Chapter 15: Investment and Finance

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Executive summary

Investors, finance and financial commitments have assumed centre stage in the global policy conversation on climate change *(high confidence)*. The Paris Agreement recognised for the first time the key role of aligning financial flows to climate targets. The awareness of climate-related financial risks, both arising from the physical impact and from a disorderly transition to a low carbon economy, has also raised concerns about financial stability, driving multiple initiatives. Yet, climate-related financial risks are still massively underestimated by financial institutions and markets, limiting the capital reallocation needed for the low-carbon transition. This leaves high uncertainty, both near-term (2020-30) and longer-term (2020-50), on the ability of countries to align their financial flows to climate targets (*high confidence*). {15.1, 15.6.1}

Climate finance has increased only modestly over past years, remaining significantly below investment needs and adding up to approximately USD 546 billion in 2018 *(medium confidence)*. Estimates of climate finance flows illustrate the highly divergent and skewed patterns across regions and sectors, representing a major challenge for developing countries, low-income regions such as Africa, specific sectors like AFOLU and specific groups with restricted access and high costs of climate finance. Energy efficiency finance volumes continue to come in at low level, only partially due to reporting and data collection challenges. While the overall split between public and private climate finance remained relatively stable over the past five years at roughly 40/60%, private finance has outpaced public finance in the energy sector (>80% in 2017-18) with only one other sector, transport, attracting significant recent volume. This concentration in the energy sector flags the challenge of private sector mobilisation for sectors with less or not yet standardised and established financially viable business models under current enabling policy environments. Persistently high levels of fossil-fuel financing are also of major concern. {15.1, 15.3.1, 15.3.2}

Significant financing gaps exist across all sectors and regions and the ability to mobilise finance varies substantially for sectors and at the country level *(high confidence)*. Total finance for mitigation remains significantly below estimated needs *(high confidence)* by around five times *(medium confidence)*. Despite rising damage costs, adaptation action remains even more underfunded. Financing needs in terms of required investments represent one element of the considerations on the magnitude of the challenge to mobilise finance, as sectors and regions offer highly divergent financial risk-return profiles and economic costs and gaps in standardisation, scalability and replicability of investment opportunities to attract private investment. Moreover, soft costs and institutional capacity for enabling environment that can be prerequisite for addressing financing gaps are often overlooked. Although a relatively small share of overall investment needs, this can hinder or delay deployment of scaled up climate finance. {15.4.2, 15.5.1, 15.5.2}

The existing speed of deployment of climate finance and scale-up of commitments does not reflect the urgency and economic rationale for ambitious climate action *(high confidence)*. Climate finance flows have only grown modestly over the past years, with declining volume in 2017, and public commitments, including those in the context of international climate cooperation and developed countries' commitments under the UNFCCC, remain uncertain. Delayed climate investments and financing and, consequently, limited alignment of investment activity with the Paris Agreement, will result in significant carbon lock-ins, stranded assets, particularly in energy, transport and urban infrastructure, and additional costs. A common understanding of debt sustainability and debt transparency, including negative implications of deferred climate investments on future GDP, stranded assets and resources to be compensated, has not yet been developed. {15.1, 15.3.2.3, 15.5.2, 15.6.7}

Ambitious global policy coordination and stepped-up (public) climate financing over the next crucial decade (2020–2030) is possible to address a deteriorating environment post-pandemic with rising macroeconomic uncertainty and public debt overhang *(high confidence)*. Political leadership and intervention, above all remains central, addressing uncertainty and the lack of credible public commitments as well as existing policy misalignments, particularly in fossil fuel subsidies. In addition to indirect and direct subsidisation, public sector's role in addressing market failures, barriers, provision of information and risk sharing would encourage private sector mobilisation efficiently.{15.2, 15.6}

Near-term actions to shift the financial system over the next decade (2020-2030) are critically important and feasible *(high confidence)*. Given the inertia of the financial system, the magnitude of the challenge and excess but risk-averse private savings, public action is needed to ensure the missing readiness of the financial sector won't remain a barrier for the transition. There is strong consensus that global COVID-19 green financial stimuli, with key central banks support, offer a unique opportunity to support faster and more sustainable growth and jobs in a global low-carbon infrastructure effort. {15.2, 15.5}

Synergies resulting from coherent regulations in the financial sector and in the real economy can add momentum for an accelerated transformation. A reliance on financial sector regulation and momentum alone is unlikely to result in substantial progress in the near-term (*medium confidence*). An enabling role of finance in tackling climate change cannot be taken for granted without appropriate fiscal, monetary and financial regulatory as well as real-economy policies. In particular, the financial system could fail to reallocate capital as needed for the low-carbon transition, if climate-related risks continue to be underestimated. Thus, credible signalling by governments and the international community can reduce uncertainty for financial decision-makers and help close transition risk gaps. In this regard, missing, late or inconsistent government action often represents a moving target for risk assessments by capital markets and their responses to reallocate capital. {15.2.4, 15.6.1, 15.6.2}

Fundamental inequities in current financing conditions exist, with climate change representing an additional burden on financing costs, especially for many developing countries *(high confidence)*. The costs and risks of financing for stakeholders at all levels remain excessively high in many developing countries in addition to their general economic vulnerability and indebtedness. Rising public fiscal costs of mitigation and adaptation to climate shocks affecting many countries, which were negatively impacting public indebtedness and country credit ratings at a time of significant stresses on public finances, are now even greater following the COVID-19 pandemic. The resulting limited fiscal headroom further shrinks their ability to actively steer the required transformation. Even in relatively more prosperous countries and regions, the social and economic vulnerability of low-income populations are in question. {15.2.4}

Ensuring and accelerating a just transition may benefit from a new global and national social compact to address inequalities, with expedited mitigation and adaptation finance commitments, budgets, investments and actions, especially by developed countries, in the near-term (2020-2030) (*high confidence*). Estimated mitigation financing needs (2030) as percentage of current GDP comes in at less than 2% for developed countries, and less than 3% for developing countries. Besides the additional burden on developing countries, the rising levels of income inequality, mismatch between capital and investment needs, home bias considerations and differences in risk perceptions between the rich and the poor, represent major challenges for commercial finance. The mismatch between capital pool in the developed world and future emissions expected in developing countries emphasise the recognition of the explicit and positive social value of such global cross-border mitigation. A significant push for international climate finance access for vulnerable and poor countries is important, given their high costs of financing, debt stress and impacts of ongoing climate change. {15.2.4, 15.6.3}

Innovative financing instruments, including de-risking instruments, robust 'green' labelling and disclosure schemes, and regulatory focus on transparency could help shift inertia *(medium confidence)*. Green bond markets and markets for sustainable finance products have increased significantly since AR5 underpinning investor preference for scalable and highly standardised investment opportunities, standardised financial products and new, convening asset classes will help in allowing a smooth integration into existing asset allocation models. Challenges remain in the green bond market, including the potential for 'greenwashing', and creditworthiness constraints in developing countries. New business models (e.g. PayG) can facilitate the aggregation of small-scale financing needs and provide investment opportunities with more attractive risk-return profiles. Greater public-private cooperation can encourage the 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. {15.1, 15.3.1, 15.5.2, 15.6.7, 15.6.8}.

Policy attention on eight key areas may have important long-term catalytic benefits *(high confidence)*: (i) stepped-up technical support and partnership in low-income and vulnerable countries and low-carbon energy access in Sub-Saharan Africa, which currently receives less than 5% of global climate financing flows {15.3.2.2, 15.5.2, 15.6}; (ii) continued strong role of MDBs, especially regional, but also national development banks {15.3.1, 15.6}; (iii) de-risking cross-border investments in low-carbon infrastructure, development of local bond markets, and transparency in fossil-fuel investments {15.4.1, 15.6}; (iv) lowering transaction costs and risks through green banks, funds and risk-sharing mechanisms for under-served small urban municipalities, sub-national finances, small-holder agriculture, SMEs, grid-connectivity of small renewables, and local transport such as cycling {15.4.1, 15.6.5}; (v) accelerated finance for nature-based solutions, forestry (REDD+), and climate-responsive social protection {15.4.2, 15.6.6}; (vi) improved financing instruments for loss and damage events, including blended finance for risk-pooling-transfer-sharing for catastrophic insurance {15.4.3, 15.6.4}; (vii) political economy options for phasing-in carbon pricing options which address equity and access {15.5.2}; and (viii) gender responsive and women empowered programs {15.6.8.3,15.2.3, 15.3.1}.

15.1. Key findings from AR5 and other IPCC publications

For the first time in IPCC, the AR5 (2014) elaborated on the role of finance in a dedicated chapter. In the following year, the Paris Agreement (PA) (UNFCCC 2015) recognised the transformative role of finance, as a means to achieving climate outcomes, and the need to align financial flows with the long-term global goals even as implementation issues were left unresolved (Bodle and Noens 2018). AR5 noted the absence of a clear definition and measurement of climate finance flows, a difficulty that continues (see Section 15.3) (Weikmans and Roberts 2019). The approach taken in AR5 was to report ranges of available information on climate finance flows from diverse sources, using a broad definition of climate finance, as in the Biennial Assessments in 2014 and again in 2018 (UNFCCC 2014a, 2018) of the Standing Committee under the United Nations Framework Convention on Climate Change (UNFCCC): Climate finance is taken to refer to local, national or transnational financing – drawn from public, private and alternative sources of financing – that seeks to support mitigation and adaptation actions that address climate change (UNFCCC 2014b). For this chapter, while the focus is primarily on mitigation, adaptation and loss and damage financing needs cannot be entirely separated because of structural relationships, trade-offs and policy coherence requirements between these sub-categories of climate finance (Box 15.1).

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 from adaptation finance which deals with the consequences of climate change (Lindenberg and Pauw 2013), they are not. Mitigation affects the scale of adaptation needs and vice-versa. If mitigation investments are inadequate to reducing global warming (as in last decade) with asymmetric adverse impacts in lower latitudes and low-lying geographies, the scale of adaptation investments has to rise, as evident from integrated assessment models (IAMs) (Markandya and González-Eguino 2019). Conversely, if adaptation investments build greater resilience, they might moderate mitigation financing costs. Similar policy coherence considerations apply to disaster finance, the scale of which depends on success with both adaptation and mitigation (Mysiak et al. 2018). In addition, the same financial actors, such as governments and the private sector, decide at any given time on their relative allocations of available funding to mitigation, adaptation and disaster-risk from a constrained common 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. 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 additionally of climate financing is essential (Brown et al. 2010). Policy coherence is also the reason why mitigation finance cannot be separated from consideration of scaling-back spending on fossil fuels to make room for climate mitigation finance. Climate change will cause the breaching of physical and social adaptation limits, resulting in climate-related impacts and residual risks (i.e. potential impacts after all feasible mitigation, adaptation, and disaster risk reduction measures, have been implemented) (Mechler et al., 2020). Because these residual losses and damages from climate-related risks are related to overall mitigation and adaptation efforts, the magnitude of potential impacts and are related as well to the overall quantum of mitigation, adaptation, and disaster risk reduction finance available (Frame et al. 2020) and need to be considered in the debate around public climate finance as a third element.

