gradually, as investor expectations of return on investment change (Coffin and Grant 2019; Sussams and Leaton 2017). A reduction in the demand for fossil fuels could imply further asset stranding upstream and downstream of global value chains in cascades (Cahen-Fourot et al. 2019).

Systemic risk may be accumulating in the financial sector in relation to the prospects and early signs of a transformation towards low-carbon technology (Battiston et al. 2017; Campiglio et al. 2018). It remains unclear exactly how fossil fuel reserves and resources and other fossil-related physical assets, and the associated risk of their potential devaluation, are valued on company balance sheets and priced in financial markets, and yet unclear what the financial impact of writing them off could be for financial stability, and this is becoming a concern for financial regulators (Campiglio et al. 2018; TCFD 2017). A review of the economic mechanisms involved in the accumulation of systemic risk associated to declining industries, with focus on fossil fuels, is given by (Semieniuk et al. 2020), where it is shown that a strong feedback exists between the declines in aggregate demand and financial value, initially triggered by technological change. Stress-testing is used to assess systemic risk from regulatory and technological changes (Bank of England 2015a; Battiston et al. 2016, 2017; Bank of England 2018).

Oil reserves, transformation and transportation assets have the highest value at risk, followed by gas and coal, reflected in their price per unit energy content (IEA 2018a). Different domains of technological change and energy use lead to different levels of risk of stranded assets. Since transportation uses around 50% of oil extracted (Thomä 2018; IEA 2018b), a rapid diffusion of electric vehicles (and other alternative vehicle types), as well as vehicles with higher efficiency combustion engines, poses the most important risk of being stranded, as it could lead to oil demand peaking before 2050 (Mercure *et al.*, 2018; Mercure *et al.*, 2018; Lam, Mercure and Pollitt, 2020). New technologies and fuel switching in aviation, heavy industry and shipping could further displace liquid fossil fuel demand (IEA 2017). A rapid diffusion of solar photovoltaic could displace electricity generation based predominantly on coal and gas (Sussams and Leaton 2017). A rapid diffusion of household and commercial indoor heating and cooling based on electricity could further reduce the demand for oil, coal and gas (Knobloch et al. 2019). The availability of other technologies could mitigate these impacts (e.g. the availability of CCS and/or other negative emissions technologies).

Impacts of stranded fossil fuel assets on domestic economies depend primarily on the relative share of industrial activity that is related to fossil fuel extraction, transformation and transportation, as well as on the degree of global competitiveness of their fossil fuel industry. Fossil-fuel exporting nations with lower competitiveness could lose substantial amounts of industrial activity and employment in scenarios of peaking or declining demand for fossil fuels. In scenarios of peaking oil demand, production is likely to concentrate towards the Middle-East and OPEC countries (IEA 2017). Losses of employment may be directly linked to losses of fossil-related industrial activity or indirectly linked through losses of large institutions, notably of government income from extraction royalties and export duties. A multiplier effect may take place making losses of employment spill out of fossil fuel extraction, transformation and transportation sectors into other supplying sectors (Mercure *et al.*, 2018). Fossil-fuel exporting nations with higher competitiveness (e.g. OPEC) may face a choice between maintaining price levels by reducing their production quota or maintain their production but allow lower commodity prices for oil and gas (IEA 2017). Producer countries may lose substantial amounts of income through lower production or lower prices, which may affect government income through losses in royalties.

Physical Risk

Significant cost increases have been observed related to increases in frequency and magnitude of extreme events has (see Section 15.2.3 on financing needs). Economic losses from weather and climate-related extremes in the Europe Economic Area over the period 1980–2017 were approximately 453 billion EUR (EEA 2019). Costs from urban flooding have already increased significantly in the Nordic countries (FinansNorge et al. 2013). Damages from climate change are expected to escalate dramatically in Europe (Forzieri et al. 2018). In the US, economic damage of climate change impacts was estimated at approximately 1.2% of GDP per increase of 1°C warming on average (Hsiang et al. 2017).

While damage costs are increasing, a significant portion of the costs are not covered by insurance. In the US, weather and climate events have had the greatest economic impact from 1980 to 2019, with 246 disasters reaching or exceeding 1 billion USD in damage (National Oceanic and Atmospheric Administration (OAA) using method from Smith and Matthews (2015)). In 2018, total economic losses from natural catastrophes and man-made disasters were 165 billion USD, of which 85 billion USD was covered by insurance. Insurance payouts for catastrophes have increased significantly over the last 10 years, with dramatic cost spikes in years with multiple major catastrophes (such as in 2018 with hurricanes Harvey, Irma, and Maria). This trend is expected to continue as climate change results in more extreme events. The gap between total damage losses and insurance payouts has also increased over the past 10 years (Swiss Re Institute 2019). The indirect costs of climate-related flooding events can be up to 50% of the total costs, the majority of which is not covered by insurance (Alnes et al. 2018).

Financial Stability

Unmitigated climate change could result in systemic instability (Campiglio et al. 2018). A non-linear increase in extreme events related to climate change and the potential for systemic disruption may be underestimated in integrated assessment models (Sutton 2019). The risk of financial instability may be further exacerbated by changing insurance trends or the limited funds of national insurance programs.

The economic impact of climate-related weather shocks will be borne disproportionately by low-income countries, with unequal distribution across household income categories (Acevedo et al. 2018).

Investment funds, pension funds, and bank loans are exposed via a significant portion of investments or loans in sectors vulnerable to changing carbon prices, either directly or indirectly (Battiston et al. 2017). Climate change can reduce firms' profitability and gradually deteriorate liquidity, climate-related damages could result in portfolio reallocations leading to declining prices of corporate bonds and resulting financial instability could adversely affect credit expansion (Campiglio et al. 2018) Systemic financial risk resulting from climate change hazards can lead to an increasing frequency of banking crises, increasing the debt to GDP ratio of most countries, with costs to public budgets of up to 31% in the case of unmitigated climate change (Lamperti et al. 2019). Systemic financial risk could also be addressed via financial sector regulation beyond climate risk disclosure measures using instruments including reserve, liquidity and capital requirements, ceilings on loan-to-value ratios and credit growth, revolving funds or green quantitative easing (Campiglio et al. 2018; Vercelli et al. 2016). Several studies point to examples of the underpricing of climate risk in financial markets (Krogstrup and Oman 2019; Kumar et al. 2019).

Substantial value exists in the financial sector that may also be at risk from changes of regulations and technology in a low-carbon transition. This value is stored in many forms of public and private production and infrastructure assets (buildings, vehicles, plants, factories, infrastructure), which may not be compliant with future fiscal and regulatory systems with regards to energy efficiency and emissions or become obsolete due to lack of demand. Transition risk could affect well over 1 trillion USD and up to 12 trillion USD of assets in the fossil fuel sector alone (Mercure et al. 2018b; Battiston et al. 2017a). Loss of value can take place in the extraction, transformation and transportation industries, as well as in power generation, and all value chains upstream. Risks to individual assets may be directly or indirectly related to climate change, since some assets may be related to activities that depend on a productive fossil fuel industry while not being directly related to fossil fuel production, transformation or transport (e.g. materials, metals, some types of manufacturing, machinery production, see Cahen-Fourot *et al.*, 2019). Building new coal-fired power plants is highly likely to lead to stranded assets (Pfeiffer et al. 2018) while jeopardising achieving the 1.5°C climate target (Tong et al. 2019).

Due to the predominantly international nature of fossil fuel markets, assets may be at risk from regulatory and technological changes domestically and in foreign countries. A concentration of oil and gas production towards the Middle East is possible in situations of contracting demand growth, due to global competitiveness and comparative advantage in oil and gas production (IEA 2017). Due to a concentration of low production cost asset ownership lying with state-owned fossil fuel companies, privately-owned fossil fuel companies are likely more at risk (Thomä 2018).

Global financial stability could be affected by large changes in value of fossil-related assets, and the value of the institutions that own these assets (Bank of England 2015, 2018). The impact of climate change on the UK insurance sector (Bank of England 2015). Some evidence shows that the risk of stranded assets is not currently fully priced into investment decisions, as markets were found inefficient in pricing 'publicly available information on carbon disclosure and performance' (Liesen et al. 2017) of firms. This suggests that the risk of systemic financial instability from stranded fossil fuel assets could accumulate and not be eliminated by suitable portfolio diversification as financial agents do not act on available information, potentially reflecting a lack of consensus on interpretation.

Global macroeconomic changes that may affect asset prices are expected to take place as a result of a possible reduction in growth or contraction of fossil fuel demand, in scenarios in which climate targets are met according to carbon budgets, but also following ongoing energy efficiency changes (Mercure *et al.*, 2018; see also Clarke *et al.*, 2014). This includes notably important structural changes taking place, sectorally and regionally, as fossil-fuel-related sectors, and their intermediate product supplying sectors, see reductions in demand, output and employment (Cahen-Fourot et al. 2019). Parallels can be made with earlier literature on great waves of innovation, eras of clustered technological innovation and diffusion between which periods of economic, financial and social instability have emerged (Freeman and Louca 2001; Perez 2009).

Stability could be affected by portfolio value shocks via equity value and creditworthiness via the complex topology of the asset ownership network globally (Battiston et al. 2016). Equity and credit ratings, influencing access to credit, can be affected through several channels: (1) directly, for companies owning physical fossil fuel assets; (2) indirectly, for companies holding exposed financial assets, or who supply intermediate or investment products to fossil fuel operations; and (3) through a general slowdown in the level of economic activity, and/or a general downward trend in capital asset prices, which may be affected by a change in investment trends or by a financial crisis (Wilkins, 2018, see also Battiston *et al.*, 2016, 2017).

Voluntary and regulatory responses to climate risk

Globally, central banks have played a central role in raising awareness and increase transparency of the potential material financial impacts of climate change. Calls for disclosure of climate risk and incorporating climate risk into financial stability monitoring and portfolio analysis have come from the Bank of England, the Financial Stability Board, the G20 Green Finance Study Group, and the network for Greening the Financial System (Bank of England 2018; Bank of England 2015a; TCFD 2019b)

On a national level, several governments and financial regulators in developed countries have called for climate risk assessments of the national economy and financial sector (UK Government 2017; U.S. Global Change Research Program 2018).

The Dutch central bank focused on the risk of impacts from water-related hazards to the financial sector (DNB 2017) while a Norwegian government national climate risk assessment focused on the impacts within the Norwegian economy of climate-related events occurring elsewhere in the world (Finansdepartementet 2018).

Voluntary initiatives in response to climate change awareness began with a bottom-up movement for divestment from fossil fuels (Bergman 2018) with limited direct impact but shifting the discourse of fiduciary duty (Bergman 2018; Ayling and Gunningham 2017; Grady-Benson and Sarathy 2016; Wirth 2018). For the whole financial system, divestment does not necessarily reduce systemic risk as it primarily downgrades the risk profile of fossil-related assets, but the assets remain in ownership (Wilkins 2018).

Investors groups focused on climate, and environmentally responsible investing have increasing membership and activity, but the impact is difficult to assess. The range of socially responsible investors covers a wide range of definitions and motivations, including those motivated by idealism as well as those motivated to mitigate climate and environmental risk (Chatzitheodorou et al. 2019). Several investor networks focusing on sustainability including climate change are active in different regions, for example, Ceres in the US, IIGCC in Europe, and the global UN Principles for Responsible Investment (PRI) group. UN PRI membership has grown from 100 members in 2006 to 2,300 in 2018, with over 80% of members (UN PRI 2018). Launched in 2017, more than 300 investors back the Climate Action 100+, pushing the largest emitting companies on climate action. Growth in sustainable investment assets under management grew by over 30% globally from 2016 to 2018, with wide variance in the regional distribution (GSIA 2018).

Although disclosure has increased since the recommendations were published, the information is still insufficient for investors and more clarity is needed on potential financial impacts and how resilient corporate strategies are under different scenarios (TCFD 2019). The voluntary recommendations by the

TCFD for climate risk disclosure were welcomed by over 500 financial institutions and companies as signatories, with reporting efforts let by France, the UK, and Germany (CDSB and CDP 2018). The implementation of the TCFD recommendations has been patchy. For example, a majority of companies report board oversight of climate issues, but only 10% provide incentives for climate risk management (CDSB and CDP 2018). Several efforts to provide guidance and tools for the application of the TCFD recommendations have been made (using SASB Standards and the CDSB Framework to Enhance Climate-Related Financial Disclosures in Mainstream Reporting TCFD Implementation Guide (CDSB and SASB 2019; UNEP FI 2018b; 2019; UNEP FI 2018a). Results of voluntary reporting have been mixed, with one study pointing to unreliable and incomparable results reported by the US utilities sector to the CDP (Stanny 2018).

Regulatory initiatives are also developing across Europe, but it is too early to see significant impact. At the EU level, the draft Sustainable Finance Action Plan includes text to mandate disclosure of climate risk and taxonomy for labelled green financial products and includes language on scenario stress-testing (European Commission 2018) (update as action plan is implemented before SOD). At the country level, France was the first country to mandate climate risk disclosure from financial institutions (via Article 173 of the law on energy transition). However, disclosure responses to date are mixed in scope and detail, with the majority of insurance companies not reporting on physical risk (Evain et al. 2018). In the UK, mandatory GHG emissions reporting for UK-listed companies has not led to substantial emissions reductions to date but could be laying the foundation for future mitigation (Tang and Demeritt 2018).

Transparency-based financial policies may have limited impact in mitigating climate risk. Transparency on climate risk can support investment decisions, but limitations of market response efficiency remain without specifically addressing policy and other barriers (Ameli et al. 2019).

Knowledge Gaps

The increase in investor awareness places new demands on climate scientists for clearer information and guidance on climate scenarios (Weber et al. 2018; Millar et al. 2018) Stress-testing against a range of climate scenarios, including a 2°C scenario, is recommended by the TCFD and noted in the draft EU Sustainable Finance package on disclosure (TCFD 2017). Yet existing climate and energy scenario information is ill-adapted to short-term and risk-based stress-testing (Clapp and Sillmann 2019). Further, the potential for systemic disruption resulting from extreme physical impact is not well understood or modelled (Sutton 2019).

Existing energy-economy models are predominantly oriented towards supply-driven perspectives on the macroeconomy, which does not track impacts related to changes in demand (Monasterolo and Raberto 2018a; Pollitt and Mercure 2018). Existing integrated assessment models (IAMs) have been used to estimate financing needs for a transition towards a low-carbon economy (McCollum et al. 2018). However, existing IAMs do not represent the financial sector explicitly, leaving an important gap of knowledge in relation to finance (Dafermos et al. 2018). Very few models used for generating socio-economic scenarios in relation to climate change and climate policy have representations of investment, banking and finance (Mercure et al. 2019).

Two types of new demands for models are emerging and being used to assess the impacts of individual and systemic risks from climate change (physical and transition risk), with two different purposes (UNEP 2018d):

1) Scenario analysis for assessing climate risk across the economy with the accumulation of climate change impacts and stranded fossil fuel assets, including notably agent-based models and post-Keynesian/evolutionary models (Lamperti et al. 2018; Bovari et al. 2018; Jackson

2019; Lamperti et al. 2019; Dafermos et al. 2018b; Mercure et al. 2018b; Monasterolo and Raberto 2018a).

2) Fat tail risk analysis for financial regulators (e.g. see Battiston et al., 2016, 2017; Stolbova, Monasterolo and Battiston, 2018), where stress-testing is used to assess systemic risk from regulatory and technological changes on financial networks.

Macroeconomic impacts observed in low-carbon transition scenarios in models depend on how they represent the financial sector, banks and investment, with different modelling approaches generating different outcomes (European Commission 2013, 2015; Mercure et al. 2019). Further research may be required for developing tools to assess the impacts on financial stability, investment, industry and employment of a transition towards a low-carbon economy.