The AR5 concluded that published assessments of financial flows whose expected effect was to reduce net greenhouse gas (GHG) emissions and/or to enhance resilience to climate change aggregated 343–385 billion USD yr^{-1} globally between 2010 and 2012 (*medium confidence*). Most of this went towards mitigation and adaptation was underfinanced. Measurement of progress towards the Paris Agreement commitment by developed countries to provide 100 billion USD yr^{-1} by 2020 to developing countries, for both mitigation and adaptation – a narrower goal than overall levels of climate finance – continued to be a challenge, given the lack of clear definition of such finance. As against these flows, annual need for global aggregate mitigation finance between 2020 and 2030 was cited briefly in the AR5 to be about 635 billion USD (mean), implying that the reported 'gap' in mitigation financing of estimated flows during 2010 to 2012 was slightly under one-half of that required (IPCC 2014).

More recent published data from the Biennial Assessments (UNFCCC 2018) and the Special Report on Global Warming of 1.5°C (IPCC 2018) have revised upwards the needs of financing between 2020 and 2030 to 2035 to contain global temperature rise to below 2°C and 1.5°C respectively by 2100: 1.7 trillion USD yr^{-1} (mean) in the Biennial Assessment 2018, and 2.4 trillion USD yr^{-1} (mean) for the energy sector alone (and three-times higher if transport and other sectors were to be included). The resulting estimated gaps in annual mitigation financing during 2014 to 2017, using reporting of climate financing from published sources was about 67% for 2015, and 76% for the energy sector alone in 2017 (*medium confidence*), and greater if other sectors were to be 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 was reported to have widened considerably (*high confidence*). In the context of policy coherence, it is also important to note that reported annual investments going into the fossil-fuel sectors, oil and gas upstream and coal mining, during the same period were about the same size as global climate finance.

Adaptation financing needs, meanwhile, were rising rapidly. The fourth Adaption Gap Report 2018 (UNEP 2018a) reported that '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 AR5 Intergovernmental Panel on Climate Change (IPCC) (which had reported a requirement of 70 billion USD to 100 billion USD yr^{-1}), and plausibly four to five times greater by 2050 (IPCC 2014). Against this, 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 meanwhile continued to rise, affecting low-income developing countries the most. Climate natural disasters – not all necessarily attributable to climate change – caused some 300 billion USD yr^{-1} economic losses and well-being losses of about 520 billion USD yr^{-1} (Hallegatte et al. 2017).

15.2. Background considerations

The term climate finance refers in this chapter to the set of financial actors, instruments and markets that are recognised to play a key role in climate mitigation and adaptation. For a definition of climate financial stock and flows see Section 15.3 and the glossary. The notion of climate finance is related to the conversation on international cooperation and the question of how cross-border investments can support climate mitigation and adaptation in developing countries. However, the notion is also related to more general questions on how financial institutions, both public and private, can assess risks and opportunities from climate investments and what roles states, policy makers, regulators and markets can play. In particular, the question of the respective roles of the public and private financial actors has become important in deliberations on climate finance in recent years. Four major events and macro trends mark the developments in climate finance in the previous five years and likely developments in the next ten years.

- First, the 2015 Paris Agreement, with the engagement of the financial sector in the climate agenda has been followed by a series of related developments in financial regulation in relation to climate change and in particular to the disclosure of climate related financial risk.
- Second, the last five years have been characterised by a series of interconnected "headwinds" (see later on in this section), including rising private and public debt which work against the objective of filling the climate investment gap.
- Third, the 2020 COVID-19 pandemic crisis has put enormous additional strain on the global economy, debt and the availability of finance, which will be longer-lasting. At the same time, while it is still too early to draw conclusions, this crisis highlights new opportunities in terms of political and policy feasibility and behavioural change in respect of realigning climate finance.
- Fourth, the sharp rise in global inequality and the effects of the pandemic have brought into renewed sharp focus the need for a Just Transition and a realignment of climate finance and policies that would be beneficial for a new social compact towards a more sustainable world.

15.2.1 Paris Agreement and the engagement of the financial sector in the climate agenda

This is the first IPCC AR chapter on investment and finance since the 2015 Paris Agreement, which represented a landmark event for climate finance because for the first time the key role of aligning financial flows to climate targets was spelled out. Since then, the financial sector has recognised the opportunity and has stepped up to centre-stage in the global policy conversation on climate change. While before the PA, only few financial professionals and regulators were acquainted with climate change, today climate change is acknowledged as a strategic priority in most financial institutions. This is a major change in the policy landscape from AR5. However, this does not mean that finance necessarily plays an adequate enabling role for climate investments. On the contrary, the literature shows that without appropriate conditions, finance can represent a barrier to fill the climate investment gap (Hafner et al. 2020). Indeed, despite the enormous acceleration in policy initiatives (e.g. such as the Network for Greening the Financial System) and coalitions of the willing in the private sectors, the effect in terms of closing the investment gap identified already in AR5 has been limited.

There has been a significant growth in the white and grey literature on why financial investors' price in climate risk only to a limited extent in their decision-making and on related conceptual challenges and how to address them. Two key aspects matter here. The first is the endogenous nature of climate financial risk and opportunities (with the term "risk" meaning here the potential for adverse financial impact whether, or not, the distribution of losses is known). The financial industry is traditionally confronted with an idea of risk that is exogenous, that is, not affected by the action of financial players themselves. In contrast, today's climate investment path affects directly the future risk itself, leading to the necessity to assess several plausible future scenarios. The main possible climate policy scenarios (see Chapter 3) include an orderly or a disorderly low-carbon transition (see Section 15.6.1 for a definition) within the time window of opportunity of 2040, as well as a no transition scenario, associated with higher physical risks. The challenge to deal with these very different risk scenarios has been raised by the scientific literature and recognised by financial regulators (Monasterolo and Battiston 2020; Bolton et al. 2020). As long as the probability of the transition is not too small, investors who want to have portfolio that withstand all scenarios would rationally rebalance the carbon intensive investments towards low-carbon ones. Indeed, sophisticated, risk-savvy investors are prepared to think in these terms, although the assessment of risk is non-trivial. In contrast, decision makers in many public and private investors keep thinking in terms of one single scenario. The result is a coordination problem whereby the majority of investors wait to move and reallocate their investments until they can follow a clear signal.

The second, and related aspect, is the fact that, despite the initial momentum of the Paris Agreement, for many investors, both public and private, the policy signal is not strong enough to induce them to realign their investment portfolios. This second aspect reinforces the first, since a strong enough policy signal is precisely what is needed in order to resolve or reduce the uncertainty on the multiple scenarios generated by the endogeneity of climate risk.

In summary, the low carbon transition does not occur by itself and requires a strong enough policy signal. Such a signal would require some policy commitment device in order to give credibility to the commitment. It would also need to convince investors that the commitment would be large enough if needed (analogous to the "whatever it takes" statement by the European Central Bank during the 2011-12 European sovereign crisis). Public investments in low carbon infrastructures (or private-public partnerships) as well as regulation (experiences with FiTs models across countries provide useful lessons) could provide the credible signal if their magnitude and time horizon are appropriate.

15.2.2 Macroeconomic context

Entering 2020, the world thus already faced large macroeconomic headwinds to meeting the climate finance gap in the near-term – barring some (unexpected and unlikely) globally coordinated action. While an understanding of the disaggregated country-by-country, project-by-project, sector-by-sector, and instrument-by-instrument approach to raising climate finances analysed in the later parts of this Chapter remains important and useful, ultimately macroeconomic drivers of finance remain crucial in the near-term.

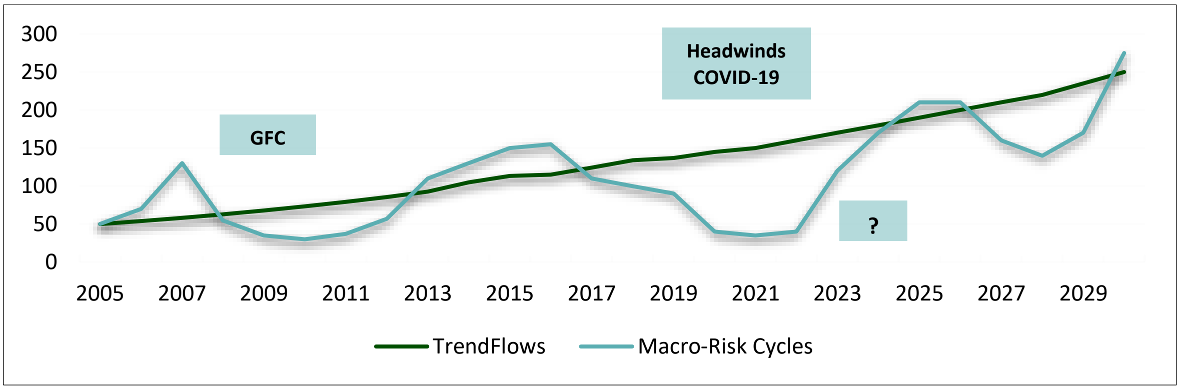


Figure 15.1 Hypothetical Representation of Trend Versus Macro-Risk Cycles of Climate Finance Note: USD billion. Illustrative calculations. For more information see Rünsler et al. (2018), Ha et al. (2020) and Claessens et al. (2011).

Such top-down factors often show strong empirically observed cycles over time, especially in terms of macroeconomic and financial cycles, and the near-term context has a significant bearing. By *near-term*, we mean here the likely cycle over the next five to ten years (2020–2025 and 2020–2030), as global macroeconomic real cycles (output, investment and consumption), with periodic asymmetric downside impacts and crises (Jordà et al. 2017), typically have strong co-movements with global financial cycles (asset prices, credit growth, interest rates, leverage, risk factors, market fear, macro-prudential and central bank policies) (Coeurdacier and Rey 2013) Both have large consequences for all principal types of financial flows such as equity, bond and banking credit markets, which in turn are likely to impact climate finance flows to all sub-sectors and geographies (with greater expected volatility in more risky and more leveraged regions, see Figure 15.1). This is by contrast to *longer-term trend considerations* (2020–2050) that are typically the attention of drivers of disaggregated flows of climate finance (as well as most other topics in other Chapters in this Report on climate developments) and policies. A hypothetical illustrative representation of the difference between a longer-term trend flows analysis versus a macro-financial risk-affected flows of climate finance is shown alongside (Figure 15.1). The cycles (with asymmetric downsides) also have potentially other consequences: they lower *cumulative* climate finance flows over a length of time, raise uncertainty and risks for longer-term climate investments and newer climate technologies, and favour a flight to near-term safety (e.g., lowest risk non-climate short-term treasury investments, highest creditworthy countries, and away from cross-border investments) – making the challenge of longer-term low-carbon transition much more difficult. There are ways through more coordinated global policies and instruments to lower such near-term risks to address this challenge, which will be discussed subsequently.

Four key aspects of the current global macroeconomy, each slightly different, pointed in a cascading fashion towards a deteriorating environment for stepped-up climate financing over the next crucial decade (2020–2030), even before COVID-19. The argument was often made that there was 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 uncertain) (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. In the words of a macroeconomic institution, 'tangible policy responses to reduce greenhouse gas emissions have been grossly insufficient to date' (IMF 2020a). The reason is global macroeconomic headwinds, which also 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 was more unstable and slowing GDP growth at individual country levels and in aggregate because of worsening climate change impact events (Donadelli et al. 2019; Kahn et al. 2019). As each warmer year keep producing more negative impacts – arising from greater and rising variability and intensity of rainfall, floods, droughts, forest fires and storms – the negative consequences have become more macro-economically significant each time such events have occurred, 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 have raised the social returns and incentives to invest more in future climate mitigation, a standard public policy argument, these macroeconomic shocks work in the opposite direction for private decisions by raising the financing costs now (Cherif and Hasanov 2018). With some climate tipping points being reached in the near term (see IPCC Sixth Assessment (AR6),WGI report) the uncertainty with regard to the economic viability and growth prospects of selected macroeconomically critical sectors increases significantly (see IPCC AR6 WGII report). Taking account of other behavioural failures, this was creating a barrier for pro-active and accelerated mitigation and adaptation action.