At the company level, consultancies have stepped forward with services and data on carbon footprinting and some elements of physical risk. (Mazzacurati, Firth, and Venturini, 2018). However, the methods are largely proprietary to the consultancies with limited transparency (Keenan, 2019), or based primarily on carbon footprinting, which is a necessary but insufficient measure of climate risk (De Bruin et al. 2018; Alnes et al. 2019). ESG (environmental, social and governance) data providers show low correlation across scores for companies from different data providers (Zhou et al. 2018).

'START BOX 15.6. HERE'

Box 15.6 Premium for green financial products

One indicator of the potential uptake of green financial products is the willingness of investors to pay a premium for the green label as a way to reduce their exposure to climate risk. Investors face a systematic under-pricing of climate risk in financial markets (Krogstrup and Oman 2019; Kumar et al. 2019). Including green or ESG labelled financial products in an investment portfolio can be a first step to manage climate risk. Green bonds are on example of a financial product where investors in certain parts of the market are starting to pay a premium for reduced climate risk.

While historically, investors for green labelled bonds have demanded higher yields, there are some recent examples of a premium for green bonds in certain parts of the market. Previously, ESG labelled bonds have not shown systematic tightening (Barclays 2016). However, in the US municipal bond market, as credit quality for green labelled bonds has increased in the past few years, a positive premium for green bonds is emerging (Karpf and Mandel 2018; Baker et al. 2018). Credit spreads for green labelled bonds denominated in USD or EUR show a recent emergence of a premium on average (Ehlers and Packer 2017), although negative green bond premiums are seen in non-government bonds in Europe and the US (Zerbib 2016).

Spillover effects of green bonds may also impact equity markets. Enhance credit quality induced by issuing green labelled bonds can lead to a lower cost of capital for issuers (Agliardi and Agliardi 2019). Issuers' reputation and use of third-party verification can also improve financing conditions for green bonds (Bachelet et al. 2019). Green bonds are strongly dependent on fixed income market movements and are impacted by significant price spillovers from the corporate and treasury bond markets (Reboredo 2018). A simulation of future green sovereign bond issuances shows that this can promote green finance via firm's expectations and the credit market (Monasterolo and Raberto 2018).

For sustainability-labelled indices, there is mixed evidence with some studies showing improved performance over non-labelled indices (Jain et al. 2019). On a risk-adjusted basis, emerging marketing ESG indices significantly outperformed non-labelled indices (Sherwood and Pollard 2018); another showed slightly higher returns for a non-fossil fuel index over sample periods in the last eight years (Halcoussis and Lowenberg 2019).

Beyond financial performance, there is, however, to date, a lack of evidence that sustainability ratings and labelling of financial products have significant impacts in terms of climate change mitigation and adaptation. See Section 15.3.3 for further discussion on labelled instruments including green bonds.

'END BOX 15.6. HERE'

15.6.4 Development of local capital markets

Situational context

Developing countries face the double-edged challenge of improving the lives of their citizens through provision of basic services such as access to electricity, water, sanitation, pension (Hafner et al. 2018; Bayliss 2013) while at the same time meeting climate change obligations through the development of low carbon, climate resilient infrastructure under the 2015 Paris Agreement (UNFCCC 2015). The 2015 Addis Ababa Agenda (AA Agenda) and the 2019 UN Roadmap for Financing the 2030 Agenda for Sustainable Development (UN SDG 2030 Roadmap) provide global frameworks for discussing the solutions pathways to common challenges faced by developing countries in addressing these gaps and integrating into national plans. These UN global frameworks recognise the heterogeneous nature of developing countries, the different climate risks each nation faces depending on geographical location. As a group, developing nations are the most vulnerable to climate change impacts due to insufficient resilience capacity and absence of adaptation mechanisms to deal with extreme weather changes including droughts, tropical storms, hurricanes, floods, cyclone and heatwaves (Kusangaya et al. 2014; Adenle et al. 2017; Ahmadalipour et al. 2019).

The significance of Africa's mitigation potential from low-carbon climate resilient infrastructure

Africa has a large infrastructure gap, is lagging behind other regions and remains mostly unelectrified: currently with some 600 million people who live without access to electricity with nearly 900 million, using hazardous biomass cooking methods which mostly impacts women and children (IEA 2019b,a) who make up over 50% of the population (McKinsey 2019; Ernst & Young 2011). A continental composition that includes Fragile and Conflict-affected States (FCs), the Least Developed Countries (LDCs) and Small Islands Developing States (SIDs), Landlocked Least Developed Countries (LLDCs) (see Table 15.9) all within the same region and taken together exacerbates vulnerability. Whilst Africa currently contributes very little to climate change Africa - a vast continent (larger than US, China, India, Europe combined) currently contributes very little to global emissions, its rapidly rising energy demands and renewable energy potential in comparison to its growing reliance on fossil fuels and 'cheap' biomass (especially charcoal use and deforestation) amid fast-rising urbanization makes it imperative that institutional investors and policy-makers recognize the very large 'leap-frog' potential for the renewable energy transition as well as risks of lock-in effects in infrastructure more general in Africa that is critical to hold the global temperatures rise to well below 2°C in the longer-term (2020 – 2050) (Williams et al. 2007; Palmer et al. 2019; van der Zwaan et al. 2018; Economist 2015; Sy 2016). Overlooking this transition opportunity, rivalling China, India, US and Europe, would be costly. Policies centered around the accelerated development of local capital markets for energy transitions are critical in Africa, as in other low-income countries and regions.

A region predicted to double its urban population from currently about a billion people or 17% of the global population with mostly under 25s and increasing industrialisation – with energy consumption and urban population growth to 2040, estimated to exceed that of China's peak economic growth (IEA 2014; UN Population Prospects 2019; OECD Environmental Outlook 2050; Calvin et al. 2016). The literature on the global importance of Africa's mitigation potential and avoiding carbon-lock-in by investing in low carbon climate investment - has a consensus pointing to the mostly untapped renewable energy endowment (IRENA 2019, Unruh 2000; Unruh and Carrillo-Hermosilla 2006; Leimbach et al

2015) with only about five gigawattes or less than one percent of the global solar installed despite Africa having the most abundant solar resources in the world (IEA 2019). Technology improvements have made solar the cheapest form of electricity for most and further scientific research in potentially even cheaper, low capital expenditure plastic-based solar photovoltaics continue to be important (Feldman et al 2014). The most up to date IEA 2019 scenario estimate for financing needs, in comparison to previous estimates by other researchers (Briceño-Garmendia et al 2009; Eberhard et al 2008; Eberhard and Shkaratan 2012; Duarte et al 2010; Gujba et al 2012; UNEP 2012; Africa Progress Report 2015 revises upward the Africa financing needs to 120 billion USD investment to be mobilised every year to 2040 - just for scaling up electricity power infrastructure alone.

Domestic resource mobilisation through improving local tax revenue including extractive sector supplemented by international assistance

The 2030 UN SDG Goal 16 (Peace, Justice and Strong Institutions), the UN AAA Agenda and the UN 2030 Financing Roadmap to help close the development gap, pay particular emphasis to improvements in domestic capacities for tax and diverse revenue collection including tackling illicit Finance Flows supplemented by international assistance. Various models in literature put an emphasis on the importance of broadening the tax base and strengthening statistical data reporting systems at both local and central government as part of strengthening the enabling environment (Mawejje and Munyambonera 2016, Jerven et al 2015, van Wyk and Rousow 2009; Manyema et al 2014; Kefela 2009; Bahl et al 1984; Pritchard and Leonard 2010). With the predicted projected population increases - policymakers will have to consider systems for improving revenue collection for growing urban population (Cobbinah et al 2019) as part of improving creditworthiness important in attracting financing for climate resilient projects including through municipal bonds financing. Whilst cities such as Johannesburg and Cape Town have issued municipal bonds (Table 15.8), World Bank estimates that only 20% of the largest 500 cities in developing countries are deemed creditworthy with most of the revenue from taxation being only sufficient to cover operating expenditure (World Bank 2013, 2015) – Initiatives such as C40 Creditworthiness (2016) and World Bank City Creditworthiness (World Bank 2015) provide technical assistance to policy makers. Gorelick 2018 refers to the cities of Johannesburg and Cape Town making use of an established track record of collaboration with development finance instituitions in achieving credit enhancement to support issuance of conventional bond markets before launching green bonds.The success of these South African municipalities the study notes the importance of decentralised governance, supportive regulatory and policy environment as a key part of the enabling environment (see 15.6.5).

A major source of central government tax revenue for developing nations in Africa is the extractives sector: Literature is replete with challenges faced by extractives-rich developing nations in collecting tax revenue to improve public finances that could be directed to low carbon, climate resilient infrastructure. In theirintegrated assessment model, McGlade and Ekins (2014) concluded that to meet the commitments under the Paris Agreement: 33% of oil reserves, 50% of gas reserves and 80% of coal reserves globally may have to be left in the ground which raises important questions for policymakers of extractives countries planning ahead by housing their natural resources to maximise efficiences and help monitor these in preparation for when some will have to be left in the ground – in the process diversifying revenue generation as part of transitioning to decentralised renewables.. Public opinion cited in the 2019 IRENA report has not only been a driver for change for climate change but has been a driver in the rise in 'NGO transparency activism literature' around developing country public finance themes such as public debt and extractive industries local tax beneficiation. The UK NGO War on Want (2016) analysis of 101 extractive companies operational in 37 sub-Sahara Africa countries listed on the London Stock Exchange said to control over a 1 trillion USD of resources and UK NGO EITI (2018) Africa extractives guides around strengthening governance and extractives tax collection are some of the examples (see Table 15.8).

The peer reviewed literature discussions on the challenges faced by extractives-rich developing nations in collecting tax revenue is well documented. Sachs and Warner (2001) asserted that in countries where natural resources are in abundance, these have slow growth than the countries which are resource deficient – an observation confirmed by the recent 2019 IMF Sub Sahara Africa Economic Outlook analysis. In their analysis of (1997, 2006, 2011) World Bank Data - Canuto and Cavallari (2012) pointed to quality governance arrangements being key and many bodies of scholarly work have confirmed the low quality of institutions in developing countries being decisive (Mehlum et al. 2006; Papyrakis and Gerlagh 2004; Dauvin and Guerreiro 2017; van Ingen et al. 2014) Several comparative studies analysing the governance arrangements around resource intensive countries and comparing to established sovereign wealth funds of Norway, Singapore for example - all point to the importance of enhanced legal frameworks,robust reporting arrangement and fiscal rules (Ingen et al 2014; Adeakin 2018; Stephens 2019; Oshionebo 2018; Le Billon 2010a,b; Hearson 2014; Jansky and Prats 2015) point to tax leakages from profit shifting and illicit flows, highlighting linkages to weak extractives regulatory governance frameworks.

Norway's Sovereign Wealth Fund – the Government Pension Fund Global (GPFG) established in 1996 to steward Norway's oil and gas, for a country with a population of about 5million has saved a fund worth over 1 trillion USD as of September 2017 in less than 30 years through accountable transparent governance (NBIM:GPFG Annual Report2018 ;). In comparison – in the past 60 years – Africa's vast natural resources endowment (IEA 2014, IEA 2019) as also cited by the NGO War on Want study pointing to 101 controlling over a 1 trillion USD of resources islagging behind all regionssignificant infrastructure gap including – 600 million people unelectrified and if current policy plans continue unchanged – by 2030, 90% of Africa will still be unelectrified (IEA 2019).

The illicit flow leakages,– some studies point to the capital flow out of developing countries being often destined to 'offshore tax havens centres (ICIJ Panama Papers 2019, Jansky and Prats 2015, Global Witness 2016). Beyond technical assistance programmes (see Table 15.8), recent examples of international co-operation in tackling illicit finance include cross-country collaboration by the US Justice Department, UK and Switzerland on the Mozambique debt issue (Washington Post 2019; Economist 2019; Hanlon 2017) and the investigation by theUK Serious Fraud Office into commodities firm Glencore (SFO 2019). The FRACCK 2018 framework for proceeds of crime being returned to developing countries such as Kenya isan example -(of strengthening co-operation and country capacity to prevent, reduce and recover illicit financial flows as articulated in theUN Roadmap for Financing SDG 2030. The significant policy option in literature points to regions such as Africa peer learning to adopt best practise by housing extractives inside sovereign wealth funds with with clear accountable institutional governance achieved through transparent, public and regulatory reporting frameworks as in the Norway SWF and robust fiscal rules on expenditure in climate resilient low carbon infrastructure, for example. The sovereign wealth fund institute documents seventeen Africa sovereign wealth funds, member countries of AfCTA agreement at different stages of development with some at consultation stage on governance arrangements (SWFI 2019).

The debt transparency UK NGO Publish What You Fund 2019 DFI transparency initiative; the UK NGO Jubilee Debt 2019 coalition of 30 civic organisations on IMF debt; the IMF review on conditionality published in 2019; the association of international banks call for debt transparency (FT 2019); 2019 G20 Finance Ministers Communique agenda discussion on debt transparency; 2019 ODI analysis on the need for new approaches around blended finance in the poorest countries; Oxfam (2018) analysis of the use of MDBs financial intermediaries in lending and Mkandawire (2010) pointing to the lack of transparency by DFIs circumscribing the scrutiny of national institutions in the countries they operate – all these literature discussions call for transparency by both the lender and borrower where public funds are transacted. In light of the scale of the challenge to mobilise trillions of dollars (2015 UN Addis Ababa Agenda) of financing for infrastructure in developing countries – with development finance institutions playing a significant role, there is an opportunity for policy makers to review policy solutions. The 2019 UN Financing for Development Report points to unresolved debts, highlighting the importance of debt transparency including IFIs such as the IMF having developing country representation. Some stakeholders have pointed to DFIs being unregulated financial instituitions contrary to international best practise (FT 2019 – leaving the option of policy makers appointing an external independent regulator of all development finance institutions including MDBs/IFIs.. Regulated financial instituitions would be subject to mandatory transparent best practise international reporting standards such as IPSAS/IFRS in operation with the European Union (Table 15.8) around public finances and financial instituitions to allow assessments of value for public money to be made. The UK's Whole of Government Accounts (WGA) of audited and accrual-based financial statements are among the most transparent, based on best practise international IPSASB standards, with all financial institutions regulated and public sector finances accounts mandated for publication with UK Treasury, Officeof Budget Responsibility, Office of National Statistics and the Bank of England at the heart of transparent governance and reporting architecture. Table 15.8 shows menu of policy options of Paris Agreement MRV support activities (Figure 15.14) such as capacity building, international co-operation, NDC and public sector finance technical assistance which policy makers can review including national statistical systems, tax and customs as part of strengthening the enabling environment.

Mobilising climate finance and long-term infrastructure finance through development of local capital markets

The literature discussion above confirms the importance of public finance management being at the heart of creating the enabling macroeconomic stability (see 15.6.1and 15.6.2) and in determining creditworthiness. Legal and regulatory frameworks that support creditor rights, contract enforcement, bankruptcy with a technically competent and well-resourced securities regulator, stable policy enviornment, trading and clearing settling systems – all form important attributes of building sustainable local capital market confidence and investor trust. The 2019 Financing for Development, 2015 UN AAAgenda and the 2015 UN SDG Roadmap recognise the development of local capital markets as part of a wider solutions roadmap in addressing SDG goals. The G20 working group made up of international organizations (IOs); World Bank Group, IMF, regional development banks (ADB, AfDB, IADB, EBRD), OECD, BIS with support from the Deutsche Bundesbank has an action plan to support regional initiatives in strengthening the development of local capital markets as part of the agenda on reform of the international monetary system. The action plan is centred around improving co-ordination of technical assistance (Table 15.8), developing a common diagnostic framework to support technical advice as well as improving the data sharing to support local bond markets (IMF 2013, 2016, 2018). The plan acknowledges the benefits of deepening the local currency bond markets include improving the resilience of the financial system and domestic economy's ability to withstand shocks, reducing reliance on foreign currency borrowing and exchange rate risks as well as supporting the strengthening of local domestic savings given the growth potential with burgeoning populations. It is widely recognised that sub-Sahara Africa has under-developed local capital markets – with bond markets still very much at a nascent stage (Mu et al. 2013).

In their review of Africa bond markets - Mu et al. (2013) acknowledge the same benefits to developing local capital markets, pointing to opportunities to develop deeper markets that provide a wider spectrum of instruments for central banks to manage monetary policy implementation and diversify hedging instruments for long term, infrastructure project financing. Given the urgency of the threat of climate change - in their discussion Duru and Nyong (2016) point to green bond issuances presenting an opportunity to make headway in mobilising climate finance and simultaneously accelerating the development of existing Africa bond markets to support infrastructure long term financing (Table 15.9). Ng and Tao (2016) highlight the potential for using local currency bonds to mobilise financing in developing countries of Asia, pointing to the importance of supportive renewable energy policies as well as the deepening of regional and local markets being important enablers. Green bonds are discussed in the development of the Paris Agreement (Tolliver et al. 2019) as one of the most readily accessible and economical options available to nations to help fund raise capital to meet environmental targets and financing the climate resilient, low carbon infrastructure projects that underpin those targets such as public transport, water services, clean energy, sanitation project which developing countries have a need for.

Governments in different regions have been using different types of fiscal incentives to jump-start the development of local green bond market. China launched national guidelines for the issuance of green bonds (Green Bond Catalogue) in December 2015 alongside introducing a combination of tax incentives and policy support to develop the greenbond market resulting in 238 billion RMB (about 36 billion USD) in Chinese green bond sales in 2016 roughly 40% of global issuance (LSEG Advisory Report 2018). In the same year, investment in renewable energy by China invested was 103 billion USD or 36% of the world's total, greater than the US/UK/Japan (44.1/22.2/36.2 billion USD) combined. In India, the Securities and Exchange Board of India (SEBI) was the driver to disclosure requirements for both the issuance and listing of green bonds; the monetary authority of Singapore introduced a grant scheme to cover the costs of a mandatory external review for green bonds issued and listed on the Singaporean Stock Exchange; Hong Kong Monetary Authority introduced a grant scheme to subsidize eligible projects certified by the local assurance agency (SBN 2018). Philanthropy institutions could play an important role in providing grants to cover the additional costs associated with green bond issuances (EU 2016). The scale of investments required for low-carbon, climate resilient infrastructure in Africa and other developing country regions - requires financing above what government and commercial bank have available. Institutional investors with growing assets estimated to be between 20–100 trillion USD (EU 2016; Azreki 2016) are widely cited as a source of additional capital to fill financing gaps. A 2012OECD survey of institutional investors holding over 7 trillion USD cited complex infrastructure risks as an example barrier to investment. Institutional Investors Group on Climate Change (IIGC) members holding 37 trillion USD signed a 2019 statement urging policy makers to accelerate action to achieve the Paris Agreement indicating priority concerns - A2019 ODI survey of global project preparation facilities showed high failure rates and recommended one-stop infrastructure shops such as ClimateOne (Table 15.8). Other example of a one stop shop infrastructure shops – multi-donor PIDG (Table 15.8) focused on sub-Sahara Africa and South Asia. In Europe, Project 2020 Project Bond Initiative was established to finance large infrastructure projects through capital markets financing and attracting institutional investors by providing credit enhancement to improve the credit quality of bonds to facilitate placement with institutional investors (EIB 2012). An example credit enhancement, an indian corporate ReNew Power's green bond was guaranteed jointly by Asian Development Bank and the India Infrastructure Finance Company raising its credit rating from sub-investment grade BBB to AA+ investment grade attractive to institutional investors (Agarwal and Singh 2018).

Ehlers et al. (2014) outline three infrastructure project cycles consisting of an early stage planning, construction and operational phase with each part having a different risk profile that requires a diverse mix of financial instruments to manage the risks. The initial phase characterised by bank loans with bonds an important refinancing mechanism in the mature, operational, project cycle as banks recycle loans for new project pipelines. Pereira dos Santos and Kearney (2018) point to the MDBs business model imposing significant limitations on use of guarantees with several proponents of standardised infrastructure funds in various forms to appeal to institutional investors: Ketterer and Powell (2018) propose refinancing through standardized national infrastructure bonds with MDB's facilitating project development and credit enhancements; IADB (2019) analysts propose country level SPVs infrastructure funds issuing bonds after the construction phase and Arezki (2016) estimate institutional investors hold over 20–100 trillion USD and point to the need for co-ordination and co-operation within the existing platforms to create a global infrastructure institution providing guarantees to mitigate project risks and the use of securitization techniques on underlying assets.

An extension to the literature discussion would be for policy makers to consider the acceleration of the development of local capital markets through country-level orregional level SPVs that issue green bonds with long duration, guaranteed by a global supra-infrastructure style institution that can provide both project level and sovereign level guarantees with the bonds listed on a stock exchange. India Kerala Investment Infrastructure Fund (Table 15.9) is cited as in preparation to issue SPV-level green bonds (ET 2019). For fiscally constrained developing nations such as those of Africa, off-balance sheet infrastructure SPVs issuing greenbonds that are listed on stock exchanges with transparent disclosure could be an addition to the menu of policy options for policymakers to consider. Africa AfCTA agreement creates opportunities to pool resources for the LDC, FCs, SIDs nations collaborating to establish country and region level infrastructure SPVs. Another consideration for policy makers is in extracting the local value chains when developing infrastructure by mandating local job creation, and co-operation with local instituitions such as science, technology, engineeering, mathematics centres of learning (Table 15.8). The IMF Africa Outlook (2019) refers to 20 million new entrants expected to enter the labour work force in Africa per year –current capital levels could be improved with infrastructure development and local job creation as envisaged in 2009 ILO Global Jobs Pact.

Monitoring, Reporting and Verification

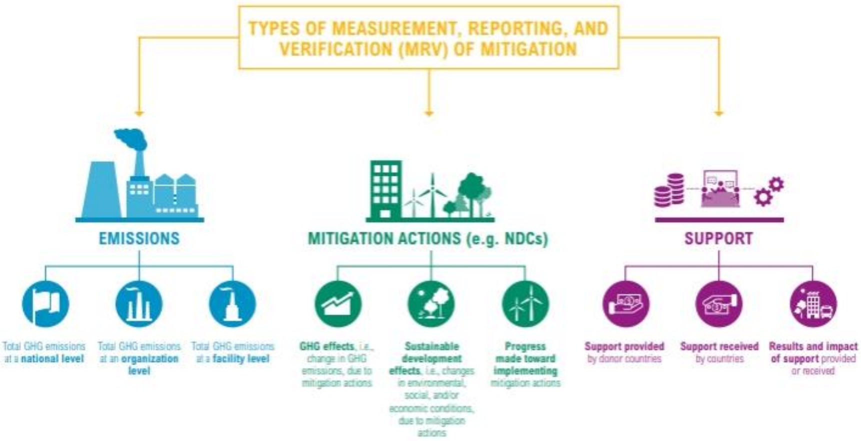

Figure 15.14 Various Types of Mitigation-related MRV

Source: World Ressource Institute (Singh et al. 2016)

The Paris Agreement (UNFCCC 2015) provides a formal transparency framework for measuring/monitoring reporting and verification (MRV) for all countries - taking into account the different national capacities. The Paris Agreement envisages both donor and recipient developing countries tracking and reporting the financial support with all countries providing emissions data and progress tracked against contributions in national MRV systems forming an important progress measurement tool of mitigation goals and policies in each country NDC. In the several pillars to the MRV in the Paris Agreement - climate finance lies within the MRV of Support (Figure 15.14). Paris Agreement MRV. The possibility also arises of establishing a new asset class of carbon remediation investments in low carbon infrastructure in developing countries by explicitly assigning values to the carbon saved by the projects and making them tradeable and available as a security for financing. A centralized cooperative carbon remediation asset (CRA) institution (Dasgupta et al. 2019; Hourcade 2015) could implement this among its members and ‘crowd-in’ funding for such an asset class in financial markets with the agreement of central banks further enhancing the power of supra-infrastructure institution with the feasibility of increased borrowing by low and lower middle-income developing countries and regions, such as Sub-Saharan Africa’s vast scale illustrated by taking US, Europe, China, India together and regions such as South Asia, which are otherwise increasingly severely affected by growing debt burden and macro-prudential risks of accelerating climate investments. More robust statistical tools can independently monitor and verify the value of these carbon assets, using enhanced information technology and science-based methods in comparison to the past more costly, archaic and painstaking methods deployed under the CDM mechanism. New policy instruments such as the CRA, the suprainfrastructure institution and any potential independent regulator of DFIs could work in synergy as part of Paris Agreement MRV.

Table 15.8 Example Paris Agreement MRV activities for policy makers: capacity building, intl. co-operation, technical assistance

Strengthening Domestic Enabling Environments	
African Economic Research Consortium	Regional economics technical assistance and economic policy advocacy
Intl. Public Sector Accounting Standards Board/IPSASB	Develops standards to improve public sector financial reporting worldwide
International Financial Reporting Standards/IFRS	Develops standards to bring transparency, accountability to financial markets worldwide
International Organization of Supreme Audit Institutions	Develops standards for the proper functioning and auditing of public entities
IMF Codes of Practise on Fiscal Transparency	Fiscal transparency frameworks including roles, responsibilities and budget processes
IMF Government Finance Statistics Manual	Statistics frameworks to support fiscal analysis
African Institute for Mathematical Sciences	Developing mathematics and STEM competences
Open Budget Initiative	Openness ratings of budget material to citizens based on surveys by local experts
Institute of Chartered Accountants England/Wales/ICAEW	Members worldwide - acts as an independent regulator to protect public interest
World Customs Organization (WCO) Arusha Declaration	Provides guidance on important requirements to enable effective national customs integrity
Platform for Collaboration on Tax	IMF-OECD-UN-WBG collaboration on tax
International Corporate Accountability Roundtable	Focus areas include governance, corruption and remedy as part of mission
European Public Sector Accounting Standards/EPSA	Accrual-based system using IPSASB standards - promotes comparability across EU
Extractive Industries Transparency Initiative	NGO Activism on transparency and governance of oil, gas and mineral resources
Jubilee Debt Campaign UK	NGO Activism on Debt Transparency
US Dep. of Justice - Africa Region Technical Assistance	OPDAT's Africa Region legal technical assistance to prosecutors, judges, law enforcement
Eurostat	Statistical office of the European Union - member countries have national statistics offices
Africa Centre for Statistics	Promoting international statistical standards and harmonizing national accounts in Africa
UK Office of National Statistics	ONS has a TA programme to support statistical systems in Africa and Middle East
Mobilising climate finance and long term infrastructure financing through development of local capital markets	
African Financial Markets Initiative	AfDB initiative on domestic resource mobilization and bond market development
African Domestic Bond Exchange Traded Fund/ETF	Fixed income ETF investing in Africa local currency sovereign and quasi-sovereign bonds
African Research Universities Alliance	Mandate to develop local research excellence and collaboration on development solutions
Amundi-IFC Greenbond Cornerstone Fund	Green Cornerstone Bond Fund buying green bonds from developing market banks
ASEAN Capital Markets Forum	ADB and ASEAN regional co-operation on local capital markets development (green bonds)
Climate Bonds Initiative	Mobilising the bond market for climate change solutions
Dev. Bank of South Africa/DBSA-GCF Climate Finance	Regional Climate Finance Facility focusing on Lesotho, Namibia, South Africa, Eswatini
Financial Deepening in Africa	Multi-donor partnership on deeping and strengthening Africa financial markets
Global Research Alliance for Sustainable Finance / Invest.	Alliance of universities promoting academic research on sustainable finance and investment
Securities Board of India	Listing of green bonds
IDA-IFC-MIGA Private Sector Window/PSW	$2.5 bn for IFC and MIGA to mobilize private in IDA only + IDA-eligible FCS countries
LDC Universities Consortium on Climate Change	Capacity building and knowledge sharing in climate change within universities
World Bank Joint Capital Markets Program (J-Cap)	Technical assistance on development of local capital markets
Government Employees Pension Fund	Africa's largest pension fund, founding signatory to UNPRI, investor in green bonds
African Insurance Organisation	Insurance company members across most of Africa
Climate Investor One	One stop-shop infrastructure financing from early stage, to construction and debt refinancing
Africa50 Infrastructure Fund	Infrastructure Investment Platform
G20 Global Infrastructure Hub	Infrastructure projects knowledge exchange
C40 Cities Finance Facility	Facilitates access to climate finance for C40 cities in developing countries
Global Infrastructure Facility	One stop project preparation partnership among governments, MDBs, investors, financiers
PIDG (TAF, Devco, InfraCo, EAIF, GuarantCo)	Multi-donor one-stop shop infrastructure instituition/technical assistance and guarantees
Infrastructure Consortium of Africa/ICA	Brings together network of Project Preparation Facilities developing infrastructure in Africa
Global Investor Coalition on Climate Change	Global platform for dialogue between investors and governments on low-carbon investment
International Forum of Sovereign Wealth Funds	Strengthening the SWF community through dialogue, research and self-assessment
AfDB Africa NDC Partnership Hub	NDC Co-ordination of technical support and resource mobilisation
NDC Partnership	NDC technical assistance and knowledge sharing portal
African Forest Landscape Restoration Initiative	REDD+ activities and country-led effors to bring land in Africa into restoration
Low Carbon Pathways - Evidence-Based Policy Making, STEM and Regulation	
African Securities Exchange Association/ASEA	ASEA with 27 Securities Exchanges signed MoU with World Federation of Exchanges
Africa Climate Policy Centre	Co-ordination of climate for development
African Foundation for Development Diaspora/AFFORD	African diaspora mobilisation with 25year presence in Europe

International Confederation of Energy Regulators	Co-operation between energy regulators from around the globe
US Power Africa	US Aid bringing together multidisciplinary experts in developing power projects in Africa
International Energy Agency	Analysis and policy recommendation on energy - produces Africa Energy Outlook
International Renewable Energy Association/IRENA	Intergovernmental organisation supporting countries transition to sustainable energy
Nordpool	Power market exchange with 380 companies from 20 countries in Europe
Association of Power Utilities of Africa	Union of Producers, Transporters and Distributors of Electric Power in Africa
Org. for Women in Science in Dev. Countries(OWSD)	OWSD-UNESCO-TWAS partners advancing science in developing countries

Sources: Websites linked in the name of each entity.