The second headwind was rising public fiscal costs of mitigation and adapting to rising climate shocks affecting many countries, which were negatively impacting public indebtedness and country credit ratings 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 were 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 (perversely often adversely impacted by countries cutting taxes for the better off in an attempt to stimulate falling growth) and cutting back fossil fuel subsidies to raise resources faced 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, vulnerable countries faced sharply rising 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 financing cost 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, and 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 new fossil fuel projects by the same large global financial institutions 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 entering 2020 was the sharply slowing global macroeconomic growth, and prospects for near-term recession (which has since occurred with the pandemic) and hence rising financial risk, both from secular stagnation and cyclical reasons (independent of ongoing climate change), which were 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. This is due to the fact that 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 risk rises sharply, causing financial institutions and savers to reallocate their financing 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 in negative-interest earning 'safer' assets in 2019, which has since risen further) in world debt markets – enough to have nearly closed the total financing gap in climate finance over a decade.

15.2.3 Impact of COVID-19 pandemic

The macroeconomic headwinds described above have worsened dramatically after the onset of COVID-19. The cumulative output losses relative to the pre-pandemic projected output path are now projected to grow from about 11 USD trillion over 2020–2021 to about 25 trillion USD over 2020 to 2025. First, virtually all countries around the world have been forced to undertake unprecedented levels of immediate public expenditures to deal with the health costs and fiscal stimulus measures to offset the consequences of lockdowns and economic activity fall during the pandemic, raising their public debt additionally by 5-10% of respective GDPs and amounting to some 12 trillion USD globally already in 2020 to cushion the fallout from the loss of jobs and activity arising from COVID-19. Second, more public expenditures are now expected to be required well into 2021 and beyond to facilitate the recovery of their economies in the next year or more, and these are likely to place the greatest emphasis on two things: short-term boost to jobs and 'bail-outs' of small and medium-enterprises with the greatest multiplier impacts on recovery, and neither of these are likely to include a shift to a climate resilient long-term investments (Hepburn et al. 2020). This will mean even more public debt with virtually no room left in public budgets to finance additional spending on climate. Third, on the public revenues side, output has collapsed everywhere, and will likely take time to recover, and with it, the scope for any additional taxes and fiscal measures for several years. Fourth, banks and financial institutions saw a sharp worsening of their balance sheets because of magnitude of loan losses and will not be in a good position to finance new longer-term investments such as climate. Instead, they will likely reduce their exposures to risk and seek to raise more capital. Fifth, the only ameliorating possibility, which some observers hope will happen out of COVID-19, is that governments and citizens will become more worried about natural catastrophic events and receptive to adopting large-scale measures to accelerate a shift towards a low-carbon economy as part of their recovery strategy. However, there is no assurance about this, since climate is still perceived by many as a risk with a longer-term horizon and not as immediate as public health, lives and livelihoods. But if such a behavioural change should happen, then the options for globally coordinated climate financing actions, including governments and central banks, and instruments such as use of sovereign guarantees to reduce private risk perceptions will become even more central then they were prior to the COVID-19 crisis.

The larger but still open public policy choice question that COVID-19 now raises is whether there is room for public policy globally and in respect of their individual economies to integrate climate more centrally to their growth, jobs and sustainable development strategies worldwide for ecological and economic survival. A recent paper (Hepburn et al. 2020) suggests the COVID-19 crisis is likely to have dramatic consequences for progress on climate change, with a clear fork on choices ahead.

An important immediate finding from the COVID-19 crisis is that the slowdown in economic activity is illustrating some of these choices: more costly and carbon-intensive coal use for energy use has tumbled in major countries such as China and the USA, while the forced 'stay-at-home' policies adopted around the major economies of the world, which led to a 30-35% peak decline in individual country GDP, has in turn been associated with a decrease in daily global CO_2 emissions by -26% at their peak in individual countries, and -17% globally (-11 to -25% for $\pm 1\sigma$) by early April 2020 compared with the mean 2019 levels, with just under half coming from changes in surface transport, city congestion and country mobility (Le Quéré et al. 2020). The impact has been to take daily carbon emissions back to where they were more than a decade ago in April 2006. Along with the carbon emissions drop has been a dramatic improvement in other parameters such as clean air quality. Moreover, longer-term behavioural impacts are also possible: a dramatic acceleration of digital technologies in communications, travel, retail trade and transport. The question is whether the world might revert to the earlier carbon-intensive path of recovery, or to a different future, and the choice of policies in shaping this future.

The positive lesson is clear: opportunities exist for accelerating structural change, and for a re-orientation of economic activity modes to a low-carbon use strategy in selected areas such as coal use in energy consumption and surface transport, city congestion and in-country mobility, for which lower-cost alternatives exist and offer potentially dramatic gains. A paper (Hepburn et al. 2020) suggests that in designing stimulus packages after the COVID-19 crisis, imminent fiscal recovery packages could either entrench or partly displace the current fossil-fuel-intensive economic system. Their survey of 231 central bank officials, finance ministry officials, and other economic experts from G20 countries on the relative performance of 25 major fiscal recovery archetypes across four dimensions (speed of implementation, economic multiplier, climate impact potential, and overall desirability) suggest five policies with high potential on both economic multiplier and climate impact metrics: clean physical infrastructure, building efficiency retrofits, investment in education and training, natural capital investment, and clean R&D. In lower-and-middle income countries (LMICs) rural support spending is of value (while clean R&D is less important). These recommendations are contextualised through their analysis of the short-run impacts of COVID-19 on greenhouse gas curtailment and plausible medium-run shifts in the habits and behaviours of humans and institutions.

A new consensus and compact towards such a structural change and economic stimulus instruments may therefore need to be redrawn worldwide, where an accelerated low carbon transition is a choice and priority; and accelerated climate finance to spur these investments may gain by becoming fully and rapidly integrated with near-term economic stimulus, growth and macroeconomic strategies for governments, central banks, and private financial systems alike. If that were to happen, COVID-19 may well be a turning point for sustainable climate policy and financing. Absent that, a return to 'business-as-usual' modes will mean a likely down-cycle in climate financing and investments in the near-term.

Expectations that recovery the package stimulus will increase economic activity rely on the assumption that increased credit investment will have a positive effect on demand, the so-called demand-led policy (Mercure et al. 2019). The argument for a green recovery also draws on the experience from the post Global Financial Crisis in 2008–2009 (GFC) recovery, in which large economies such as China, South Korea, the US and the EU observed that green investments propelled the development of new industrial sectors. Noticeably, this had a positive net effect on job creation when compared to the investment in traditional infrastructure (Jaeger et al. 2020; Vona et al. 2018; UKERC 2014). For a more in-depth discussion on macroeconomic-finance possible response see Section 15.6.3. Here, we conclude with the options for reviving a better *globally coordinated macroeconomic climate action*. The options are some combinations of four possible elements:

(a) G-20 governments running coordinated fiscal deficits ('green fiscal stimulus') to accelerate the financing of low carbon investments.

(b) introducing new actions, including regulatory, to take some of the risks off-the-table from institutional financial players investing in climate mitigation investment and insurance. This could include 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 bigger 'multipliers' of such fiscal action to catalyse private investment than direct public investment) and the bigger social value of such investments (Article 108, UNFCCC) (Krogstrup and Oman 2019).

(c) facilitating and incentivizing 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.

(d) global central banks acting in unison to include climate finance as intrinsic part of their monetary policy stimulus ('green QE') (Carney and Bank 2019; Jordà et al. 2019).

15.2.4 Realigning climate finance towards a Just Transition

Evidence from COVID-19 pandemic suggests that a shift to a new social compact for a Just Transition in all public policies, including climate finance, has also now become urgent — because as in the case for climate impacts, not only was the ongoing global burden of disease distributed unevenly but capabilities to prevent and treat disease were asymmetrical and those in greatest vulnerability often had the least access to human, physical, and financial resources (Ruger and Horton 2020). This is on top of the already building vulnerabilities of the past decade and more of rising inequality and growing vulnerability of the bottom half of populations, exacerbated by rising shares of incomes of the top percentiles of populations and falling progressivity of taxes, while the history of pandemics is known to worsen such inequality (IMF and World Bank 2020). In addition, new evidence suggests from data on 133 countries between 2001–2018 that smaller pandemics caused rising social unrest, especially when starting inequality was high as measured by net income Gini (net of transfers) greater than 0.4 and worst when social transfers were low (Sedik and Xu 2016). In the absence of changes in social compact, countries could slip back to a business-as-usual path of rising inequality and excessive climate emissions consumption which would be catastrophic, unless the political economy elites and governments, under pressure from citizens below, are able to adopt a new social compact that would reverse inequality, adopt redistributive taxes and lower consumption, and strengthen state capacity to deliver safety nets, health, education with accelerated climate and environmental sustainability within and across countries (see Figure 15.2).

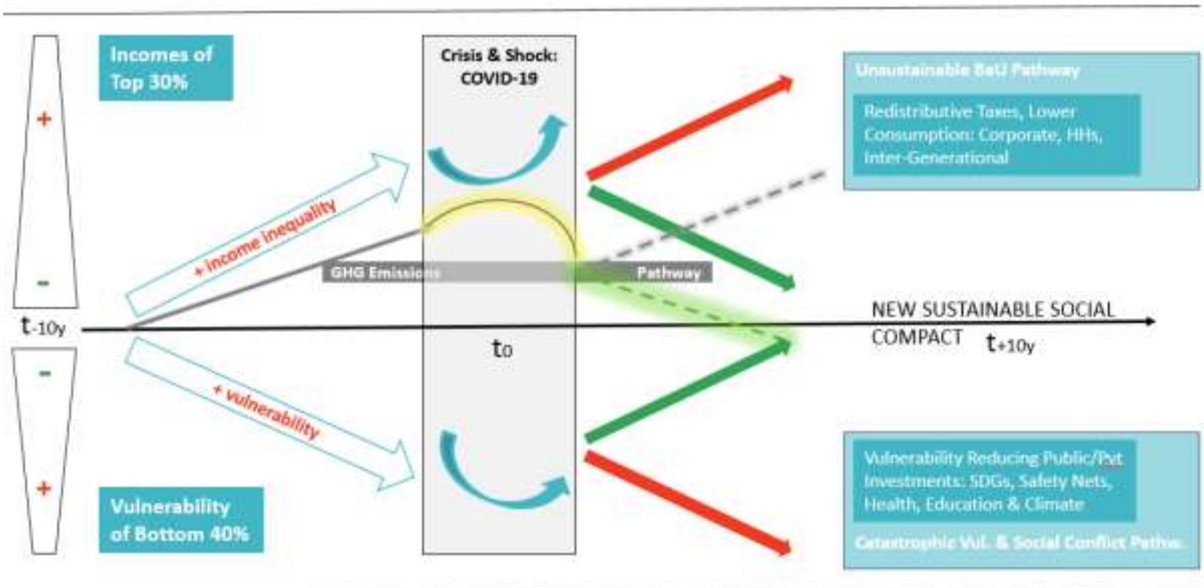


Figure 15.2 Just Transition Climate Finance Path After COVID-19
Note: Illustrative calculations. For more information see IMF and Wold Bank (2020), Sedik and Xu (2016), Guido (2020), Jordà et al. (2020) and Stiglitz (2020)

Such a redrawing of a new social compact has happened often in the past, for example, historically after the 1860s 'gilded age of capital' with the enlargement of the franchise in democratisation waves in Europe and the Americas which reduced the threat of social conflict (Dasgupta and Ziblatt 2016, 2015). Not only can social conflict be avoided but growth outcomes can become more equitable and faster. Comprehensive modern social safety nets and progressive taxation, for example, started in the Great Depression and extended in the post-war period, had both a positive pro-growth and lower inequality (Brida et al. 2020). The need for a shift to a Just Transition path globally in the context of the COVID-19 pandemic is gathering momentum. The Just Transition discussion has picked up steam since the Paris Agreement. Originating from civil society discourse and activism around issues of environmental and labour/workers' rights, it has now become intertwined with the equity and justice presuppositions of climate change discussions and the implicit and explicit underlying principles of equity in the UNFCCC. This was explicitly recognised in the Paris Agreement and the 2018 Just Transition Declaration signed by 53 countries at COP24, which 'recognised the need to factor in the needs of workers and communities to build public support for a rapid shift to a zero-carbon economy.'

There are three levels at which attention now needs to be focused. The first is the need for addressing the global equity issues in a more carefully constructed globally cooperative public policy approach. The second is to address issues appropriately with enhanced support, at the country level, especially in low-income countries with the least access to resources for a Just Transition. The third level is to work it down further, to addressing needs at local community levels. Because private investors and financing mostly deal with allocation to climate finance at a global portfolio level, then to allocation by countries, and finally to individual projects, the challenge for them is to refocus attention to Just Transition issues at the country level, but also globally as well as locally (in other words, at all three levels).

For the first level, COVID-19 pandemic illustrates the global distributional challenges in terms of enhanced access to global finance necessary for a Just Transition. The overwhelming evidence is that richer countries were able to spend far more (four times higher and about 4 trillion USD in absolute size so far in 2020) for discretionary fiscal stimulus (about 11% of their GDP) in the pandemic, even with higher fiscal debt, than did middle-income developing ones (3.5% of GDP) and the least (1.5% of GDP) in low-income countries (IMF 2020b), with constraints on credit ratings and costly debt burden (contrasted with the exceptionally low interest rate settings in developed economies) driving the limited fiscal response in the latter groups (Benmelech and Tzur-Ilan 2020). Similarly, unconventional monetary policies (quantitative easing) by central banks during the pandemic were bigger, in part because of the exceptional privilege of global reserve currencies: the EU and USA together added unconventional additional liquidity injections of about 8 trillion USD so far in 2020 into their domestic economies (20% of GDP), whereas most developing countries faced higher local currency yields as portfolio investors withdrew, and had only limited capacity (average of 3% of GDP) to inject quantitative easing.

The result is that the divergence in income prospects for the developed and developing countries are set to worsen in the aftermath of the pandemic, absent offsetting policies, with output losses in developing economies (excluding China) set to worsen to -8% by 2021 as compared to -4.7% in developed countries (IMF 2020c). The crucial policy relevant question is whether a better coordinated and cooperative approach, instead of unilateralism, might have worked better, providing greater support to better outcomes in all countries with mutually supportive agreements (as evident earlier during the Great Financial Crisis of 2008)? The answer is yes. Greater international cooperation to allow emerging and low-income countries to undertake bigger fiscal responses during the pandemic would have been ‘extraordinarily beneficial’, with all countries benefiting (McKibbin and Vines 2020). Simulations clearly suggest the need for coordinated action among both richer and developing countries, since much of the emissions will occur in the latter without such coordinated actions and stepped-up Paris Agreement envisaged transfers for the low-carbon transition (IMF 2020c).

For the future, as this pandemic demonstrates, there is need for accelerating Just Transition in access to climate finance not only within countries but also across countries, which needs to be shepherded by globally coordinated measures to accelerate equitable financial access across countries and borders, especially in low-income countries such as in Sub-Saharan Africa.

One of the most pressing actions that would be beneficial is to accelerate the implementation of the 100 billion USD a year and more in climate finance commitment from developed to developing countries, by agreeing rapidly on key definitions. Shifting to a grant equivalent net flows definition of climate finance, which is now universally accepted for all other aid flows by all parties since 2014 and which took effect since 2019 on every other public international good finance provision (under the SDGs), with the sole exception of climate finance, would resolve many uncertainties: the disbursement of climate finance flows on a grant equivalent basis that is comparable across institutions, instruments and countries, and measure with precision the effective transfer of resources. The journey to get to a clear and precise definition of net Overseas Development Assistance (ODA) took enormous time: the original proposal was first initiated in the 1960s (Pincus 1963) but it was not till MDB’s and many others laid out the compelling reasons why this needed to be done (Chang et al. 1998), especially to resolve the decades of confusion and inconsistency between different types of financial flows and hence the perennial measurement problems and ‘the compromise between political expediency and statistical reality’ (Scott 2017; Hynes and Scott 2013; Scott 2015; Bulow and Rogoff 2005). Even private flows would benefit, by gaining clearer access to public funds defined on a grant equivalent basis. It makes little sense to have continuing debates on how these flows are to be defined and which flows are to be included, indefinitely (Khan et al. 2020) except in terms of avoiding responsibilities, even where the benefits would be high (Klöck et al. 2018) and by causing (unnecessary) fragmentation and complexity and often ‘strategic’ ambiguity by many actors (Pickering et al. 2017). The world would gain collectively if this issue were to be decided soon and clearly, even if this means that the starting commitments and phasing of reaching that goal, as well as the choice of principal instruments (such as the greater use of sovereign loan guarantees), might have to be reasonably reset where necessary. The absence of such a collective decision continues to be exceptionally costly for the implementation of the Paris Agreement and its collective actions because of the fractious and seemingly insoluble negotiating climate that this has created (Roberts and Weikmans 2017).

There are many other issues to be decided on the collective approach, especially on how to accelerate climate action for a Build Back Better (BBB) plan for climate after the pandemic. For example, global recovery from the pandemic will take much longer than initially envisaged (IMF, 2020; OECD, 2020), and the issue of better and more resilient jobs in which accelerating climate action might play a key role is part of the Just Transitions question. Already, there is enough evidence accumulated that a more sustainable climate path would generate many more net productive jobs (with much higher employment multipliers from given spending) than would any other large-scale alternative but would nevertheless require a carefully managed transition globally, including access to climate financing in developing economies (Muttitt and Kartha 2020). The multilateral finance institutions have generally played a supportive role, expanding their financing to developing countries during the pandemic (even as bilateral aid flows have fallen sharply), as in climate finance, but have been limited by their explicit roles in the Just Transition and limits within their mandates. Political leadership and direction will be again crucial to enhance their roles.

A review of past crisis episodes nevertheless suggests that collective actions to avoid large global or multi-country risks work well primarily when the problems are well-defined, a small number of actors are involved, solutions are relatively well-established scientifically, and public costs to address them are relatively small (Sandler 1998, 2015) (for example, dealing with early pandemic outbreaks such as Ebola, TB, and cholera; extending global vaccination programs such as smallpox, measles and polio; early warning systems and actions such as tsunamis, hurricanes/cyclones and volcanic disasters; Montreal Protocol for ozone depleting refrigerants, and renewables wind and solar energy development), but do not work well for more complex problems which are costly, technologically complex, and political and institutional leadership is fragmented (as in multi-country or multi-jurisdictional air quality management, deforestation, forest fires, global pandemics response, new vaccine development and COVID-19). These problems require political leadership, especially when the impacts are not near-term or imminent, diffuse, slow-moving and long-term, and preventive disaster avoidance costs are costly even when these costs are low compared to the longer-term damages—till we reach a tipping points of reduced ‘stressors’ and increasing ‘facilitators’ (Jagers et al. 2020). As one observer notes: *“Climate policies impose costs on specific sectors to create a public good. The climate benefits they produce are non-excludable; that is, everyone gains, including those who do not bear the costs of climate policies why workers in the fossil fuel and trucking industries view themselves as carrying the burden of climate protection—without much compensation. Unequal burden-sharing fosters a sense of victimhood, leading to a backlash against climate policies. that imposes costs disproportionately on specific sectors did not focus on equity in terms of helping those who bear the costs of climate policies.”*

Private institutional investors equally might pay attention to the issues. It would be useful for investors to identify support to such initiatives, and more clearly identifying the benefits of such transition measures envisaged by both countries and investment financing proposals, including requiring such initiatives in their support to ESG (environmental, social and governance) and labelled green bond financing proposals.

The second level of attention needed on Just Transitions has to do with inequities within a large country setting. As the ongoing pandemic illustrates, the first hit is often felt most acutely at the level of states and cities, with most of them having not enough fiscal capacity or ability to mount an adequate discretionary counter policy. Only national governments have that ability to borrow more in their fiscal accounts and to address large collective problems, whether pandemics or climate change. Therefore, it is important that national policies and funds be available for programs to address the Just Transition issues for larger sub-national states, cities and regions. This would be helped by countries including as a first-cut Just Transition initiatives in their NDCs for financing (as South Africa has recently done), and more attention by external agents and MDBs to the local adverse impacts issues in their climate policies and investments. It may be important for large-scale financing initiatives to explicitly discuss the Just Transition initiatives planned under the proposals. For example, the EU Green Deal plans to accomplish that through several initiatives (focusing on industries, regions and workers adversely affected with explicit programs to address them).

The third level of argument is for a shift in focus from an exclusive attention to financing of mitigation and low-carbon new investments projects to also better understanding and addressing the local adverse impacts of climate change on communities and people, who are vulnerable and increasingly dispossessed due to losses and damages from climate change or even those who are impacted by de-carbonisation measures in the fossil fuel sectors, transportation, as well as those who are harmed by polluting sectors: indigenous men and women, people of colour and generally the poor. It is evident that very few resources are available to countries, investors, civil society, and international development institutions seeking to achieve a just transition (Robins and Rydge 2020).

Finally, much greater support is warranted for local networks, SMEs, communities, local authorities and universities for more carefully prepared research ideas and proposals. For example, The Banking on a Just Transition project was launched in 2019 by the Grantham with the Sustainability Research Institute/ in partnership with UK Finance and the Place-based Climate Action Network (PCAN)/funded by HSBC and the London School of Economics.

15.3. Current flows and trends

15.3.1 Key concepts and elements of scope

Finance for climate action, or climate finance, is a subset of environmental finance, which also covers other environmental priorities such as water, air pollution and biodiversity, and is in turn a subset of sustainable finance. In addition to environmental objectives, sustainable finance encompasses issues relating to socio-economic and governance issues, i.e. the ESG set of criteria. Rather than being mutually exclusive, these concepts interact and complement each other as (ICMA 2020a; UNEP Inquiry 2016a). Their combination should lead to individual investments and financing activities contributing to multiple SDGs at once or, at a minimum, doing no harm to those SDGs not being targeted. Broadly speaking, climate finance refers to finance “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, significant room for interpretation and context-specific considerations remain, e.g. if and when to consider provided to cover the cost incurred from natural disasters and extreme climate events as climate finance (see Section 15.6.4 and WG II).