Table 15.9 Menu of policy options in mobilising CF through development of local capital markets

Africa and Middle East	
1. Kenya Local Currency Project Bond	Kenya Treasury has liquid local currency bonds up to 20 years in maturity, has issued several 12 yr infr. project bonds with diaspora components and proceeds earmarked for rural electrification. Kenya multistakeholder Green Bond programme - a with IFC technical assistance has given market signal of green bond issuances to come.
2. Kenya Local Currency Bond	Three year Ministry of Finance mobile phone local currency Treasury Bond M-Kiba targetted at stimulating public savings participation in local capital markets building on Kenya's innovative M-Pesa mobile money system.
3. Kenya Local Currency Green Bond	Local property developer Acorn issued Kenya's first local currency green bond, with 5 yr maturity, rated B1 by Moody's, notch higher than country rating. Received credit enhancement from PIDG (Table 1) and externally reviewed by DNVGL.
4. Namibia Local CurrencyGreen Bond	Locally-owned commercial bank partnered with French DFI AFD to issue greenbonds under a domestic, local currency medium term note programme with local listing on Namibia Stock Exchange, complying with the Sustainable Stock ExchangesInitiative, a UN Partnership Programme. Proceeds earmarked for mitigation and adaptation in line with NDC ambitions
5. Nigeria Diaspora Bond	Sub-Sahara Africa five year diaspora, retail bond targetting global diaspora expatriate community registered with both UKLA and US SEC with proceeds earmarked for infrastructure projects
6. Nigeria Local Currency Green Bond	Mobilising both domestic and international investor with eligible adaptation and mitigation projects in line with Nigeria's NDC targets - the five year green bond was externally verified by DNV GL , listed on Nigeria Stock Exchange
7. Nigeria Local Currency Green Bond Access Bank	Access Bank became the largest bank in Nigeria and the first corporate from Africa to issue a certified climate five year green bond, externally verified by PWC.
8. SIDs S *Seychelles*	SIDS nation Seychelles is made up of an archipelago of 115 islands in the Indian Ocean off East Africa. Theself-labelled green bond (termed as blue bond as targetting marine resources) with World Bank technical assistance. Bond was privately placement with investment firm Calvert Impact Capital, global investment manager Nuveen and Insurance group Prudential.
9. South Africa Local Cur. Green B.	Municipality of Johannesbury, South Africa - first C40 Cities and Climate Leadership group member to issue a green bond with International guidance provided from Green City Bonds Coalition. Ten year self-labelled green bond was priced at 185 basis points (1.85%) above the R2023 Government Bond and will mature in 2024 with proceeds earmarked for infrastructure related projects.
10. South Africa Local Currency Green Bond	Municipality of Cape Town, South Africa C40 Cities member – issued green bond priced at 133 basis points above the R186 government bond [2026, 10.5%], externally reviewed by KPMG, with proceeds mostly earmarked for infrastructure related projects.
11. South Africa Local Currency Green Bond	Nedbank, a large financial services group in South Africa's second climate bond, external review by Carbon Trust, aligning with South Africa's NDCs
Asia and Developing Pacific	
12. SIDS Fiji Local Currency Green Bond	Local currency sovereign green bond issued by SIDs nation Fiji with approx population of 900,000 with proceeds mostly earmarked for adaptation. In 2010 Fiji's small capital markets made up of 77% debt markets, 20% equity securities with the managed funds industry making up 2.7% - issued green bonds sliced into tranchesmobilising both domestic and international investors including banks, pension funds, insurance sectors. Technical assistance provided by IFC with sovereign guidance lessons learnt published
13. India	Kerala Infrastructure Investment Board SPV described in the 2017-18 annual report as an SPV housing renewable energy projects and has signaled to market an intent to issue SPV green bonds
Latin America and Caribbean Region	
14. Chile Local Currency Green	Aguas Andinas, the largest water utility in Chile - listed on green and social segment on Santiago Stock Exchange, with second party opinion provided by Vigeo Eiris. Proceeds earmarked for mixed purposes including resilient infrastructure and sanitation projectsz
15. Caribbean	Caribbean Development Bank, CDB a 2001 Revised Treaty of Chaguaramas Single Market and Economy, Caribbean Community (CARICOM)) regional development instituition has priority focus lending including water, sanitation, mitigation and adaptation projects. CDB published a thought-piece with UNDP on financing the 'blue economy' and partners with local stakeholders such as University of West Indies. CDB also issued a 15year bond in US Capital Markets in 2012 via private placement.
Europe	
16. Poland	Investment grade Poland has the largest economy in Central Europe and mostly reliant on coal for electricity generation. Established Polish Green Bond Framework with Poland Ministry of Finance advised by legal law firm White & Case Warsaw for the inaugural, first ever sovereign greenbond with five years maturity with proceeeds focused on renewable energy sector with external review bySustainalytics. Second sovereign greenbond of longer maturity of eight years - further building the green bonds benchmark yield curve, listed on Luxembourg Green Exchange platform. Third greenbond sovereign issuance, extended the Poland green yield curve further by issuing tranches of 10 years and some for 30 years. EIB has issued local currency Polish Zloty floating rate notes and ten year local currency PLN climate awareness bond placed with Japan Post Insurance

Source: Extraction of different websites linked in each initatives name.

15.6.5 Widening the focus of relevant actors: the role of communities, cities and sub-national levels

There is a demand to meet the finance needs of the climate change actions not only at national level but also at the subnational level, to achieve the low-carbon and climate-resilient cities and communities (Barnard 2015; C40 Cities Finance Facility and CDP and Global Covenant of Mayors 2018). Scaling up urban and community climate finance and investment is a necessary condition to achieve climate change mitigation and adaptation actions, but not a sufficient condition to achieve them. Sub-national climate financing and investment needs to overcome the barriers in the larger context of infrastructure investment and the development contexts.

Cities consume around two-thirds of generated energy and produce 70% of the world's carbon emissions, and they are also vulnerable to the climate change effects, including coastal flooding and urban heat island effects (IRENA 2019a). By 2030, the fifty largest cities will have a larger economic footprint than many small- and medium-income countries (IRENA 2019a). The majority of NDCs, 113 of 164, show urban context, and 58 of 113 NDCs focus on adaptation (UN Habitat 2017). In order to support subnational climate change actions, decentralized and devolved climate finance systems have been established in many countries (Sharma et al. 2015; IIED 2017).

In this section, we touch on characteristics of existing urban and community climate finance and investment and their challenges and opportunities.

Urban climate finance and investment

Urban climate finance is prominent in the current landscape of global climate finance (CCFLA 2015; CPI 2019). The literature on urban climate finance is large, but mostly focuses on infrastructure and low carbon measures (Foxon et al. 2015; Koppenjan 2015; Silver 2015; Granoff et al. 2016). The literature is pervaded by a concern for mitigation and less about adaptation. Existing literature on urban climate finance and investment mainly address infrastructure investment with sectoral focuses such as transport, energy networks, buildings, and water sectors (Foxon et al. 2015; Cook and Chu 2018; Floater et al. 2017).

Challenges and opportunities

Key challenges of urban climate finance and investment include:

(i) scaling up private financing,
(ii) deficient existing architecture in providing financing on the scale and with the characteristics needed,
(iii) political economic uncertainties, and
(iv) lack of positive value capture. Urban climate finance and investment usually only focus on economy value, risks of innovation and lock-in barriers.

As for (i), infrastructure investments being often delivered or mediated by the government (because of their characteristics as natural monopolies and difficulties of capturing spillover benefits and imposing negative externalities) leads to limitation of existing economic model using cost-benefit analysis to evaluate infrastructure investments (Foxon et al. 2015) and difficulties to scaling up private financing (Granoff et al. 2016). (ii) is because the existing financial structure is not fit to provide financing on the scale and with the characteristics needed, including lack of adequate project preparation facilities and resource supports (Anguelovski and Carmin 2011; Brugmann 2012). Reason for (iii) is political economic uncertainties and immature regulatory framework, especially related to innovation and lock-in barriers, that increase investment risks (Unruh 2002; Cook and Chu 2018; White and Wahba 2019). And (iv), much of the existing assessment of climate infrastructure investment is framed around the need to cover the incremental costs of low-carbon options instead of internalising the valuation of positive social and environmental externalities (Foxon et al. 2015; Granoff et al. 2016; White and Wahba 2019). Existing financial structures and arrangements have failed to incorporate social and environmental aspects in capital markets (Salzmann 2013; Sandberg 2015; Zhan and Jong 2018).

Determinants of finance mechanisms that could facilitate urban climate investment include:

(i) fiscal decentralisation/municipal finance,
(ii) bonds and debt financing,
(iii) land value capture,
(iv) pricing, regulation and standards, national investment vehicles, international finance, public-private partnerships,
(v) blended finance to mitigate investment risks and enhance municipalities credibility as borrowers,
(vi) own-source revenue mobilization, and
(vii) sub-sovereign credit ratings (Granoff et al. 2016; Floater et al. 2017; Gorelick 2018; White and Wahba 2019).

Moving from the dominant view of finance, profit-oriented model, by capturing economic, social, fiscal, ecological value into account is critical (Sandberg 2015; Foxon et al. 2015). Further, the discussion requires shifting away from 'project-based' urban climate financing towards public policy, government institutions and development choices that can shift private and public capital resources towards impactful infrastructure investment (Granoff et al. 2016; Cook and Chu 2018; White and Wahba 2019).

Urban climate finance gaps

It should be noted that different countries have different arrangements for the level of government responsible for infrastructure and climate investment, and often designing and arranging infrastructure are done at the national level with minimum understanding of urban finance and contexts. Coherent and standardized approaches for urban emission sectors when available can create opportunities to reduce methodological, monitoring and institutional complexity (Padigala and Kraleti 2014). Strengthening government oversights are critical to ensure effective public-private partnerships (Almarri and Blackwell 2014; Granoff et al. 2016; Ko and Górka 2016; Zhan and Jong 2018).

Gaps between wealthy and poorer nations and cities are prominent in research and policy debates about urban climate finance and investment (White and Wahba 2019; CPI 2019). Different challenges associated with wealthy and poorer countries and cities are compounded into three main issues: (i) scarcity and access of financial resources (Bahl and Linn 2014; Colenbrander et al. 2018b; Cook and Chu 2018; Gorelick 2018), (ii) the level of implication from the existing distributional uncertainties to the current financing of infrastructural decarbonization across carbon markets (Silver 2015), and (iii) the policy and administrative ambiguity in urban public finance institutions (Cook and Chu 2018). In poorer countries, these differing features continue to be inhibited by contextual characteristics of municipal finance, including gaps in domestic and foreign capital (Meltzer 2016), mismatch between investment needs and available finance (Gorelick 2018), poor financial autonomy, fiscal status and creditworthiness (Bahl and Linn 2014), lack of diversified funding sources and stakeholders (Zhan and Jong 2018; Zhan et al. 2018; Gorelick 2018), and weak enabling environments (Granoff et al. 2016).

Given the urban climate finance nested within broader municipal finance and that cities pursue climate actions that fit with their existing political, institutional contexts and vulnerabilities (Anguelovski and Carmin 2011; Silver 2015; Koppenjan 2015; Colenbrander et al. 2018a; Hadfield and Cook 2018), critical aspects of urban climate financing gaps rely on addressing the larger development investment gaps and the governing of development regardless the level and context of development (UNEP FI 2014; Martinez-Fernandez et al. 2015; Farid et al. 2016). A great deal of research has already been conducted on urban climate finance in the domain of conceptual underpinning and financial mechanisms (Liu and Salzberg 2012; Braun and Hazelroth 2015; Kościelniak and Górka 2016). However, only few elaborate successful innovative urban climate finances from the broader perspective of public policy, government institutions and development choices that can enable conditions and reduce barriers for innovative financing activities in different development context (Padigala and Kraleti 2014; Colenbrander et al. 2018a; Cook and Chu 2018 ; Zhan and Jong 2018; White and Wahba 2019). Arguably, this is due to tendency of climate finance to focus on technical matters which inspire more of the design of mechanisms rather than the policy and institutional practices and relations.

Climate investment and finance for communities

As for community finance, the literature is very limited, and there is a lack of evidence that which financing schemes contribute to climate change mitigation and adaptations at community levels. Existing white literature focuses on finance for rural communities in developing countries, with a focus on climate change adaptation and agriculture sector, and microfinance and remittance schemes. With regard to the microfinance, there is growing interest in the linkages between microfinance and adaptation in the literature, and many of the literature focus on agriculture sector (Agrawala and Carraro 2010; Fenton et al. 2015; Chirambo 2016; Dowla 2018; Climate Investment Funds 2018), however the limits to which microfinance can facilitate adaptation are unknown, and also although microfinance institutions are vulnerable to climate change, little evidence exists regarding the extent to which internal climate-proofing operations of microfinance institutions has taken place (Fenton et al. 2015). Also, there is literature on the relations between remittances and adaptation, which remittances can be both a weakness created within the vulnerability context and a strength that enables to cope with and recover from shocks (Le De et al. 2013).

In addition, in the adaptation context, there is discussion in the literature on the finance for community-based adaptation actions (Sharma et al. 2014; Fenton et al. 2014). However, there is a lack of literature in linking community climate change mitigation and adaptation actions and various financing instruments, such as community development credit, community development loan/venture capital, local financing through cooperatives, impact investment, and public-private community partnership.

With regard to mitigation, there is less discussion on community finance for mitigation compared with adaptation. Carbon offsetting schemes and REDD+ finance allocate very limited finance/benefits to local communities. Carbon offsetting schemes and REDD+ finance frequently receive concerns that the schemes may provide negative impacts to local communities (Blum and Eva 2019, Wong et al. 2019).

Implications for transformation pathway

There are inherited costs of transformation from conventional towards low-emission, climate-resilient infrastructure (Parry et al. 2009; Hughes et al. 2010; Martinez-Fernandez et al. 2015). For cities, these costs include social and economic externalities (e.g., mismatch between autonomy and obligations), urban planning (e.g., Dilemma between urban service provision vs low carbon urban growth), regulatory and financial instruments (e.g., bias towards projects with quick cash flows generation), and project implementation mechanisms (e.g. inability to scale up projects leading to high transaction cost for the project making (Ellis and Kamel 2007; Parry et al. 2009; Cook and Chu 2018). Literature recognise that in many cases, climate financial planning systems need to be sensitive to shadow systems influencing organizational ability to translate adaptive capacity into actions (Leck and Roberts 2015; Colenbrander et al. 2018a) that can exacerbate the cost of transformation or hinder the transformation, including increasing local discretion and downwards accountability (IPCC 2013) and continuing political injustice (Barrett 2013). Deepening understanding of the differing responsibilities among and within cities and communities and design of policy and institutional practices and relations are needed to reduce negative implications of transformation pathway where prevailing modes of development create additional burden to disadvantaged groups (Steele et al. 2015).

15.6.6 Climate-risk pooling and insurance approaches

Since 2000, the world has been experiencing significant increase in economic losses and damages from natural disasters and weather perils such as tropical cyclones, earthquake, flooding and drought. Total global estimate of damage is about 4,210 billion USD (Aon Benfield UCL Hazard Research Centre 2019). The largest portion of this is attributed to tropical cyclones (1,253 billion USD), followed by flooding (914 billion USD), earthquakes (757 billion USD) and drought (approximately 372 billion USD, or about 20 billion USD per year losses) (Aon Benfield UCL Hazard Research Centre 2019). Other perils calculated in the total include severe weather, wildfires, EU-windstorms. In the period 2017–2018, natural catastrophe losses total approximately 219 billion USD (Bevere 2019). The US alone experienced 4,000 tornados, hails, straight-line winds in 2019 (Insurance Journal 2019). And, according to the National Oceanic and Atmospheric Administration 14 weather and climate disasters cost 91 billion USD in 2018 (NOAA NCEI 2019). The European Environment Agency reports that 'disasters caused by weather and climate-related extremes accounted for some 83% of the monetary losses over the period 1980–2017 for EU Member States (EU-28) and that weather and climate-related losses amounted to 426 billion EUR2017[8], (EEA 2019). Asia Pacific has been particularly impacted by typhoon and flooding (China, India, the Philippines) resulting in economic losses of 58 billion USD, 2000–2017 and combination of flooding typhoon and drought totalling 89 billion USD in 2018 (Aon Benfield UCL Hazard Research Centre 2019). Based on past historical analysis, a region such as the Caribbean, which has experienced climate-related losses equal to 1% of GDP each year since 1960 is expected to have significant increases in such losses in the future leading to possible upwards of 8% of projected GDP in 2080 (Commonwealth Secretariat 2016). In 2017–2018, a few of the islands of the Caribbean Antigua and Barbuda, the Bahamas and Dominica and were devastated by tropical cyclones and hurricanes that destroyed infrastructure. 'The World Bank estimates Dominica's total damages and losses from the hurricane at 1.3 billion USD or 224% of its Gross Domestic Product (GDP)' (WMO 2019). Similarly, Latin America countries, such as Argentina, El Salvador and Guatemala, experienced severe losses in agriculture totalling about 6 billion USD due to drought (Aon Benfield UCL Hazard Research Centre 2019). In the African region, where climate change is projected to get significantly warmer, continuing severe drought in parts of east Africa Tropical and Cyclone Idai, had devastating economic impacts on Mozambique, Zimbabwe and Malawi (WMO 2019). According to Munich Re, loss from about 100 significant events in 2018 for Africa are estimated at 1.4 billion USD (Munich Re 2019).