In practice, specifying the scope of climate finance requires defining two terms: what qualifies as “finance” and as “climate” respectively. In terms of what type of finance to consider, options include considering investments or total costs (see Box 15.2), stocks or flows, gross or net (the latter taking into account reflows and/or depreciation), a selection of or all financial actors and instruments (see Box 15.3), domestic or cross-border, public or private (see Box 15.4). In terms of what may be considered as “climate”, a key difference relates to measuring climate-specific finance (only accounts for the portion finance resulting in climate benefits) or climate-related finance (captures total project costs and aims to measure the mainstreaming of climate considerations).

Box 15.2 Core terms

This box defines some core terms used in this chapter as well as in other chapters addressing finance issues: cost, investment, financing, public and private. The aim is to clarify respective scope and avoid misinterpretations. The chapter makes broad use of the "finance" to refer to all types of transactions involving monetary amounts. It avoids the use of the terms "funds" and "funding" to the extent possible, which should otherwise be understood as synonyms for "money" and "money provided".

Cost, investment and financing: different but intertwined concepts. Cost refers to expenditures over the lifetime of a project. These include capital expenditures (CAPEX or upfront investment value), operating and maintenance expenditures (OPEX), as well as financing costs. While relatively large projects such as building and operating infrastructure typically involve all three categories of costs, some project types may only involve OPEX (e.g. staff costs) but no CAPEX, or may not incur direct financing costs (e.g. if fully financed via own funds and grants).

Investment, in an economic sense, is the purchase of (or CAPEX for) a physical asset (notably infrastructure or equipment) or intangible asset (e.g. patents, IT solutions) not consumed immediately but used over time to satisfy a need and create value. For financial investors, an investment corresponds to the purchase of an asset (physical, intangible, or financial such as bonds or stocks), expecting that the asset will provide income or be sold at a higher price. In practice, investment decisions (whether to invest, as well as the choice of a given investment between multiple options) are motivated by a calculation of an expected return that takes into account all expected costs, as well as an assessments of different types of risks that may impact the costs, outcomes and returns of the investment. Such risks include but are not limited to climate-related risks, as further discussed in Section 15.6.1.

Incremental cost (or investment) accounts for the difference between the cost (or investment value) for a climate projects compared to the cost (or investment value) of a counterfactual reference project (or investment). In cases where climate projects and investments are more cost effective than the counterfactual, the incremental cost will be negative.

Financing refers to the process of securing the money needed to cover an investment or project cost. Financing can rely on debt (e.g. through bond issuance or loan subscription), equity issuances (listed or unlisted shares), own funds (typically savings or retained earnings), as well as on grants and subsidies. Some sources of financing come at a cost (most notably interests due for debt), which increases the total financing needed for a given investment or project.

Public and private: statistical standard and grey zones. International statistics classify economic actors as pertaining to the public or private sectors. Households always qualify as private and governmental bodies and agencies as public. Criteria are needed for other types of actors such as enterprises and financial institutions. Most statistics rely on the majority ownership and control principle. This is the case for the Balance of Payment, which records transactions between residents of a country and the rest of the world (IMF 2009).

Such a strict boundary between public and private sectors may not always be suitable for mapping and assessing investment and financing activities. On the one hand, some publicly owned entities may have a mandate to operate on a fully- or semi-commercial basis, e.g. state-owned enterprises, commercial banks, and pension funds, as well as sovereign wealth funds. On the other hand, some privately owned or - controlled entities can pursue non-for-profit objectives, e.g. philanthropies and charities. The present chapter considers these nuances to the extent made possible by available data and information.

Box 15.3 Financial actors and instruments

Finance for climate action is 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.

Box 15.3, Table 1: From sources of finance to economic activities

Source	Actor	Instrument	Project Initiator	Climate-relevant sectors:
Taxes and levies Earnings and savings Capital markets	Governments Public financial institutions Commercial financial inst. Corporates Institutional investors Philanthropies / Households	Grants Debt Equity Guarantees Insurances	Public authorities Corporations SMEs Households	Agriculture Buildings Energy Industry Transport

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

Actors and instruments active in investing and financing activities with climate change mitigation and adaptation benefits vary greatly depending on, inter alia, different stages of technology maturity and project development, sectors (see finance sections of sector-specific chapters) as well as geographies. For instance, certain categories of actors, notably equity investors, may have a home bias, due to a combination of reasons relating in particular to risk, information and familiarity, e.g. (Lindblom et al. 2018).

In many cases, the scope of what may be considered as "climate finance" will also depend on the context of implementation such as priorities and activities listed in NDCs (UNFCCC 2019a) as well as national development plans more broadly targeting the achievement of SDGs. Hence, rather than opposing the different options listed above, the choice of one or the other depends on the desired scope of measurement, which in turn depends on the policy objective being pursued. The increasingly diverse initiatives and body of grey literature address a range of different information needs. They provide analyses at the levels of domestic finance flows (e.g. (Hainaut and Cochran 2018; UNDP 2015)), international flows (e.g. Joint-MDB (2018) and OECD (2016)), global flows ((UNFCCC 2018; CPI 2019a)), the financial system (e.g. (UNEP Inquiry 2016a)) or specific financial instruments such as bonds (e.g. (Climate Bonds Initiative 2018)). Reporting transparency as well as common language is, however, necessary in order to identify overlaps, commonalities and differences between these different measurements in terms of scope and underlying definitions.

Box 15.4: International climate finance architecture

International climate finance can flow through different bilateral, multilateral, and national channels, involving a range of different types of institutions both public (official) and private (commercial). In practice, the architecture of international public climate finance is rapidly evolving, with the creation of new public sources and channels of over the years (Climate Funds Update 2018). The operationalisation of the GCF, which channels the majority of its funds via accredited entities, has notably attracted particular attention since AR5. Section 14.3.2 of Chapter 14 provides a further assessment of progress and challenges of financial mechanisms under the UNFCCC, notably the GCF.

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 2019a; Geddes et al. 2018; Smallridge et al. 2013). The multiplication of sources and channels of international climate finance partly results from increased decentralisation and financial innovation, which in turn can increase the effectiveness of finance provided. There is, however, also evidence that increased complexity implies significant transaction costs (Brunner and Enting 2014). This is in part due to bureaucracy and intra-governmental factors (Peterson and Skovgaard 2019), which are most often not accounted for in assessments of international climate finance. On the ground, activities by international providers operating in the same countries may overlap, with sub-optimal coordination and hence duplication of efforts, both on the bilateral and multilateral sides (Ahluwalia et al. 2016). There are further emerging providers of development co-operation, both bilateral (see (Benn and Luijkx 2017)), multilateral (e.g. Asian Infrastructure Investment Bank), but also non-governmental actors such as philanthropies (OECD 2018a) . These necessarily interplay with (e.g. (Gallagher et al. 2018), compete with or run in parallel to (Humphrey and Michaelowa 2019) financing provided by traditional donor countries and institutions

Beyond the need to scale up 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 (UNFCCC 2015). This is a recognition that the mitigation and resilience goals cannot be achieved without finance, and without both the real economy and the financial system as a whole, being aligned. Since AR5, in addition to measuring and analysing climate finance, an increasing focus has been placed on monitoring the consistency or alignment, as well as respectively the inconsistency or misalignment, of finance with climate objectives.

Assessing climate consistency or alignment implies looking at all investment and financing activities, whether they target, contribute to, undermine or have no particular impact on climate objectives. This all-encompassing scope notably includes remaining fossil fuel-related investments and financing as well as other high-GHG emission activities that may be incompatible with remaining carbon budgets, but also activities that may play a transition role in climate mitigation pathways and scenarios. As a result, any meaningful assessments of progress implies the use of different shades to categorise activities based on their negative, neutral (“do no harm”) or positive contributions, e.g. (Cochran and Pauthier 2019; Natixis 2019; CICERO 2015). It further requires compiling, though not necessarily aggregating, a wide range of indicators across economic activities and financial value chain, covering both financial markets and the real economy (Jachnik et al. 2019), as well as the monitoring of public interventions that directly or indirectly affect investment and financing decisions (ODI et al. 2018).

15.3.2 Assessment of current financial flows

15.3.2.1 Financial flows and stocks: orders of magnitude

Assessments of finance for climate action need to be placed within the broader perspective of all investments and financing flows and stocks. This section provides aggregate level reference points of relevance to the remainder of this Chapter, notably when assessing current levels of climate and fossil fuel-related investments and financing (Sections 15.3.2.2 and 15.3.2.3 respectively), as well as estimates investment and financing needed to meet climate objectives (Section 15.4).

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). On the flows side, GDP, a System of National Accounts (SNA) statistical standard, aggregates flows of investments, operating expenses and consumption, all of which have a significant direct and indirect climate footprints. In 2019, global GDP reached 88 trillion USD, out of which developed countries represented close to 60% (Figure 15.3). The GDP metric has numerous limitations (e.g. lack of any indication relating to human wellbeing or SDG achievements) and even produces perverse incentives. From an environmental perspective, GDP counts positively activities that negatively impact the environment, without making deductions for the depletion and degradation of natural resources.

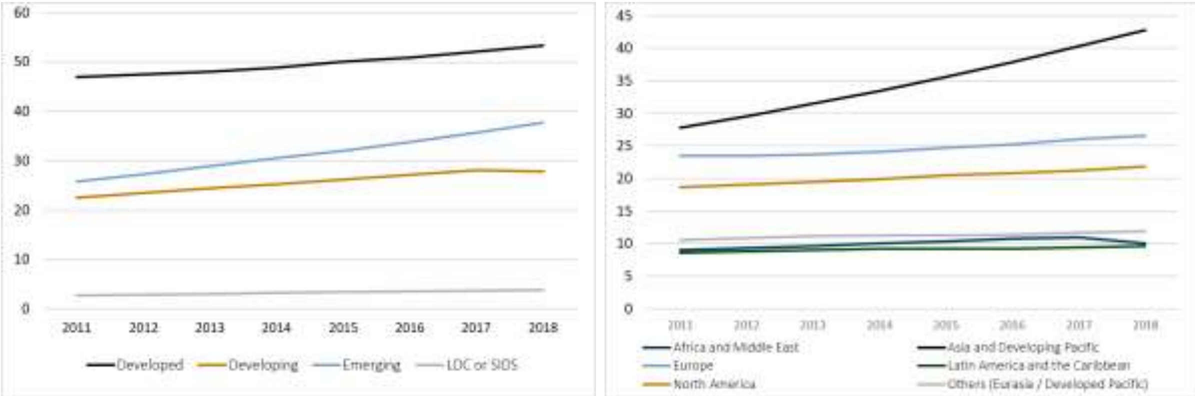


Figure 15.3 Financial flows – GDP by Type of Economy (left) and Region (right)
Note: Emerging represents BRICS countries (Brazil, Russia, India, China, South Africa). Developing represents official UN country classification minus Emerging, LDC or SIDS. Regions represent combination of IPCC RC5 and RC10 to ensure regional neutrality to the most possible extend. GDP in 2017 constant intl. dollar.
Source: World Bank Data (2020a,b)

Gross-fixed capital formation (GFCF), another SNA standard that covers tangible and intangible assets, is a good proxy for investment flows in the real economy. It notably captures investments in infrastructure, with infrastructure estimated to be directly responsible for over 60% of GHG emissions over its lifetime (New Climate Economy 2016). In 2018, global GFCF reached 21.9 billion USD compared to 15.4 billion USD in 2008, a 42% increase (Figure 15.4). Global GFCF represents about a quarter of global GDP, a relatively stable ratio since 2008. This share is, however, much higher for emerging economies, notably in Asia, which are building new infrastructure at scale. As analysed in Sections 15.4 and 15.5, infrastructure investment needs and gaps in developing countries are significant. How these are met over the next decade will critically influence the likelihood of reaching the Paris Agreement temperature goal (add cross reference to other chapters as relevant).