[8] For the EEA member countries (EEA-33), the 'total reported economic losses caused by weather and climate-related extremes' over the period 1980–2017 amounted to approximately 453 billion EUR2017 (EEA 2019).

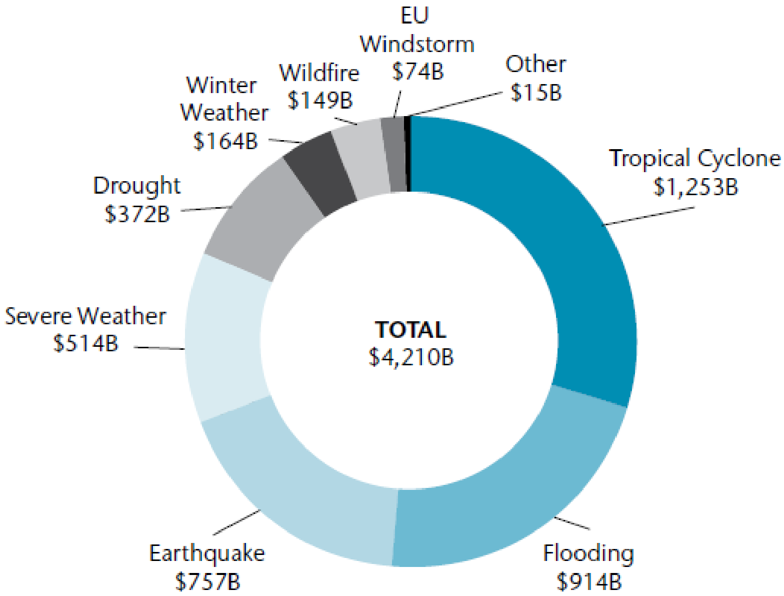

Figure 15.15 Aggregate economic losses, by peril since 2000

Note: All numbers in billion USD, aggregated since 2000. Total 4,210 billion USD.

Source: Weather, Climate and Catastrophe Insight (AON 2019).

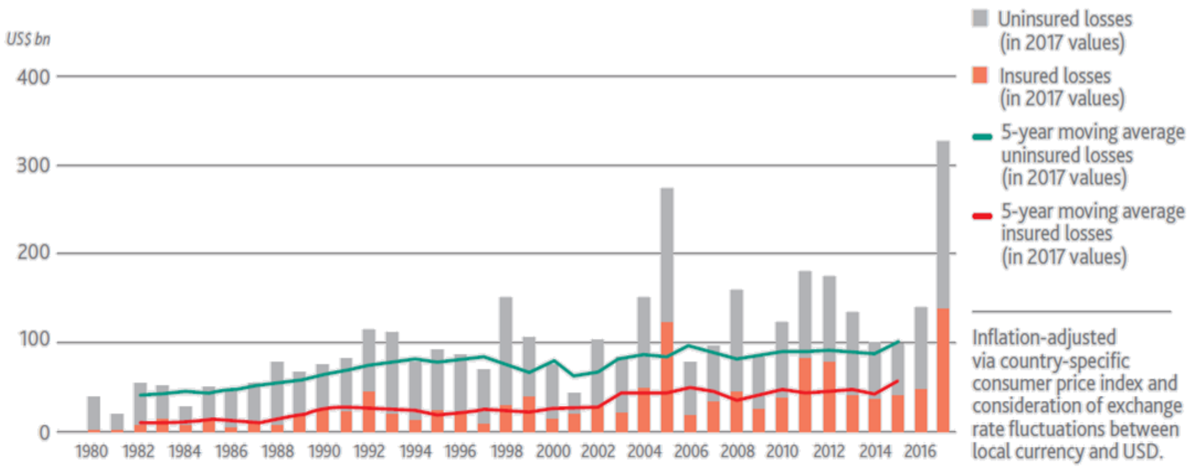

Figure 15.16 Yearly global weather-related loss events, by insurance type (1980-2017)

Note: Uninsured and insured loses with 5-year moving average show that overall, loss volumes are on the rise and volatility is increasing. Values in billion USD2017.

Source: Munich Re (2018) in the Report: Managing Physical Climate Risk: Leveraging Innovations in Catastrophe Risk Modelling (The Geneva Association 2018).

Individual, households, communities, business and national governments can seek to manage climate risk with a variety of insurance products. While there are questions about the sufficiency of insurance products to address the losses and damages of climate-related disasters, it is generally agreed that insurance can help to cover immediate needs directly, provide rapid response and transfer financial risk in times of extreme crisis (GIZ 2015; Kreft and Schäfer 2017; Lucas 2015; Martinez-diaz et al. 2019; Matias et al. 2018; Schoenmaker and Zachmann 2015; EEA 2019b; Broberg and Hovani 2019; Hermann et al. 2016; UNECA 2018; UNESCAP 2017; Wolfrom and Yokoi-Arai 2016).

The traditional approach to such protective or hedging position has been indemnity and other classical insurance micro, meso and macro level schemes (Hermann et al. 2016). These include micro insurance schemes such as index insurance and weather derivative approaches that cover individual's specific needs such as coverage for farm crops. Meso level insurance schemes, which primarily benefit intermediary institutions, such as NGOs, credit union, financial institutions and farmer credit entities, seek to reduce losses caused by credit default thereby 'enhancing investment potential', whereas macro-level insurance schemes 'allow both insured and uninsured individuals to be compensated for damages caused by extreme weather events' (Hermann et al. 2016). These macro-level insurance include catastrophe bonds and weather derivatives etc. that transfer risk to capital market (Hermann et al. 2016). Over the last decade, there have been growing resort to parametric insurance, index-based, predefined pay-out risk pooling instrument as a preferred insurance approach, especially for developing countries. It has gained favour with governments in the developing regions such as Africa, the Caribbean and the Pacific because it provides certainty and predictability about funding - financial preparedness - for emergency actions and initial reconstruction and reduces moral hazard. This 'financial resilience' is also increasingly appealing to the business sector, particularly MSMEs, in developing countries.

To date, sovereign parametric climate risk pooling as a way of managing climate risk does not seem to have much traction in developed countries and does not appear to be attractive to actors in the G-20 countries. No G-20 members are yet party to any climate risk pooling initiative (Kreft and Schäfer 2017). However, international donors such as the USAID, DfID, BMZ-the German development ministry, Agence Francaise de Development, SIDA, EC, Japan's International Cooperation Agency, International and regional development banks, the World Bank Group, Asian Development Bank, the African Development Bank, the Caribbean Development Bank and the European development bank, are all, to different extent, supporters of the various climate risk pooling initiatives now operational in developing countries.

As noted also in IPCC AR5, risk sharing and risk transfer strategies provide 'pre-disaster financing arrangements that shift economic risk from one party to another' (IPCC 2012). Risk pooling among countries and regions is advantageous when compared to conventional insurance because of the effective subsiding of 'affected regions' using revenues from unaffected regions which involve pooling among a large subset of countries (Lucas 2015). In general, the premiums are less costly than what an individual country or entity can achieve (Lucas 2015: World Bank 2014) disbursement is rapid and there are also fewer transaction costs. The World Bank argues that experience with PCRIP and ARC show saving of 50% in obtaining insurance cover for pooled risk compared with purchasing comparable coverage individually (World Bank 2014; African Risk Capacity 2016; Lucas 2015). However, it requires, as noted by UNESCAP, 'extensive coordination across participating countries, and entities' (Lucas 2015).

At the same time, this approach is not risk proof as there is substantial basis risk, (actual losses do not equal financial compensation) (Hermann et al. 2016). Pay-out are pre-defined and based on risk modelling rather than on the ground damage assessment so may be less than, equal to, or greater than the actual damage. It does not cover actual losses and damage and therefore, may be insufficient to meet the cost of rehabilitation and reconstruction. It may also be 'non-viable or damaging to livelihood in the long run (UNFCCC 2008; Hellmuth et al. 2009; Hermann et al. 2016). Additionally, if the required threshold is not met, there may be no pay-out, though a country may have experienced substantial damages from a climatic event. (This occurred for the Solomon Islands in 2014 which discontinued its insurance with the Pacific Catastrophe Risk Insurance Pilot when neither its Santa Cruz earthquake nor the 2014 flash floods were eligible to receive a pay-out under the terms of the insurance (Lucas 2015)).

The growth of risk pooling is paralleling the increased risk awareness and the consequential move by governments towards a more proactive, integrated approach to climate and weather impacts (The Geneva Association 2018). This has noted by the Geneva association include:

- Risk assessment, underpinning causes of risks, risk awareness
- Risk reduction and prevention
- Financial planning, risk financing and risk transfer
- Resilience building through better reconstruction post-event

Increasingly, climate risk insurance scheme is being blended into disaster risk management as part of a comprehensive risk management approach. The best-known example is the Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC 2018), which involves cooperation among Caribbean states, Japan, Canada, UK and France and international organizations such as World Bank (UNESCAP 2017). But there are growing platforms of such an approach including, the Pacific Catastrophe Risk Assessment and Financing Initiative) for the Pacific Islands, the African Risk Capacity and the African Risk Capacity Insurance Company Limited (African Risk Capacity 2016) and in the Asian region, the South East Asian Disaster Risk Insurance Facility (SEADRIF) and the ASEAN Disaster Risk Financing and Insurance Program (ADRFI).

However, as noted above, climate risk pooling is not a panacea. They have very obvious and significant challenges. According to (Kreft and Schäfer 2017), limitations of insurance schemes, include:

- The challenges of coordination;
- The possibility that the value of the premium, which is a function of risk exposure, could rise faster than a government's ability to pay for the premium, which in turn could destabilize a regional scheme should a country be forced to exit;
- Most of the existing arrangements outside of the UNFCCC are targeted at disaster risk management in relation to present climate variability and related extreme events and not at responding to the impacts of anthropogenic climate change due to for example, human-induced changes in extreme events, climate variability, sea-level rise and storm surge increases and ocean acidification (Schaeffer et al. 2014);
- The fragmented approach of the international arrangements outside of the UNFCCC falls far short of providing the African continent with the coordination, consistency, scale, funding, capacity and technology that is needed to bridge the existing gaps (Schaeffer et al. 2014);
- The existing international arrangements do not address permanent losses and non-economic losses, and losses from sudden and slow-onset events are only partially addressed (Schaeffer et al. 2014).

There are also challenges with risk diversification, replication and scalability. For example, CCRIF is extending both its membership and diversifying its geographic dimensions into Central America as part of seeking to lower covariate risk. (See Case study below). Risk insurance does not obviate from the need to engage in capacity building to scale-up as well as having process for addressing systemic risk. Currently, risk pools have limited sectoral reach and may cover agriculture but not other important sectors such as fisheries and public utilities. Others, the like CCRIF only cover a small subset of perils, such as tropical cyclone, earthquake and excess rainfall but do not include other perils such as drought. In some regions and countries, there may also be limited access to reinsurance (Lucas 2015; Schaeffer et al. 2014).

An important down-side of climate risk pooling is that it does not cover the actual cost of damage and losses. Though on the positive side, pay-out may exceed costs, but it may also be less than cost. Hence, the parametric approach is not a panacea and does not preclude having recourse to traditional indemnity insurance, which will cover full damage costs after a climate change event as it involves full on the ground assessment of factors such as the necessity and costs of repair versus say replacement value of damaged infrastructure. This may be important for governmental and publicly provided services such as schools, hospitals, roads, airports, communications equipment and water supply facilities.

Given the success of parametric insurance and climate risk pooling, there are very ambitious attempts to expand this approach on several fronts. (Schoenmaker and Zachmann 2015) have proposed a global climate risk pool to help the most vulnerable countries (Schoenmaker and Zachmann 2015). The pathway to this includes capacity building in underdeveloped financing sectors of developing countries. They argue that as climate extreme become more normalized, they will wipe out significant part of the infrastructure and productive capacity of developing countries. This will have knock-on impact on fiscal capacity due to lowered tax revenue and high rebuilding costs. 'Developing countries, Schoenmaker and Zachmann argue, 'cannot insure against such event on a market basis, nor would it be sensible to divert scare fiscal resources away from infrastructure investment into accumulating a financial buffer for such a situation (Schoenmaker and Zachmann 2015). In that context, Schoenmaker and Zachmann call for international risk pooling as the only sensible strategy. The proposed global risk pool can build on the experiences of regional insurance pool such as ARC and CCRIF SPC and PCRAF. The premium they argue should be partly based on a country's carbon footprint to provide an incentive for mitigation—the 'polluter pays' principle.

Along the same line, the insuResilience Global Partnership vision 2020 (June 2019) seek to strengthen the resilience of developing countries and protect the lives and livelihoods of poor and vulnerable people from the impacts of disaster by enabling a substantial scale-up in the use of climate and disaster finance and insurance solutions and approaches by developing countries (InsuResilience 2019). Two of the six metrics for the partnership include increased cost-effectiveness/value for money of the risk-finance and insurance arrangements and 'increase in evidence relating to the most effective and most cost-efficient climate and disaster risk finance insurance' (CDRFI) solutions (InsuResilience 2019).

Kreft and Schäfer (2017) offer a three-step process for how the G20 can cement their agenda in advancing risk pooling instruments. They propose that the group: First, work to address the major gaps in climate risk insurance for poor and vulnerable communities. Second, work to enhance demand through 'smart support instrument' for premium support. Third, develop a principle-based approach to climate risk that drives an action plan as well as stimulate a global partnership on climate risk insurance.

The major gap that is seen in climate risk instruments is partly due to the limited uptake of regional institutions such as ARC, CCRIF SPC which are only in three regions of the world (with missing mechanism in South America, and not very utilized in many G-20 countries, where individual risk pool may exist. They point out that no G-20 country is a member of a regional risk pool. Additionally, the existing regional mechanisms, while they perform very well, only cover a portion of climatic hazards (such as ARC – drought, others extreme rainfall).

Other gaps and challenges flagged by Kreft and Schäfer (2017b) include limited coverage of the full spectrum of contingency risks experienced by countries, inadequate role of risk management as a standard for all regional pools, though there are some emerging best practices in terms of data provision on weather-related risks, and incentivisation of risk reduction. Here, they recognize the work of ARC's Africa Risk view for not only providing the infrastructure to trigger disbursement but for also promoting national risk analysis. They also point to achievement of the CCRIF in successfully establishing itself as regional risk managing entity. Another important gap in the landscape of climate risk pooling is the missing focused and expanded attention to financial institutions' lending portfolio that they argue is vulnerable to weather shocks. Kreft and Schäfer (2017) argue that subsidies as part of innovative financing schemes facilitated by the donor community can encourage the uptake of meso-level climate risk insurance solutions (Kreft and Schäfer 2017).

Current state of the art in climate risk pooling, as noted by Kreft and Schäfer (2017) and the Vulnerable group of 20 states, have the challenge of dealing or not dealing with covariant risks hence 'primary insurers, individual and governments (especially in small states) may need to rely more on multi-regional and global pooling mechanism' (Kreft and Schäfer 2017). Current risk pooling mechanisms also face the challenge of lack of capacities to adequately engage at country-level and to develop technologies (such as access to satellite-based information) to facilitate a more comprehensive understanding of parametric insurance among clientele. They also suffer from inadequate financing to keep their products available. This calls for a 'strategic approach in how to bridge existing funding gaps and secure long term funding' (Kreft and Schäfer 2017).

Case Study: The Caribbean Catastrophic Risk Insurance Facility (CCRIF)

The CCRIF Segregated Portfolio Company (SPC) was the first multi-national parametric catastrophic insurance instrument. It is a not-for-profit risk pooling facility with a segregated portfolio owned by and operated for Caribbean governments, which offers parametric insurance against earthquakes, cyclones, and excess rainfall. Participating country pay an annual premium to purchase coverage of up to approximately 100 million USD for each insured hazard. Pay-outs are based on loss model and are triggered when the magnitude of hazards equals or exceeds predefined levels (CCRIF SPC 2015). It models the damage to physical infrastructure and damage estimate incorporate the effect of wind, storm surge and wave action.

Since 2015, it also supports Caribbean and Central American governments by quickly providing short-term liquidity when a parametric insurance policy is triggered. CCRIF was developed under the technical leadership of the World Bank and with a grant from the Government of Japan. According to CCRIF's Annual report, the institution's financial sustainability remains intact even after 2017–2018 record-breaking year in terms of pay-outs. CCRIF SPC met its targets for probability of default (0.01%), minimum claims-paying capacity and financial strength of reinsurers and bondholders (at least an A-rating). CCRIF SPC's total capital at risk for 2017/2018 comprised the retention of 35.65 million USD within the risk transfer programme and a further - 42 million USD above the reinsurance programme up to the 1-in-1,000-year loss of - 205 million USD. The claims-paying capacity of CCRIF for the 2017/2018 policy year was thus significantly greater than the modelled aggregate annual loss with a 1-in-1,000 year chance of occurring, thus comfortably falling within CCRIF's guidelines for financial security and it was substantially better than any of its peers in either the public or private sectors (CCRIF SPC 2018). CCRIF is also seeking to expand its sectoral coverage to include fisheries and public utilities as well as expand its coverage of perils to include drought.

Case Study 2 (optional): The African Risk Capacity

The African Risk Capacity (ARC) is a specialized agency of the Africa Union (AU). It was set up in established to help African governments improve their capacities to better plan, prepare, and respond to extreme weather events and natural disasters. The ARC is comprised of two entities: the African Risk Capacity Agency and the ARC Insurance Company Limited. It is hence a sovereign risk pool and mutual insurer which provide early warning, contingency planning and climate finance to its members. It is also a hybrid mutual insurer ad financial agency that performs risk pooling/ insurance underwriting and asset management function for its members. Unlike CCRIF SPC and PCRIF, 'ARC's initial product offering and the first parametric insurance product for drought in the world, the drought risk model and insurance product has helped African governments quantify their drought risk and respond early to the impacts of drought events'. ARC is also pioneering the development of a risk model and parametric insurance product for river floods. The index-based insurance product as the first of its kind globally to respond to the disruptive impacts of river floods on African livelihoods and economies (e.g. African Risk Capacity 2019). ARC is developing the Extreme Climate Facility (XCF), a data-driven, multi-year, insurance-like vehicle that will provide financial support to eligible AU countries based on a multi-hazard index. XCF will be a mechanism for African states to access financing to respond to the impacts of increased climate volatility (African Risk Capacity 2016).

Case Study 3 (optional): Loan Portfolio Coverage (LPC)

LPC is a meso-level risk transfer climate risk insurance solution aimed at financial institutions. A Munich climate insurance initiative, it is a parametric insurance policy designed to protect loan portfolios from climate shocks and eventual loan default and help financial institutions to manage their credit risk better. Participating institutions can select the level of insurance cover to be applied to their overall exposed loan portfolio. A pay-out is triggered when predetermined threshold values for wind speed and/or rainfall are exceeded, irrespective of any proven loan default the financial institution may have suffered. This enables stability of the financial position of the institutions after an extreme weather event so that they are able to continue at a minimum their pre-crisis level of lending activity as well as terms of lending.

15.6.7 Facilitating the development of new business models

This section focuses on new finance and business opportunities in the two areas, nature-based solutions and gender considerations that are difficult to attract climate investment and finance.

New finance and possible business model for nature-based solutions including REDD+

First is the discussion on finance and business opportunities for nature-based solutions. Nature-based solutions are considered to be cost-effective climate change mitigation and adaptation options that are able to produce multiple benefits (i.e. environmental, economic and social benefits). In order to enhance and sustainably implement the nature-based solutions, attracting a wide range of finance and investment, especially private finance will be the key, since existing public finance does not meet the finance needs. However, because of the nature of nature-based solutions, they have difficulty in attracting private finance, and existing finance and investment structures do not meet the finance needs of nature-based solutions.

Concept of the nature-based solutions is still new, and studies on the finance for the nature-based solutions is still very limited. However, finance for one of the nature-based solutions, the reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) has already been actively discussed under the UNFCCC, and this section also draws the lessons from finance for REDD+.

15.6.7.1 Nature-based business models

Nature-based solution is a new concept, and academic literature has started to use this concept recently. There is no single definition for this concept, however, the following two are the major explanation for the nature-based solutions. The International Union for Conservation of Nature (IUCN) defines it as ‘actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al. 2016)‘, while European Commission defines, and ‘living solutions inspired by, continuously supported by and using Nature designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social and environmental benefits (Maes and Jacobs 2017)". Nature-based solutions include ecosystem restoration approaches, issue-specific ecosystem-related approaches (e.g. ecosystem-based mitigation and adaptation), infrastructure-related approaches (e.g. green infrastructure), ecosystem-based management approaches, and ecosystem protection approaches (Cohen-Shacham et al. 2016).

If effectively implemented, nature-based solutions can be cost-effective measures and able to provide multiple benefits, such as enhanced climate resilience, enhanced climate change mitigation, biodiversity habitat, water filtration, soil health, and amenity values (Griscom et al. 2017; Keesstra et al. 2018; OECD 2019d). Natural climate solutions can provide 37% of cost-effective CO_2 mitigation needed through 2030 to stabilize global temperature rise below 2°C, and one-third of this cost-effective mitigation can be delivered at or below 10 USD $MgCO_2^{-1}$ (Griscom et al. 2017). Nature-based solutions can enhance mainstreaming of environmental targets into sectors in policy, business and practice, and also foster innovative planning and governance, new models for business, finance, institutions and wider society, and also can contribute in accelerating social innovation in cities and the transition to sustainability (Nesshöve et al., 2017; Faivre et al. 2020). Existing literature shows that nature-based solutions can contribute to achieve more sustainable and resilient urban/cities, and provide some conditions or framework that guide the implementation of nature-based solutions in cities (Raymond et al. 2017; Lafortezza and Sanesi 2019; Bush and Doyon 2019; Frantzeskaki 2019). Although the nature-based solutions have large potential to address climate change and other sustainable development issues, existing finance and investment do not meet the needs, for example, land-based sequestration efforts receive only about 2.5% of climate change mitigation finance (Griscom et al. 2017). More finance and investment is required to implement nature-based solutions (Wamsler et al. 2019). Since relying on grants are not able to cover full financing needs of the activities of nature-based solutions for long-term, finance and investment models that generates its own revenues or consistently saves costs over time are necessary (Schäfer et al. 2019).

REDD+

Agriculture, forestry, land use and land use change sector (AFOLU) accounted for 24% of global greenhouse gas emissions in 2010 (IPCC AR5). In nature-based solutions, especially forest-related activities are important. Forest-related activities account for 68% of total carbon mitigation potential of natural climate solutions, and forest conservation and avoided deforestation and degradation are immediate climate change mitigation options (Guarnaschelli et al. 2018).

Finance is required to implement sustainable forest management that contributes to climate change mitigation and other co-benefits. REDD+ which mechanism has been developed under the UNFCCC, can be considered as an innovative and a cross-sectoral form of sustainable forest management financing (Singer 2016). If well-implemented, REDD+ can significantly contribute to climate change mitigation and also produce other co-benefits like climate change adaptation, biodiversity conservation, and poverty reduction (Morita and Matsumoto 2018). Since AR5, active discussion on financing mechanisms for REDD+ and analysis on challenges and opportunities of REDD+ financing have been made in the literature.

REDD+ and its finance have unique characteristics. REDD+ uses a phased approach to implement REDD+ which are Phase 1 Readiness, Phase 2 Implementation, and Phase 3 Results-based finance. There is no formal consensus on what REDD+ finance is and there are various financial sources currently providing funding for activities within the three phases of REDD+, including bilateral and multilateral, public and private, and international and domestic financial sources (Lujan and Silva-Chávez 2018). Finance for REDD+ can be levied through different mechanisms, but currently, major funding comes from public sources (Singer, 2016, Well and Carrapatoso, 2017). 1.4 billion USD in targeted REDD+ finance (cumulative since 2010), combined with the expectation of results-based payments for emission reductions, has motivated more than fifty countries to make REDD+ a priority of their national forest policies, and many of their countries have strengthened their capacities, established policy dialogues, and developed strategies to reduce forest emissions (The New York Declaration on Forest 2017).

However, more finance is essential to enhance the REDD+ implementation, since public finance for REDD+ is limited, and there is no adequate, predictable and sustainable finance for REDD+. Most REDD+ initiatives aim for leveraging private funding, however, few have been successful in integrating private finance in support of government programs, and attracting private finance (The New York Declaration on Forest 2017). Further, private funding of REDD+ projects is currently limited mostly to the voluntary carbon market (McFarland 2015).

Current challenges of REDD+ finance include institutional fragmentation (limited coordination in REDD+ financing, both the supply side and demand side; and the weak link between international funding and local implementation), and lack of predictable and funding for REDD+ (limited REDD+ funding including limited readiness funding and private sector engaging with funding REDD+, small group of funders dominate international REDD+ funding), and uncertainty in effectiveness of the use of REDD+ finance (REDD+'s results-based payment approach does not guarantee an effective REDD+, and limited finance is allocated to local actions) (Well and Carrapatoso, 2017, Recio, 2019, McFarland, 2015; Atmadja et al. 2018; Lujan and Silva-Chávez 2018; Lund et al. 2017; Wong et al. 2019; Pinsky et al. 2019).

Although the private sector has been engaging with funding REDD+, there is a number of reasons that makes difficult to engage more private sector in REDD+ finance. One is the risks and factors necessary to create an enabling environment for private sector investments in reducing deforestation in many developing countries have yet to be sufficiently explored including carbon rights, tenure security, and law enforcement (Lujan and Silva-Chávez 2018; Atmadja et al. 2018). The challenge of private sector developers is the insufficient commercial return for forest-based NDC activities and the inability of current carbon prices to close the gap, and as for the government side, the challenge is that forest-based NDC activities have lower economic returns and come at greater fiscal cost than business as usual over the short-to-medium term (World Bank 2017d). Second is some characteristics of REDD+ makes difficult to involve private sector, such as the evolution of REDD+ to focus on national approaches has discouraged projects (project approach) that some private sector actors are familiar with (Lujan and Silva-Chávez 2018); the majority of benefit-sharing mechanism-based REDD+ projects have been implemented deviate from the market-based incentive model but they adopted more command-and-control subsidies that ignore the fact that different types of costs are distributed among multiple stakeholders (Sheng et al. 2019). Third is the challenges related to forest carbon certification such as non-permanence risk and carbon debt (storage of carbon in forest biomass and soil is reversible and permanence of the climate change mitigation benefit cannot be fully guaranteed; forestry projects are unable to deliver carbon credits within a year after beginning the projects like other types of projects such as in energy and agriculture sectors, and in the kick-off period may entail an initial carbon debt that can take decades to be offset by enhanced tree growth and fossil fuel substitution) and monitoring uncertainty and costs (monitored values include the uncertainty and may differ from the real values, and also more precise monitoring may be costly) (Grimault et al. 2018). Fourth is the challenges of supply side of sustainable landscape investment opportunities, investment opportunities on the ground rarely meet the financial requirements of commercial investors, especially when technical assistance, monitoring and enforcement of environmental standards increase costs of the transition to more sustainable production (Rode et al. 2019).

There are no great solutions for adequate, predictable and sustainable REDD+ finance but the promising ways of supporting REDD+ are building new blended finance models combining different funding sources like public and private finance (Streck 2016; Rode et al. 2019). Since direct, non-performance based payments schemes do not ensure sufficient investment to achieve the results for which payments would be made, enhanced bonds (which seek to use performance-based payment for future mitigation performance to attract upfront private capital toward forest-based NDC activities at a larger scale than might be achieved through currently available financing instruments) can be one of the possible blended finance instruments for catalyzing forest-related NDC actions (World Bank 2017d).

Private finance opportunities for nature-based solutions

Nature-based solutions, including REDD+ are probably one of the most difficult sectors to attract private finance. However, the demand of establishing new finance and business models to attract both public and private finance to nature-based solutions is increasing, not only under the concept of finance for nature-based solutions and REDD+, but also under the similar concepts like landscape finance and conservation finance. Mobilizing private capital through blended finance is essential to unlock the market opportunities in this field (Guarnaschelli et al. 2018).

The factors that are necessary to build new finance and business models in this field include: coordination between public investors and more direct link between public funding and private investments; a deeper mutual understanding between investors and providers of projects (to enable the scalability through addressing the geographically and topically fragmented investment vehicles or products offered to financial markets and ecosystem-related cash flows into which funds are invested, and also the mechanisms to ensure measurable and verifiable financial and conservation impacts); and commercial support for early-stage project ideas with scale-up potential (Credit Suisse Group AG, WWF, and McKinsey Center for Business and Environment 2014; Guarnaschelli et al. 2018).

'START BOX 15.7. HERE'

Box 15.7 The role of fintech

The internet revolution spurred an increase in electronic transactions via mobile devices, resulting in lower financial transaction costs achieved through economies of scale (Lee and Shin 2018). Financial technology or 'fintech' applies to innovative data-driven technological solutions and aims to improve financial services (Dorfleitner et al. 2017; Schueffel 2016; Lee and Shin 2018). From a climate perspective fintech can support new business models that address multiple financial topics, with both opportunities and challenges. Driven by the shared economy, applications of fintech are evolving rapidly. Behind the large set of, for example, mobile payments or registries for collateral, digital transactions are ensured by security systems such as digital identities (van der Lugt 2019; Nassiry 2018).

Blockchain is a highly discussed technology for securing individual transactions and has many applications with high impact potential but is also associated with high uncertainty (World Energy Council 2017). Using smart contract encryption methodology blockchain technology can guarantee the authenticity and traceability of sustainable financial products (Cen and He 2018). Potentially, it can remove the need for trusted intermediaries such as banks (Nassiry 2018) and therefore limit the power to local elites (Schmidt and Sandner 2017). In the energy sector, blockchain applications could have potential implications for centralized generation and grid distribution (Nassiry 2018) and for synthesizing across a patchwork of emission-related data (Sachs et al. 2019).

In Table 1, applications and examples are clustered to relevant climate change issues, including several broad applications across energy and finance.

Box 15.7, Table 1 Clustered fintech applications with regard to climate change

Sustainable development	Electricity and renewable energy applications	Carbon credits	Financial instruments
Tracking assets in the supply chain transparency across sectors such as forestry, fisheries, or energy (Nassiry 2018)	Electric power system applications using blockchain for peer-to-peer and grid transactions, energy financing, sustainability attribution or electric vehicles (Livingston et al. 2018)	Accounting of emissions from the project level throughout the value chain across regional levels and commodity markets (Sachs et al. 2019).	Green Asset-Backed-Securities (ABS) applications that attract large institutional investors, and the use of cryptocurrencies as a financial currency by the use of distributed ledger technology applications (Knuth 2018).
Credit scoring, using, for example, mobile phone and payment histories, to expand access to credit for farmers or loan applicants in other sectors (Davidovic et al. 2019)	Renewable energy and distributed energy applications such as peer-to-peer energy transactions, carbon credits, and climate finance (Livingston et al. 2018)	Supporting formation and liquidity of carbon emission reduction trading markets (Cen and He 2018).	Supporting transparency for green bonds and green financial instruments to facilitate continued momentum in market growth (Kyriakou et al. 2017). For instance, using blockchain to secure transactions, verifying green uses of proceeds (Stockholm Green Digital Finance 2017).
Digital insurance for agricultural crops can support farmers to build resilience to weather-related shocks (Kramer and Ceballos 2018)	PAYG systems target a decentralized electricity market. New technologies can distribute resources, utilities, flexible energy supply/demand, peer-to-peer renewable energy, as well as community distributed energy generation (UNEP Inquiry 2016)	MRV systems using standard units for carbon accounting that supports scalability of large-scale climate projects (Sachs et al. 2019)	Supporting climate-friendly decision-making by institutional investors through new data on the investment value chain, such as sustainability rating schemes for climate-smart infrastructure (van Der Lugt 2019).