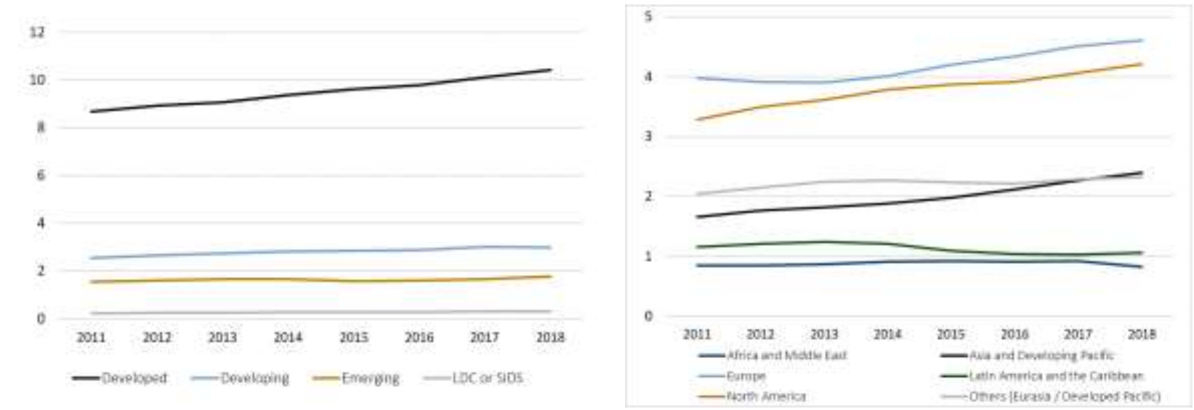


Figure 15.4 Financial flows – Gross Fixed Capital Formation per Type of Economy and Regions
Note: Emerging represents BRICS countries (Brazil, Russia, India, China, South Africa). Developing represents official UN country classification minus Emerging, LDC or SIDS. Regions represent combination of IPCC RC5 and RC10 to ensure regional neutrality to the most possible extend. Gross fixed capital formation (GFCF) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. GDP in 2017 constant intl. dollar.
Source: World Bank Data (2020a,b)

One the stock side (Figure 15.5), there is a growing gap between the values of tangible and financial assets, which results from the financialisaton of economies at domestic and international levels. In other words, an increasingly significant portion of available capital is not financing the real economy. This trend, however remains uneven between developed countries, most of which have relatively deep capital markets, and developing countries, where local capital market development remains partial or elusive (Section 15.6.7). Bonds, a form of debt financing, represent a significant share of total financial assets. As of August 2020, the overall size of the global bond markets (amount outstanding) was estimated at approximately 128.3 trillion USD, out of which over two thirds from “supranational, sovereign, and agencies”, and just under a third from corporations (ICMA 2020b). As discussed in following sections of the Chapter, since AR5, an increasing number and volume of bonds have been earmarked for climate action but these still only represent a small share of the total bond market, while already raising concerns in terms of both underlying definitions (Section 15.6.6) and risks of increased climate-related indebtedness (Section 15.6.1, 15.6.3).

From the perspective of climate change action, these orders of magnitude make it possible to highlight three points. First, the relatively small size of current climate finance flows and relatively larger size of remaining fossil fuel-related finance flows, as highlighted in the following two sub-sections. Second, the significant scale of financial flows and stocks that have to be made consistent with climate goals. Third, the in principle availability of necessary volumes of finance for addressing climate-related investment needs (Section 15.4) and gaps (Section 15.5).

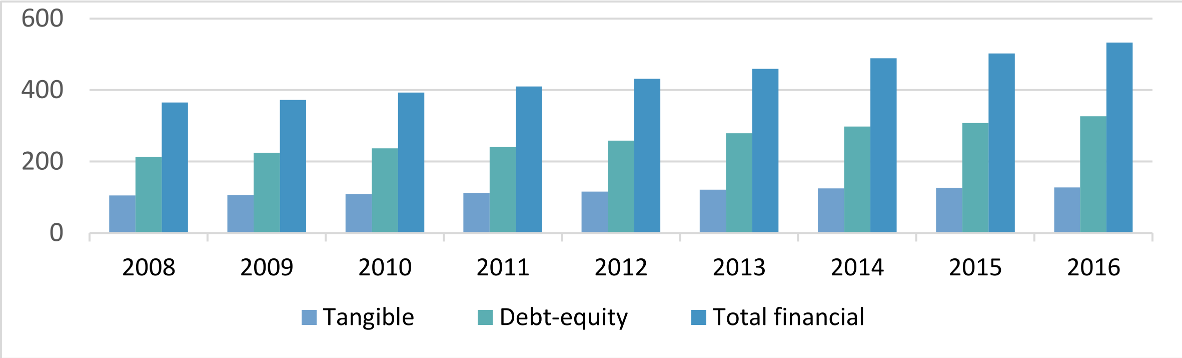


Figure 15.5 Stock Assets (OECD and BRICs) Note: Data series to be updated. "Tangible" notably covers buildings, infrastructure and equipment. "Debt-equity" refers to loans, bonds and stocks, while "Total financial" also includes further elements such as gold reserves, bank deposits, insurances and pensions entitlements as well as financial derivatives.

Source: OECD.Stat (2019a,b).

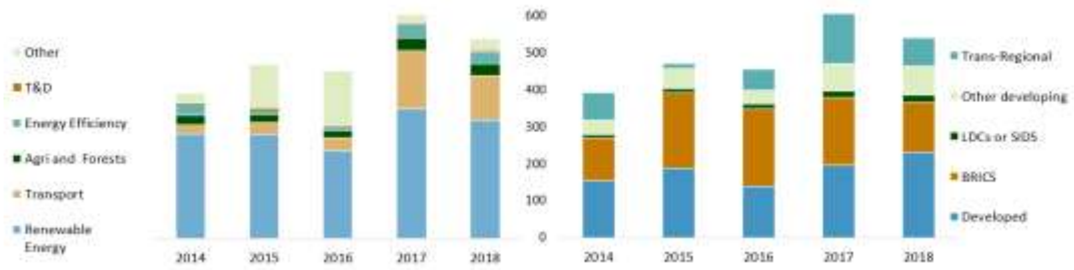
15.3.2.2 Estimates of climate finance flows

The measurement of climate finance flows continues to face similar definitional, coverage and reliability issues than at the time of AR5 and special report on the impacts of global warming of 1.5°C, 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 (Table 15.1) of 681 billion USD in 2016 (UNFCCC 2018). Latest available estimates, however, indicate a drop in 2018 (CPI 2019a) and a rebound in 2019 (forthcoming). Although not directly comparable in terms of scope, current climate finance flows remain small (approximately 3%) compared to the GFCF reference point introduced in Section 15.3.1, as well as needs to be put in perspective with remaining fossil fuel financing (see Section 15.3.2.2). The scale of current climate finance is also significantly below estimate of needs presented in Section 15.4.

Table 15.1: Total climate finance flows between 2013 and 2019

Source	Type	2013	2014	2015	2016	2017	2018	2019
UNFCCC SCF total high		687	584	680	681	tbc	tbc	n/a
UNFCCC SCF total low / CPI		339	392	472	456	tbc/608	tbc/540	n/a

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 excludes from the lower bound and CPI's estimates. CPI numbers slightly differ from official publication due to IPCC country classification and non-allocable flows. Source: (CPI 2019a; UNFCCC 2018). CPI numbers slightly differ from CPI publications due to allocation objectives (e.g. for the year 2018, CPI reports 546bn in total in (CPI 2019a)).



Sector **Type of Economy**

Figure 15.6: Available estimates of global climate finance between 2014 and 2018

Source: Own calculations, based on CPI database. Numbers in billion USD

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 2019a). This indicates that the home bias of finance and investment introduced in Section 15.2 and further discussed in the context of investment and financing gaps in Section 15.5, holds for climate finance. It also reinforces the point that national policies and settings remain crucial (Section 15.6.2), along with the development of local capital markets (Section 15.6.7).

Climate finance in developing countries remains heavily concentrated in emerging economies, with BRICS accounting for 25% to 43% depending on the year, a share similar to that represented by developed countries. LDCs and SIDs, on the other hand, continue to represent less than 5% year-on-year (BNEF 2019; CPI 2019a). Further, the relatively modest growth of climate finance in developed countries is a matter of concern given that economic circumstances are, in most cases, relatively more amenable to greater financing, savings and affordability than in developing countries.

The majority of tracked climate finance is assessed as coming from private actors (CPI 2019a), although, as discussed in Box 15.2, the boundaries between private and public finance include significant grey zones. Further, private investments in climate projects and activities often benefit from public support in the form of co-financing, guarantees or fiscal measures. In terms of financial instruments and mechanisms, debt and balance sheet financing (which can rely on both own resources and further debt) represent the lion's share. In this context, the rapid rise of climate-related bond issuances since AR5 (CBI 2020a) represents an opportunity for scaling up climate finance but also poses underlying issues of integrity (Nicol et al 2018; Shislov et al. 2018) and additionality (Schneeweiss 2019), as further discussed in Section 15.6.6.

Mitigation continues to represent the lion's share of global climate finance (93% on average in 2017-18), and in particular renewable energy and energy efficiency (70% to 80% combined depending on the year) (CPI 2019a; UNFCCC 2018). While capacity additions on the ground kept rising, 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 (IRENA 2019a; BNEF 2019). However, such cost reduction should in principle free up investment and financing capacities for potential use in other climate-related activities.

Tracking adaptation finance continues to pose significant challenges in terms of data and methods. Notably, the mainstreaming of resilience into investments and business decisions makes it difficult to identify relevant activities within financial datasets (Averchenkova et al. 2016; Agrawala et al. 2011; Brown et at., 2020). Despite these limitations, evidence shows that finance for adaptation remains fragmented and significantly below rapidly rising needs (Section 15.4 and Working Group II). Further, there is increasing awareness about the need to improved coherence between climate change adaptation and disaster-risk-reduction (DRR) towards achieving resilience (OECD 2020a). Watson et al., (2015) however, 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 (Watson et al. 2015; Nokhooda et al. 2014; Climate Funds Update 2014). 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).

More generally, 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 (CPI 2019a; UNFCCC 2018).
- In contrast to international public climate finance, domestic public finance data is very partial despite initiatives to track domestic climate finance (e.g. (Hainaut and Cochran 2018)) and public

expenditures (for instance based on the UNDP's Climate Public Expenditure and Institutional Review approach).

- Data on private and commercial finance remains very patchy, particularly for balance sheet corporate investments and bilateral loan financing provided by commercial banks (Jachnik et al. 2019).

Further, as individual source of aggregate reporting (FS-UNEP Centre and BNEF 2020; CPI 2019a; UNFCCC 2018) 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.

Such data gaps as well as varying definitions of what qualifies as "climate" (or more broadly as "green" and "sustainable") not only pose a measurement challenge. They also result in a lack of clarity for investors and financiers seeking climate-related opportunities. Such uncertainty can lead both to reduced climate finance as well as to a lack of transparency in climate-related reporting (further discussed in Section 15.6.1), which in turn further hinders reliable measurement.

In terms of finance provided and mobilised by developed countries for climate action in developing countries, accounting scope and methodologies continue to be debated (see Box 15.4). A consensus, however, exists, on a need to further scale up public finance and improve its effectiveness in mobilising private finance (OECD 2020b), as well as to further prioritise adaptation financing, in particular towards the most vulnerable countries (Oxfam 2020). The relatively low share of adaptation may in part due to a low level of obligation and precision in 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).

Box 15.5 Measuring progress towards the 100 billion USD yr^{-1} **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 dollars a 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 2009). As the parameters for what and how to count were not defined when the goal was set, there remains well documented interpretations and debates on how to account for progress (Jachnik et al. 2015; Stadelmann et al. 2013; Clapp et al. 2012; Weikmans and Roberts 2019).

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, e.g. pledges, commitments, disbursements. There can be significant lags between these different points in time, e.g. disbursements may spread over time. Further, the choice of point of measurement can have an impact on both the volumes and on the characteristics (geographical origin, labelling as public or private) of the finance tracked. The enhanced transparency framework under the Paris Agreement may lead to improvements and more consensus in the way climate finance is accounted for and reported under the UNFCCC. Available analyses specifically aimed at assessing progress towards the 100 billion USD goal remain rare, e.g. the UNFCCC SCF Biennial Assessments do not directly address this point (UNFCCC 2018). Dedicated OECD reports provide figures based on accounting for gross flows of climate finance based on analysing activity-level data recorded by the UNFCCC (bilateral public climate finance) and the OECD (multilateral public climate finance, mobilised private climate finance and climate-related export credits) (OECD 2019b, 2015a, 2020b). For

2018, the OECD analysis resulted in a total of 78.9 billion USD, out of which 62.2 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%.

Reports by Oxfam provide a complementary view on public climate finance, building on OECD figures and underlying data sources to translates gross flows of bilateral and multilateral public climate finance in grant equivalent terms (Oxfam 2018a, 2016, 2020). Annual averages for 2015– 2016 and 2017–2018, indicate that grant equivalence represents between 32% (low bound) and 44% (high bound) of gross public climate finance. The difference with OECD figures stems from the high share represented by loans, both concessional and non-concessional, in public climate finance, i.e. 74% in 2018 2018 (OECD 2020b). Further, Oxfam also partly discounts bilateral climate finance for some donors to account for possible over-reporting of finance for activities with only low climate relevance.

A point of method that attracts much attention relates to how to account for private finance mobilised. OECD figures rely on methods to attribute private finance at activity level to public finance providers involved, based on the characteristics of the finance they provide (mechanism, risk, volume) (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 (AfDB et al. 2020). MDB estimates of mobilised private finance and the underlying methodology (World Bank 2018a), however, neither correspond to the geographical scope of the 100 billion USD goal, nor address the issue of attribution to the extent required in that context. Notwithstanding methodological discussions under the UNFCCC, there is still some distance from the 100 billion USD a 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 15.4), its fulfilment can both contribute 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)

15.3.2.3 Fossil fuel-related and transition finance

As called for by Article 2.1c of the Paris Agreement and introduced in Section 15.3.1, achieving the temperature goal of the Paris Agreement requires making all finance consistent with this goal. Data on investments and financing detrimental to climate mitigation remain very partial and difficult to access, as relevant actors currently have little incentive or obligations to disclose such information compared to reporting on and communicating about their activities contributing to climate action. Further, the development of methodologies to assess finance for activities misaligned with climate mitigation goals, for hard- and costly-to-abate sectors such as heavy industries, as well as for activities that eventually need to be phased out but can play a transition role for given period, remain work in progress. This results in limited empirical evidence to date.

Scenarios compatible with a below 2°C warming, however, make it clear that the share of fossil fuels in energy supply has to decrease (oil) or even be phased out (coal). To avoid locking GHG emissions incompatible with remaining carbon budgets, this implies a rapid scaling down of new fossil fuel-related investments. However, available estimates indicate these remain significant in absolute and relative terms.

The International Energy Agency provides comprehensive analyses of global energy investments, estimated at about 1.8 trillion USD a year over 2017–2019 (IEA 2020a, 2019a), which represents about

8% of global GFCF (Section 15.3.2.1). In the power sector, fossil fuel-related investments reached an estimated 130 billion USD yr^{-1} on average over 2017–2019, which remains well above the level that underpin the IEA's own Paris-compatible Sustainable Development Scenario (SDS) scenario. The IEA observes a similar inconsistency with its SDS scenario for supply side new investments: in 2019, an estimated 700 billion USD were invested in oil supply and 100 billion USD in coal supply. These estimates also result in fossil fuel investments remaining larger in aggregate than the total tracked climate finance worldwide (Section 15.3.2.2). For oil and gas companies, which are amongst the world largest corporations and sometimes government owned or backed, low-carbon solutions are estimated to represent less than 1% of capital expenditure (IEA 2020a). As discussed in the remainder of this Chapter, shifting investments towards low-carbon solutions requires a combination of conducive public policies and attractive investment opportunities.

In terms of underlying financing provided to fossil fuel investments, a limited set of civil society analyses point out to a still significant role played by commercial banks and export credit agencies. Commercial banks provide both direct lending as well as underwriting services, the latter facilitating capital raising from investors in the form of bond or share issuance. Available estimates indicate that lending and underwriting extended over 2016 –2019 by 35 of the world's largest banks to 2,100 companies active across the fossil fuel life cycle, reached USD 687 billion yr^{-1} on average (Rainforest Action Network et al. 2020). Official export credit agencies, which are owned or backed by their government, de-risk exports by providing guarantees and insurances or, less often, loans. In 2016–2018, available estimates indicate the provision of about 31 billion USD yr^{-1} worth of fossil fuel-related official export credits, out of which close to 80% for the oil and gas, and over 20% for coal (Oil Change International and Friends of the Earth - U.S. 2020).

Finance for new fossil fuel-related assets lock in future GHG emissions that may be inconsistent with remaining carbon budgets and, therefore, with emission pathways to reach the Paris Agreement temperature goal. This inconsistency exposes investors and asset owners to the risk of stranded assets, which results from potential sharp strengthening climate public policies (transition risk). As a result, a growing number of investors and financiers are assessing climate-related risks with the aim to disclose information about their current level of exposure (to both transition and physical climate-related risks), as well as to inform their future decisions (TCFD 2017). Reporting to date is, however, inconsistent across geographies and jurisdictions (CDSB and CDP 2018; Perera et al. 2019). Further developed in Sections 15.6.3, there is currently not enough evidence in order to conclude whether climate-related risk assessments result in increased climate action and alignment on the ground (e.g. 2° Investing Initiative 2017).

As developed in Section 15.6.3, the insufficient level of ambition and coherence of public policies at national and international level remains the root cause of the still significant misalignment of investment and financing compared to pathways compatible with the Paris Agreement temperature goal (UNEP 2018b). Such lack of coherence includes misaligned policies in non-climate policy areas such as fiscal, trade, industrial and investment policy, and financial regulation (OECD 2015b), which is further specified in sectoral chapters 6 to 12.

The most documented policy misalignment relates to the remaining very large scale of public direct and indirect financial support for fossil fuel-related production and consumption in many parts of the world (Climate Transparency 2020; Coady et al. 2017; Bast et al. 2015). Fossil fuel subsidies are embedded across economic sectors as well as policy areas, e.g. from a trade policy perspective, in most countries, import tariffs and non-tariff barriers are substantially lower on relatively more CO_2 intensive industries (Shapiro 2020). Available inventories of fossil fuel subsidies (in the form of direct budgetary transfers, revenue forgone, risk transfers, or induced transfers), covering 76 economies, indicate a rise to USD 340 billion in 2017, a 5% increase compared to 2016. Such trend is due to slowed down progress in reducing support among OECD and G20 economies in 2017 (OECD 2018b) and to a rise in fossil-fuel subsidies for consumption in several developing economies (Matsumura and Adam 2019). Given the scale of historical support to fossil fuel 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, transport and buildings sectors, remain high, and the risk return profile of fossil fuel-related investments it still positive in many instance (Hanif et al. 2019). Political economy constraints of fossil fuel subsidy reform continue to be a major hurdle for climate action (Röttgers and Anderson 2018; Schwanitz et al. 2014). On the other hand, a gradual phasing out of fossil fuels subsidies could provide an effective market signal and reduce risks of stranded assets and of negative distributive effects of a low carbon transition, in particular when coupled with fiscal policies (e.g. a carbon tax) and reinvestments of revenues to support low-carbon energy investments (Monasterolo and Raberto 2019).

15.3.3 Consideration on the impact of sustainable finance products

Investments that are managed taking into account sustainability criteria, have increased constantly over the last years. According to the 2018 biennial assessment by Global Sustainable Investment Alliance, sustainable investments in five major developed economies grew by 34%since 2016. The primary ESG approaches leveraged were exclusion criteria/negative screening and ESG integration, which together amounted to over USD 37 trillion, accounting for two-thirds of the assessed sustainable investments, with novel strategies such as best-in class screening and sustainability themed investing showing significant growth, although together they accounted for a little over USD three trillion, less than six percent of the investments. Shareholder activism/corporate engagement is the other key approach, which has been well established and continued to grow to nearly USD 10 trillion (GSIA 2018). While obvious in the case of direct impact investing, questions have arisen with regard to the direct impact of sustainable finance products based on exclusion criteria and best-in-class approaches on emission reductions. This also against the background of emerging mandatory impact reporting for asset managers. While there is a lack of research on sustainable finance products, divestment impact has been assessed in more detail. Although research points towards the ambiguous direct impact of divestment on reducing GHG emissions or on the financial performance of fossil fuel companies, its indirect impact on framing the narrative around sustainable finance decisions (Bergman 2018) and the inherent potential of the movement for building awareness and mobilizing broader public support for effective climate policies, could be considered to be the more relevant outcomes (Braungardt et al. 2019). Arguments against divestment point to its largely symbolic nature with minimal impact on tangibly achieving climate goals, but Braungardt et al. (2019) elaborate on the broader positive impacts of divestment, which includes its ability to stigmatise and reduce the power of the fossil fuel companies on policy-making and spur climate action as a moral imperative, and the potential of the approach to mitigate systemic financial risks arising due to climate change and address the legal responsibilities of investors merging in this regard. As there is still at best an emerging trend of price premiums for green investments in the market, as seen in the green bonds market (see Section 15.6.6), the broader impact of sustainable investment initiatives could play a key role in strengthening the demand and supply of such investment opportunities for the near future.