Fintech could have transformative potential for sustainable development (UN Environment Inquiry 2017). Innovations in new technologies could accelerate the flow of capital to a more sustainable economy technology and contribute to climate-friendly investments, coupled with the signals from the Paris Agreement and Sustainable Development Goals (Nassiry 2018). This can be aligned with the technology needs in creating effective communications between climate-related markets, addressing the need to generate, manage, and harmonize information on the outcomes of GHG mitigation actions across sectors and government jurisdictions(Sachs et al. 2019). Fintech has the potential to reduce transaction cost further, improve information asymmetry, and make green and sustainable finance more inclusive (Cen and He 2018; Nassiry 2018). The International Energy Agency (IEA 2018 p. 98) has stated: 'Although still early-stage and small-scale projects of this kind suggest that decentralized energy, flexibility from transactive energy and blockchain could develop together to positive effect.' (Nassiry 2018).

Small-to-medium enterprises (SMEs), in particular, can benefit from bypassing traditional finance with fintech solutions that bring entrepreneurs closer to their funders, diversify the types of funding and multiply the channels for allocation – with specific benefits to SMEs in developing countries (UN Environment Inquiry 2017). According to a survey, 25% of SMEs globally have already adopted some kind of fintech service (Ernst and Young 2019).

However, there are also several challenges with Fintech as a sustainable business model. High energy consumption is associated with the decentralized nature of blockchain and its application to secure cryptocurrency ledgers, such as bitcoin, which are used in multiple applications (Mora et al. 2018). According to one study, GHG-emissions are already massive: given that 60% of the most critical and unique bitcoin verification processes go into electricity consumption, bitcoin emits 33.5MTCO_2eq per year (Mora et al. 2018).

Further, blockchain and digital currency applications are not covered by a governance system (Tapscott and Kirkland 2016; Nassiry 2018). This can lead to problems with security (Davidovic et al. 2019) with impacts on the trustworthiness of green financial data or negative implications to the privacy of information for individuals for instance when personal data is used to access creditworthiness. Further changes in licensing and prudential supervision frameworks can impact the emergence of new fintech business models.

'END BOX 15.7 HERE'

15.6.7.2 Gender-responsive climate finance

Global and national recognition of the lack of finance for women has led to increasing emphasis on financial inclusion for women. Currently, it is estimated that 980 million women are excluded from formal financial system (Miles and Wiedmaier-Pfister 2018); and there is a 9% gender gap in financial access across developing countries (Demirguc-Kunt et al. 2018). Thus global financial sector policymakers and regulators have prioritized closing the gender gap in financial inclusion in light of recent evidence that points to engendered sustainable investing as the best way to tackle climate change (Beslik 2018; UN Women 2018; Hawkins 2017). Global governance and development finance institutions have put in place the following initiatives, framework and new models to enhance women's access to finance, including climate finance.

The 2017 G20 Financial Inclusion Action Plan (GPFI) - the G20 Leaders' commitment to advance financial inclusion put the focus on underserved groups, including women (GPFI 2017).

The Alliance for Financial Inclusion (AFI) Denarau Action Plan seeks to increase the number of women with access to quality and affordable financial services globally by 2021 (AFI 2017).

A commitment to mobilize 3 billion USD by 2020 to invest in businesses and funds that contribute to gender equality. Development finance institutions[9] committed to funding women's inclusion in programming to promote gender equality and women's empowerment (2X Challenge 2018).

The concept of a gender dividend is also attractive governments and institutions. 'Gender dividend is the increased economic growth that could be realized with investments in women and girls. […] A gender dividend can flow from lower fertility rates, which reduce women's burden of caring for dependents and free up time for other productive activities, notably formal employment' (PRB 2019). As a result, there is significant upscaling of work gender equality in climate change interventions, including climate finance. Proponents make strong argument that integrating gender into climate finance is not just a matter of equity and inclusion but ensures better decision-making and sustainable

[9] DFIs from Canada (FinDev Canada), France (Proparco), Germany (DEG), Italy (Cassa Depositi e Prestiti – CDP), Japan (JBIC and JICA), the United Kingdom (CDC) and the United States (Overseas Private Investment Corporation - OPIC). The DFIs are hosting an online platform (2xchallenge.org) to publicly track their progress and coordinate efforts made by other 2X Challenge participants. Additionally, 2X Invest2Impact Business Competition. Invest2Impact will provide 100 women-owned SMEs with mentorships, business development services, visibility and the opportunity for funding.

outcomes and results in order to better outreach to vulnerable groups and key actors, particularly with regard to NAPs and NDCs, (Green Climate Fund 2017; Wong 2014).

Since AR5, there remains many questions and not enough evidence on the gender, distribution and allocative effectiveness of climate finance in the context of gender equality and women's empowerment (Wong et al. 2019; Williams 2015 Chan et al 2018). This is despite recent experiences with the distribution and allocation of climate finance by multilateral climate funds such as the CIFs, the GEF, the Adaptation Fund, the Green Climate Fund; multilateral development banks such as the ADB (Adams et al. 2014; African Development Bank; Asian Development Bank; European Bank for Reconstruction and Development; European Investment Bank; Inter-American Development Bank Group; the Islamic Development Bank; World Bank Group; and African Development Bank 2018), and with bilateral and other national flows (Schalatek and Nakhooda 2013; Schalatek 2015; Williams and Williams 2015). Similarly, it is also case, that despite a growing trend of making the 'business case for gender and climate finance', the private sector, both on the corporate side, where there are attempts at making the business case for investing in gender and women's empowerment concerns into private flows, and on the philanthropic and social investment sides, gender is not fully integrated into climate finance (Harris et al 2018; IFC 2017; Miles and Wiedmaier-Pfister 2018). Nonetheless, the existing global policy framework (entry points, policy priorities etc.) of climate finance is gradually improving in order to support women's financial inclusion in both the public and the private dimensions of climate finance/investment (Chan et al. 2018; Schalatek 2015).

At the level of public multilateral climate funds, there have been significant improvements in integrating gender equality and women's empowerment issues in the governance structures, policies, project approval and implementation processes of existing climate funds such as the Climate Investment Funds (Climate Investment Funds 2018b), the Adaptation Fund (Adapatation Fund 2017), the Global Environment Facility (GEF), the CIFs and the Green Climate Fund (Green Climate Fund 2017b; GGCA 2015; Schalatek 2015). However, the integration of gender into operational policies and programme is fragmented and there is lack of an 'adequate, systematic and comprehensive gender equality approach for the allocation and distribution of funds for projects and programme on the ground (Global Environment Facility Independent Evaluation Office 2017; Schalatek 2018). This was the finding of a recent review of GEF projects and programme in its climate change focal here where the review found that 'almost half of the analysed sample of 70 climate projects judged to be largely gender-blind, and only 5% considered to have successfully mainstreamed gender, including in two LDCF adaptation projects' (Global Environment Facility Independent Evaluation Office 2017; Schalatek 2018). While the GCF requires funding proposals to consider gender impact (and include a gender action plan) as part of their investment framework, the fund does not have its own funding stream target to women's project on the ground, nor is there as yet an evaluation has to how implementing entities are actually implementing gender action plan in the projects. In the case of the CIFs, as noted by Schalatek (2018) 'gender is not included in the operational principles of the Pilot Program on Climate Resilience (PPCR), which funds programmatic adaptation portfolios in a few developing countries, although most pilot countries have included some gender dimensions'. And, 'gender is not integrated into the operations of the Clean Technology Fund (CTF), which finances large-scale mitigation in large economies and accounts for 70% of the CIFs pledged funding portfolio of 8.2 billion USD' (Schalatek 2018). However, both the Forest Investment Program (FIP) and the Scaling-Up Renewable Energy in Low-Income Countries Program (SREP) have integrated gender equality as either a co-benefit or core criteria of these programmes (Schalatek 2018). Efforts to promote gender responsive/sensitive climate finance, at national and local levels, both in the public and private dimensions remains deficient.

Private Sector financing and gender: Mechanisms, Instruments, Funds and Processes

At the level of private climate finance and investment, there are some limited attempts to make climate finance instruments such as risk insurance/climate risk management strategy (including index insurance) more sensitive and responsive to gender issues (Harris and Abbott 2018). These include: Gender Lens Investing (GLI)/Gender based social impact investing (SRI)/gender lens portfolio strategy-pink and green bonds etc./Parity portfolio/Matterhorn group and Gender oriented crowdfunding.

Gender (and ESG) screen: Women in leadership (WIL metrics)

Companies with women in leadership outperform cohorts. WIL metric linked to excess stock market returns and to superior corporate profit (Credit Suisse 2016).

The Gender Parity Strategy Parity portfolio - *Matterhorn group/Morgan Stanley*

The Parity Portfolio includes 25 to 35 US-based companies with a minimum of three women on their boards. The strategy also looks at other metrics, such as whether companies have completed a pay equity audit or have a history of gender discrimination or other violations against women). Gender Parity is a US all-cap value portfolio. Morgan Stanley encourages analysis to include gender score in investment analysis. Research (Catalyst, The Committee for Economic Development, Deloitte, McKinsey and Company, Credit Suisse, Ernst and Young, Columbia University, and Pepperdine University, among others), reveals a correlation between gender diversity on corporate boards and/or in senior leadership positions and company financial strength (Matterhorn 2019).

Gender-based (social impact investing) - Gender Lens Investing (GLI): Total 1.3 billion USD in assets. Investors in this stream include institutional investors, private equity/venture capital, and private debt funds. BNY Mellon (5th largest asset management firm worldwide), 2018 State Street global advisers, offer SPDR SSGA gender diversity EFT (Project Sage, n.d.).

Linkage to sectoral climate change issues and gender and climate finance: Energy and the Environment is one of the top three sectors invested by the 58 funds (Chui 2018). These subsectors of action include: divestment from fossil fuels, investment in clean energy, redirecting funds to support women and vulnerable region and insurance for climate risk management. Insurance providers are arguing that 'given the fact that women are disproportionately affected by climate change, there could be new finance innovations to address this gap.' AXA and IFC estimate that the global women's insurance market has the opportunity to grow to three times its current size, to 1.7 trillion USD by 2030 (AXA and IFC 2015; AII et al. 2017). All the relevant sectors and activity areas will have significant implications for women in their multiple roles as caretakers, managers of households/community resources, workers and business owner.

Despite improvements in the substantive gender sensitization and operational gender responsiveness of climate finance funds operations, current flows of public and climate finance do not seem to be going to women and the local communities. At the same time, evaluations of the effectiveness of climate finance show that equitable flow of climate finance can play an important role in levelling the playing field and in enabling women and men to successful respond to climate change and to enable the success and sustainability of locally to promote effective and sustainable climate strategies that can contribute to the global goals of the Paris Agreement (Eastin 2018; Minniti and Naudé 2010; Barrett 2014; Bird et al. 2013). This is particularly, so in the case of female that female own MSMEs, who, the literature increasingly show, are key to promoting resilience at micro and macro scale in many developing countries (Omolo et al. 2017; Atela et al. 2018; Crick, F. et al. 2018).

15.6.8 Conclusions on the relevance and complementary of approaches to address financing gaps identified in 15.4

[Will be filled after FOD. First we need clear information about the financing gaps]

15.7 Pathways for the financial sector

Political leadership is central, financial sector can only do so much. Climate finance flows and access are deeply affected by political uncertainty and lack of credible public commitments to supporting public finances, policies and regulations. Central banks and treasuries, among others, also need to do much more to scale up finance.

Finance is key. A vast and extensive literature suggests fundamentally three main reasons why the world is currently massively underinvesting even the relatively modest sums required in climate mitigation, which will lead to multiple disaster in adaptation and loss and damages (high confidence). Macroeconomic headwinds are making matters worse.

The first is the all-encompassing pursuit of national interest, not global, not helped by the current weak architecture of climate commitments and organized vested interest in the status quo and under-investing in the low carbon transition, especially in richer developed countries (65% of global wealth). The second is supportive rhetoric but not the reality of more ambitious support to low and lower-middle income countries where the mitigation challenges and promises are the highest and least-cost. The third is understating and avoiding public sector actions, including those by treasuries and central banks, to overcome the barriers to private climate finance which otherwise face much higher risks in newer technologies, asset classes and longer-term financing in riskier environments.

All three factors lead to the conclusion that political commitment, backed by reliable action, or credible commitment, is essential to avoid a catastrophe. Economists incidentally may have overstated the role of higher carbon prices (and markets) as a generic substitute, because their burden invariably falls on the less well-off, making it politically difficult to implement. Technology and finance are both available and with greater credible commitment to political action on several fronts - stronger frameworks for cooperative actions, financing for developing countries, support to risk reduction in private investment - faster and larger climate mitigation investment is possible, generating jobs, incomes and growth and a solid transition to a safer, low carbon future.

In general, we might work with three suggested scenarios or pathways:

Scenario 1: A catastrophic outcome path on a 'business as usual' scenario, where the financial pathway accompanies a business as usual pathway of GHG emissions, something like what has been happening in the past decade, a 3°C+ scenario where the near-term financial flows in 2020-2035 scenario mimics or fails to support the expected GHG scenario. Modestly increasing levels but nowhere near that needed.

Scenario 2: An optimistic path would be an optimistic scenario of what it would require in increased financing flows to accompany a 2°C scenario. Some measure of investment requirements might be forthcoming from the simulations.

Scenario 3: The best possible outcome path would be the most favourable path that lay out the scale of investments required to accompany the 1.5°C pathway from the simulations.

The climate finance flows numbers will need to be adequately 'modelled'. The IAMs work with actual investment paths. The climate finance flows discussed in our chapter are instead primarily commitments to projects, whose disbursements will happen usually an expected lag of about 4-5 years? Therefore, to mesh with the IAMs, our climate finance flows pathways will either need to assume that there is no 'lag', for instance flows reflect actual disbursements rather than commitments (which is not the case), or that somehow, the flows required start to happen much earlier to generate the investments needed to synchronize with the forecast investments from the IAM GHG emissions scenarios consistent with the set temperature 'goals'.

Apart from 'downloading' the three investment scenarios accompanying the relevant IAMs, to which the required or accompanying climate finance pathways are to be attached. The main policy issues might be able to pick up are the following at this stage to describe what is implicit in the three pathways above for climate finance flows:

Even Scenario 1 (Scenario 3°C+) might be a stretch in terms of 'near-term' financing prospects between 2020-2030/2035. The macroeconomic headwinds, continued investment and subsidies for fossil-fuels, the slow current climate investment rates in Europe and OECD, the inability to raise public resources or carbon taxes, the inability to support cross-border financing requirements in developing countries of requisite scale, and the increasing macroeconomic slowdowns and credit-rating troubles with indebtedness, investment and savings in developing countries - all tend to suggest that even the INDCs target (3°C) conditional or unconditional scenarios would not be met as far as the financing pathways are concerned. That would also make matters much worse for adaptation finance needs and raise the costs of loss and damage sharply. This is therefore a 'business as usual' case that portends a worsening climate financing crisis in the years ahead. What would be dramatic is to show what happens to Adaptation and Loss and Damage financing requirements under this scenario - highlighting a Catastrophic outcome path as a distinct possibility which is actually worse than the base-case 3C model. Binding finance constraints would make even the 3°C path very unlikely and with steadily worsening and unmet Adaptation and Loss and Damage financing.

Scenario 2°C would therefore require something behaviourally and systematically dramatic in terms of changes required for financing the global climate public goods challenge. Not certain how one would describe the nature of the key changes required. Mostly, public policy actions - to spur required risk mitigation and grant-based Adaptation and Loss and Damage financing and to spur greater private financial markets flows and changes in behaviour. This is closest to the main message shown above.

Scenario 3 is where financial markets decide in a sense to 'lead the way' beyond public action. There is still a lot of uncertainties in the literature on this, when and under what circumstances this happens or not. The best possible outcome path: I would imagine we have to write a differentiated path here where somehow we achieve an s-curve of transformative system dynamics of the political situation and decision-making, now involving both public government and central bank actions to lead to this outcome, plus accompanying technological changes and gains and breakthroughs in private financing architecture.

The additional 'behavioural' literature review to accompany the three scenarios above might be along the following lines:

Scenario 1: Focusing on a hopeful message about progress is quite detrimental to induce real change. It is better to say the uncomfortable truths.

Hornsey and Fielding (2016) suggest that emotional distress is strongly correlated with motivation; hope is not. Optimistic messages about carbon emissions reduce climate change risk perceptions. Less risk leads to less distress, which in turn, lowers mitigation motivation. Pessimistic climate change messages avoid complacency without eroding efficacy. There are additional insights: emotions that support policy action should draw specific attention to things that matter, not just large categories, such as the scope and scale of disasters and adaptation needs (Wang et al. 2018).

Similarly, studies show that increased threat is positively correlated with efficacy in beliefs about climate change; as is constructive threat (e.g., the reality of the threat, the need for more action) (Druckman and McGrath 2019) work better.

However, we may have locked ourselves into a low-effective decentralized pathway, reliant on every party doing what is best placed to do. Collaboration that is not self-enforcing does not work and leads to only shallow gains, not deep gains (Keohane and Victor 2016).

Scenario 2: Constructive hope (e.g., human progress, the rise of clean energy) and better governance institutions can play a big role. Design to induce deeper action must provide better incentives for action but must function well and not do the bidding of only a few actors. Also, if universal agreements with targets and timetables are not feasible, then smaller climate clubs, stronger pledge and review mechanisms, coordinated research on technologies, and substantial incentives and benefits for states taking action are some stepping stones to deeper coordinated action. (Keohane and Victor 2016).

Similarly, *ratcheting upwards of scaled-up actions frequently over time* and making sure benefits are well-targeted so that scaling up ambitions is possible is another pathway strategy (Pahle et al. 2017).

The ancillary non-climate benefit frames (Walker et al. 2018) of enhanced climate action such as Developmental benefits (jobs, incomes, economic and scientific advancement) and Benevolence benefits (moral, caring, ethical society benefits) (Bain and Bongiorno 2020) might also play powerful roles to motivate action, even across ideological divides.

Scenario 3: Bridging funding gaps for climate to reach the 1.5°C goal would require massive transformative changes going even further. In a world where natural capital is underpriced or undervalued making resource exploitation very lucrative cannot do so simply by pointing to the availability and claims about the potential for 'unlocking' trillions of dollars in available finance in a linear fashion (Clark et al. 2018). It may need to do so in a more deliberative fashion: (a) enabling investment reforms going well beyond mere voluntary announcements or commitment, to policies to value such assets or natural capital, scaling-up support to private investment through risk mitigation, and addressing political risks; (b) centralized informational processes on technologies and practices; (c) bridging financing gaps.

- It has to include gives not just to the practical technical possibilities, but to the political sphere—'systems and structures that facilitate or constrain practical responses to climate change' (O'Brien 2018)

- And to transition management, a dynamic process of change that often has a s-curve characteristic which breaks down systematic barriers to change

The financial sector-specific literature on alternative Financial Instruments and pathways would follow my earlier literature review (See Annex attached). In sum, the extensive literature review of alternative Financial Policy Instruments suggests the following key conclusions, where a mix of all five approaches seem to be the best bet, expanded in various categories:

Efficient financial markets thesis does not work in extreme form, only in very weak form, suggesting some benefits to greater information and risk disclosure parameters, but reality is very weak progress, insufficient; paradoxically, the 'financial engineering' school has done better by introducing newer instruments and possibilities.

Higher Carbon prices/taxes to include externalities and allow markets to work better much advocated as a panacea but overstates the possibility of spiking prices and political impossibility of very high taxes/subsidies required. Instead, use of 'shadow' prices could do better, as within corporations but also across countries in sovereign guarantees (see below) in North-South clubs.

Behavioural finance instruments, nudges, expanded public investment, de-risking private investment have no one set of recommendations, but essentially wishes to address the observed reasons why financial sector is slow to respond: corporate behavioural 'blind-spots', short-termism, risk-aversion, and regulatory uncertainty. Key issue is risk, and what public role can do.

Creating Markets and Schumpeterian waves of creative destruction, approach that supports expanded role of the state in financing and taking on more risks. Deliberately and to induce faster scaled-up responses. FITs is a prominent example of this approach working, but also city solar lighting and LEDs. Possibilities in areas such as storage batteries, now back in play, after initial failure?

Strengthening Cooperative Solutions in Large Scale North-South Climate Finance Clubs relies on game-theoretic finding that weak enforcement rules lead to weak results with large-scale free-riding, and stronger arrangements with better incentives and actions and instruments, including sovereign risk guarantees, may allow much faster benefits to occur. Some positive experience, such as role of risk mitigation, but not enough on scale to date.

A Theory of Change on Alternative Financial Policy Options to advance Low-Carbon Outcomes

A theory of change (TOC) is an integrated view of the psychological, behavioural, social and economic logic of possible alternative actions and accompanying changes in institutions and their behaviour that lead to a desired social outcome (Burnes 2004; Mayne 2015; Lott and North 1992). Such a TOC view on climate actions to achieve the scale of climate finance requirements depends, however, on competing paradigms and views[10] about the nature and role of climate finance:

(a) *an 'efficient' finance markets information perspective*, derived from neoclassical economics, in which a focus on accelerating climate finance does not really matter: financial markets can be expected, like any other contributory factor of production to capital, to respond efficiently (reallocate assets) to rising climate investment needs and urgency for finance as more information comes in on those requirements, raising market prices and signals, while additional public interventions cannot really improve on that outcome (also because of potential public information and regulatory 'failures'), and the principal decision choice is on limited and efficient *public policy to improve financial market information*;

(b) an alternative *externalities of climate change view* that the market for climate finance would undersupply needs because of these externalities of costs of carbon, 'lumpiness' of investment decisions, 'path dependency' (trend following practices) and frictions in long-term financial commitments and investment decisions in the presence of incomplete futures markets for carbon prices, which are best addressed by imposing needed *public taxes or market surrogates* to alter prices and incentives for investors and their financial backers;

(c) a third *behavioural finance view* that markets for climate finance, as in the case of financial markets in general, are subject to deep information asymmetry, risk-aversion and herd behaviour (contagion and bandwagon effects) favouring continued status-quo fossil-fuel investments and deterring rising climate finance which would require sufficient behavioural *public spending, investment and policy 'nudges' to alter private financial and investment behaviour*;

(d) a fourth *technological shifts in market capitalism view*, that a shift to clean or green energy options are fundamentally driven by waves of 'creative destruction' of older, established form of organization,

[10] The literature provides a more extensive menu of climate finance policy instruments, some 15 distinct proposals, with overlaps (and excluding agriculture, forestry and land-use policies), which are sub-grouped here under five main TOC typologies. Agriculture, forestry and other land-use (AFOLU) policy instruments and choices form a separate category.

technology and firms and their replacement by newer technologies and innovations brought about by newly emerging firms, a 'neo-Schumpeterian' model of change, that calls for *state policy to accelerate financial markets support to innovation and diffusion of low carbon investments*; and,

(e) a fifth *'game-theoretic' view of climate actions at the international state-interactions* level in which a tragedy of the commons is more likely because of the impossibility of enforcing voluntary commitments and free-riding behaviour or reneging of commitments, unless cooperative models can be encouraged by behavioural change and repeated interactions to cement trust and confidence with penalties for free-riding; a change to cooperative behaviour is especially important in climate finance and the *formation of financial 'clubs' of cooperating countries, with credible financial commitment devices to cement financial and economic cooperation* and advantages of belonging to such clubs.

These are contrasting theories of change in the choice of financial instruments and policies in dealing with climate. Which one, or their possible combinations, should policymakers rely more on and why? We set out the arguments for each in this concluding section.

Table 15.10 summarizes the competing instruments and an illustrative numerical exercise (based on underlying data from available literature) to show the types of sub-instruments and magnitudes of possible gains under each of the alternative instruments, to meet the current financing gap of about 1.4 trillion USD per year by 2030-2035. There are five main directions that this exercise suggests for the TOC (cautiously, subject to caveats on its illustrative nature, and not independently validated):

- *Even though the absolute financing gap is very large, especially compared to the current levels of proximate financing that we had examined earlier, it appears possible to close this gap only partially under the 2°C scenario, and even then to require massive changes from the current practices*. *Achieving the 1.5°C pathways would require even further deep-seated changes and globally coordinated actions which are a very unlikely 'stretch target'*. This is not really surprising given that the size of the ten-year cumulative climate financing needs (25 trillion USD) is quite large (about 6.5%) relative to the total stock of financial assets globally available in bank and non-bank debt, bond and equity markets (over 386 trillion USD in the 1.5°C Report) (de Coninck et al. 2018). Moreover, we are locked into the current 2015-2018 mode of financial markets of climate action which is seen as only marginal change from the prevailing dominant view. Political action required to engineer either the 2°C or the 1.5°C outcomes appears highly uncertain at this time, given a very weak decentralized operating environment for climate financing, the distributed INDCs, the past history, and the likely macroeconomic headwinds ahead. Still, the salient features:
- *Private financial market flows (efficient markets option) appear to have the largest current and prospective impact*, which is also unsurprising given the relative scale of private financial markets (in aggregate assets) and state of public finances (in aggregate deficit).
- *But the importance of the public financing options cannot be understated*, especially through its budgetary spending impact, once it is more explicitly recognized, and through its policy and leveraging influence, as crucial. Private markets remain risk-averse, and public support is important.
- *A combination of instruments is likely to deliver a more balanced outcome*. The five options all represent valid, even if competing for attention choices by proponents. The explicit carbon taxes and cutting fossil-fuel subsidies option remain important and still relatively underutilized but face extremely strong political hurdles and pushbacks. The behavioural finance option is a time-varying instrument that has the biggest likely impact in early stages, it's signalling effects should be captured more explicitly in public budgets and has significant overlaps with the option on creating neo-Schumpeterian markets and waves of innovation.

- *Incrementally, the biggest 'bang for the buck' may come from the impact of national and international sovereign guarantees*, especially to address the 'home-bias' problem, the extent of risk-aversion in private investment, and very large consequent gaps in cross-border financing flows to developing countries, given tightly constrained public finances, potentially larger leveraging effects on risk-averse private climate finance than other instruments, and limited utilization of this instrument till date (because public finance managers are also risk-averse).

Ultimately, how long might such a large-scale transition in characteristic non-linear s-shapes of technology substitution and diffusion, take? The evidence is that strategic public policy choices along with engagement of key private actors, and the marshalling of finance, play a crucial role in shortening the expected time (Sovacool 2016; Kern and Rogge 2016), although there is a risk of failing to communicate that such quick transitions involve 'multiple determinants of the rates of change of complex social, economic, and technological systems that need to be translated into carefully designed policies, incentives, and communication strategies in order to achieve accelerated transitions'(Grubler et al. 2016).

Table 15.10 Climate Finance Flows Pathways for Mitigation, Alternative instruments by main typologies and their size, 2030-2035 compared to finance flows - Required for 2°C and 1.5°C Scenarios

Instruments	1.Efficient Financial Markets Information	2.Market Taxes and Subsidies for Climate Externalities	3.Behavioural Finance Nudges	4.Creating Markets and Schumpeterian Waves of Innovation	5.International Cross-Border Financial Transfers to Developing
Sub-Instruments	-Financial Transparency -Risk Disclosure -Financial Engineering (Structured Finance, Asset-backed Non-Recourse Debt, Venture Capital, Private Equity etc.) -Stranded assets	-Carbon Taxes -Emissions Trading Schemes -Fossil Fuel Subsidy Reduction	-Tagging, aligning and measuring national and local Budget support to climate mitigation -Tax benefits to accelerate low-carbon investments -National Development Banks and 'green' banks support -Corporate and Business Leadership	-Public guarantees domestic, early-stage R&D investment and direct investment support -Innovation intermediaries -public-private partnerships -Enabling Policy Support (feed-in tariffs, reverse auctions, etc.)	-Multilateral and bilateral climate funds -Accelerated and higher MDB lending targets and recapitalization and greater shares of -'blended' finance to leverage private investment -Multi-sovereign and other guarantee support to de-risk and leverage private investment
Institutions	-Financial Regulatory Institutions -Central Banks -Credit Rating Agencies -Banks and Institutional Investors	-Ministry of Finance and Treasury -Financial Regulatory Agency -Ministry of Power/Environment	-Ministry of Finance and Treasury -Ministry of Environment -Large corporates, supply-chain	-Ministry of Finance and Treasury -National and regional development banks and green banks -cities and states	-Climate Funds -MDBs -Multi-Sovereign guarantee mechanisms
Illustrative Magnitudes of Incremental Impact on 2015-2018 Climate Finance Flows Baseline **<u>2°C Scenario</u>** Per year (double 2015-2018)	-Financial Transparency Impact (xxx) -Green Bond Markets (xxx) -Finance Engineering Climate Lending (xxx) -Recognized Stranded Assets Size (xxx)	-Carbon Revenues (xxx) -Feed-in Tariff Net Cost (xxx) -Fossil Fuel Subsidy Cost (xxx)	-Tagged National and Tagged Budgets (xxx) -Tax Benefits (e.g. accelerated depreciation, etc.) (xxx) -NDB and green banks lending (xxx) -Large corporate (xxx)	-Public guarantees domestic and R&D investments Impact (xxx) -Innovation investments (xxx)	-Climate Funds (xxx) -MDB Lending (xxx) -Sovereign Guarantees funded (xx)
Total: xxx	xxx	xxx	xxx	xxx	xxx
Illustrative Stretch Targets for 2030-2035 Annual flows: **<u>1.5°C Scenario</u>**	-Financial Transparency Impact (xxx) -Green Bond Markets (xxx) -Financial Engineering Climate Lending (xxx) -Stranded Assets Size annual write-off (xxx)	-Carbon Revenues (xxx) -Fossil Fuel Subsidy Cost (xxx)	-Tagged National and Tagged Budgets (xxx) -Tax Benefits (e,g. accelerated Depreciation, etc.) (xxx) -NDB and green banks lending (xxx) -Large corporate (xxx)	-Public guarantees domestic and R&D investments Impact (xxx) -Innovation investments (xxx)	-Climate Funds (xxx) -MDB Lending (xxx) -Sovereign Guarantees funded (xxx)
TOTAL xxx	xxx	xxx	xxx	xxx	xxx

(xxx): When appropriate data is available, USD will be represented in this table.

Frequently Asked Questions

FAQ 15.1 Which share of global financial flows is currently consistent with the Paris Agreement meeting the requirements of Article 2.1c, and which progress has been made on financial flows targeting adaptation (2.1b)?

FAQ 15.2 What do we mean by ‘climate finance’ and ‘climate investments’ in chapter 15 and across the report?

FAQ 15.3 What defines a financing gap, and where are the critically identified gaps?

FAQ 15.4 Which role can IPCC scenarios play for the private finance sector?

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