Based on currently available data for fund managers, exclusion criteria as well as best-in-class approaches have focused primarily on the current performance of companies rather than taking a forward-looking approach as needed to assess the alignment with long-term global goals. This highlights the need for more extensive ESG disclosure on a corporate level. Challenges remain with regard to standardised definitions of sustainable investment opportunities, which also vary depending on social norms and pathways. The ongoing shift towards sustainable investment strategies and increased sustainable development awareness in the financial sector points to the ability of civil society movements, such as the divestment campaign, to influence investor behaviour to an extent, especially if backed by regulatory or policy measures. In its status report, TCFD stated that over 1,500 organisations, representing a combined market capitalisation of USD 12.6 trillion and around USD 150 trillion in assets, have expressed their support for adopting TCFD recommendations for integrating climate risk assessments and disclosing these (TCFD 2020). Research, focused on developed economies, indicates towards a positive relation between ESG criteria and disclosure, and economic sustainability or corporate financial performance of a firm (Friede et al. 2015; Alsayegh et al. 2020; Giese et al. 2019) and that sustainable finance initiatives, such as divestment doesn't adversely impact investment portfolio performance (Trinks et al. 2018; Henriques and Sadorsky 2018). However, studies show that ESG investors and those investing in asset classes such as green bonds, are largely doing so at present for the non-financial business case, with incentives including an ability to attract new category of customers and opportunity to invest in verified green or sustainable projects, rather than for a tangible financial advantage in the form of higher returns (Maltais and Nykvist 2020; van Duuren et al. 2016). This further illustrates the importance of changing demand patterns and raising awareness among asset owners.

The indications of the growing greening of the finance sector is further reiterated by the spate of recent announcements by leading finance institutes in the developed economies, ranging from investment funds like BlackRock's new climate-aligned investment strategy (Black Rock 2020) and Barclays ambition to be a net zero bank by 2050 (Barclays 2020). Further, investor led collaborative initiatives too are paving the way for growing sustainable investments, including Climate Action 100+, the Sustainable Banking Network and the One Planet initiative, with each being backed by over USD 30 trillion in assets . Most recently, the Net Zero Asset Managers initiative was launched, with the 30 founding signatories with over USD 9 trillion worth of assets under management, committing to net zero GHG emissions by 2050 (IPE 2020). It should be noted that integration of ESG criteria and disclosures on their own are unlikely to enable climate-aligned investments, especially in the emerging economies, as support and clear direction from regulatory and policy mechanisms are required to drive institutional investors at large (Ameli et al. 2019).

15.4. Financing needs

15.4.1. Definitions and qualitative assessment of financing needs

Financing needs are discussed in various contexts only one being international climate politics and finance. Also, financing needs are used an indicator for required system changes (when compared to current flows and/or asset bases) and an indicator for near- to long-term investment opportunities from the perspective of investors and corporates. Investment needs are widely used as an indicator focussing on initial investments required to realise new infrastructure. It compares relatively well with private sector flows which are dominated by return-generating investments but lacks comparability and explanatory power with regard to the needs in the context of international climate cooperation where considerations on economic costs play a stronger role. Chapter 12 elaborates on global economic cost estimates for various technologies, which as a stand-alone indicator suffers from various disadvantages as well. In addition, there are financing needs not directly related to the realisation of physical infrastructure and which are not covered in both, investment and cost estimates. For instance, the need for building institutional capacity might not be significant, but an enabling environment for future investments would not be established without satisfying it. Moreover, comprehending financial needs for addressing loss and damage can hardly be measured in terms of the indicators introduced before.

Understanding the magnitude of the challenge to scale-up finance in sectors and regions requires a more comprehensive (and qualitative) assessment of the needs. For finance to become an enabler of the transition, domestic and/or international public interventions can be needed to ensure a sufficient supply of finance across sectors, regions and stakeholders. The location of financing needs and vicinity to capital matter given home bias, transaction costs and risk considerations. Most of the finance is mobilised domestically but the depth of capital markets is substantially greater in developed countries increasing the challenges to mobilise substantial volumes of additional funding for many developing countries. The same applies to various stakeholders with limited connections into the financial sector. In addition, enabling financial market frameworks, guidelines and supportive infrastructure by governments is crucial for inclusive finance for the bottom of the pyramid (BoP), especially disadvantaged and economically marginalised segments of society.

The attractiveness of a sector and/or region for capital markets depend on a number of factors. Some important elements are the payback period and profile as long payback periods and heavily heterogeneous returns represent challenges in the financing of mitigation technologies and policies. After the financial crisis and restricted access to long-term debt, a long payback period of investment opportunities for mitigation technologies has been a crucial challenge. Also, implicit discount rates applied during the investment decision process vary depending on the payback profile, with research particularly covering the difference between the financing of assets generating revenues versus costs (Jaffe et al. 2004; Schleich et al. 2016). In addition, a low correlation between the project and dominating asset classes might provide an opportunity in climate action by satisfying the appetite of institutional investors, which tend to manage portfolios with consideration of the Markowitz modern portfolio theory (Marinoni et al. 2011). Transaction cost is an important barrier creating challenges on the diffusion and commercialisation of low-carbon technologies and business models but also adaptation action. High transaction costs, attributed from various factors, such as complexity and limited standardisation of investments, limited pipelines, complex institutional and administrative procedures, create significant opportunity costs (IRENA 2016; Nelson et al. 2016; Feldman et al. 2018). For example, challenges of transaction costs are commonly observed in small-scale, dispersed independent renewable energy systems, especially in a rural area, and energy efficiency projects (Hunecke et al. 2019). A stronger standardisation and alignment of power purchase agreement terms with best practices globally has led to a substantially increased interest of capital markets also in less developed countries. Notably, Power Purchase Agreement (PPA) significantly increase the probability for more balanced investment and development outcomes and ultimately more sustainable independent power projects in African countries. Therefore, lowering transaction costs would be essential for creating investor appetite. The role of intermediaries bundling demand for financing has been demonstrated to reduce transaction costs and to reach the critical size for investors. In addition, new innovative approaches, such as fintech and blockchain (see Section 15.6.8), have been discussed for providing new opportunities in the energy sector. Decentralisation of the system based on blockchain technology allows all participant to enter and make transactions in the network without third-party intermediaries and consequently increase transparency and reduce transaction costs (IRENA 2019b; Schletz et al. 2020).

Economic viability of investments – ideally not relying on the pricing of positive externalities – has been a key driver of momentum in the past. The falling technology costs and the competitiveness of renewable technologies, especially of solar and wind, has been accelerated the deployment of renewable technologies over the past years, and renewable energy technologies now often competitive in selected markets, even without financial support from the public sector (IEA 2020b; FS-UNEP Centre and BNEF 2015, 2016, 2017, 2018, 2019) and without pricing of the avoided carbon emissions. In contrast, the dependency on regulatory interventions and public financial support to create financial viability has provided a source of volatile investor appetite. The annual volume of renewable investment by country often volatiles reflecting ending and new regulations and policies (IEA 2019a). For example, the recent Chinese policy direction towards tougher access to and a substantial cut in feed-in-tariff in 2018 led the significant drop in renewable investment and new capacity addition in China (Hover 2020; FS-UNEP

Centre and BNEF, 2019). Investors had proven to be willing to work with transparent support mechanisms, such as with the Clean Development Mechanism (CDM), which stimulated emission reductions and by allowing industrialised countries to implement emission-reduction projects in developing countries to meet their own emission targets. However, the collapse of carbon markets and prices, especially of EU ETS, led to the continuous decline of CER issuances from CDM in the past years (World Bank Group 2020a). Also, the dependency on regulatory intervention to ensure fair market access only has proven to burden investor appetite.

A significant share of investment needs in heavily regulated sectors, such as electricity, public transport, and telecom, emphasises the importance of regulatory intervention, such as ownership and market access (OECD 2017). The regulated ownership of the private sector contributed to the low level of investment in infrastructure research and innovation (European Commission 2017). Moreover, changes in regulation may create uncertainty of investment, and barriers to market entry and exit also potentially limit the competition in the market and restrict the entrance of new investment (EIB 2016).

The positive development in the energy sector has clearly benefitted from the clear stand-alone character of renewable energy generation projects. These greenfield type projects were realised by first movers with investors and developers acting from conviction. Such action is not possible to this extent in the field of energy efficiency with related investment rather representing an add-on component and consequently requiring the support of decision-makers used to business as usual projects. Despite improvement of energy efficiency having a number of benefits that can contribute to curbing energy consumption, mitigating greenhouse gas emissions, and providing multiple co-benefits (IEA 2014), investment in energy efficiency is at a low priority for firms, and the financial environment is not favourable due to lacking awareness on energy efficiency by financial institutions, existing administrative barriers, lack of expertise to develop projects, asymmetric information, and split incentives (UNEP DTU 2017; Cattaneo 2019). While Energy Service Companies (ESCO) business model is expected to facilitate the investment in energy efficiency by sharing a portion of financial risk and providing expertise, there has been limited progress made with ESCO business models, and only slightly over 20% of projects used financing through ESCOs (UNEP DTU 2017).

The investment needs and existing challenges differ by sector as each sector has different characteristics along the arguments listed above making the supply of finance by commercial investor an enabling factor or barrier. In the transport sector, transformation towards green mobility would provide significant co-benefits for human health through the reduction of transport-related air pollution, so the transport sector cannot achieve such transformation in isolation with other sectors. A significant involvement of the public sector in many transportation infrastructure projects, however, is given and the absence of a standard solution increases transaction costs (including bidding package, estimating, drawing up a contract, administering the contract, corruption and so on). In the agriculture sector, financial constraints, including access to sufficient and adequate finance, pose a significant challenge, especially for SMEs and smallholder farmers. The distortion created by government failure and a lack of effective policies create barriers to financing for agriculture, and the inability to manage the impact of the agriculture-related risks, such as seasonality, increases uncertainty in financial management. Moreover, inadequate infrastructure, such as electricity and telecommunication, makes financial institutions to reach agricultural SMEs and farmers difficult and increases transaction costs (World Bank Group 2016). Low economies of scale, low bargaining power, poor connectivity to markets, and information asymmetry also lead to higher transaction cost (Pingali et al. 2019). In other industrial manufacturing and residential sector, gaining energy efficiency remains one of the critical challenges. Investment in achieving energy efficiency encounters stringent hurdles when it may not necessarily generate direct or indirect benefits, such as increase in production capacity or productivity and improvement in product quality. Also, early-stage, high upfront cost and future, stable revenue stream structure suggest the needs for a better enabling environment, such as a strong financial market, awareness of financial institutions, and regulatory frameworks (e.g., stringent building codes, incentives for ESCOs) (Barnsley et al. 2015; IEA 2014).

15.4.2. Quantitative assessment of financing needs

Multiple stakeholders prepare and present quantitative funding needs assessments with methodologies applied varying significantly. The differences relate to the scope of the assessments with regard to sectors, regions and time periods, top-down versus bottom-up approaches as well as methodological issues around boundaries of climate related investment needs, in particular full vs incremental costs and the ex/inclusion of consumer level investments. 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 analysis of renewable power generation costs carried out by the International Renewable Energy (IRENA) demonstrates the extremely broad ranges of LCOE (equal to the agreed auction prices and power purchase agreement tariffs) for renewable energy projects (IRENA 2020a). For example, the 5th and 95th percentile range of LCOE for utility-scale PV projects in 2019 ranged from 0.052 USD kWh^{-1} to 0.190 USD kWh^{-1}. In addition, the modelling community has underestimated repeatedly economies of scale with assumptions on future technology prices. This has led to very conservative assumptions when it comes to competitiveness of low-carbon technologies, limited consideration of the momentum created by falling technology costs and high investment forecasts despite conservative assumptions on for example renewable energy capacity to be added. Figure 15.7 below illustrates the range of current technology cost assumptions for 2020, 2030 and 2050, exemplary for solar PV and onshore wind.

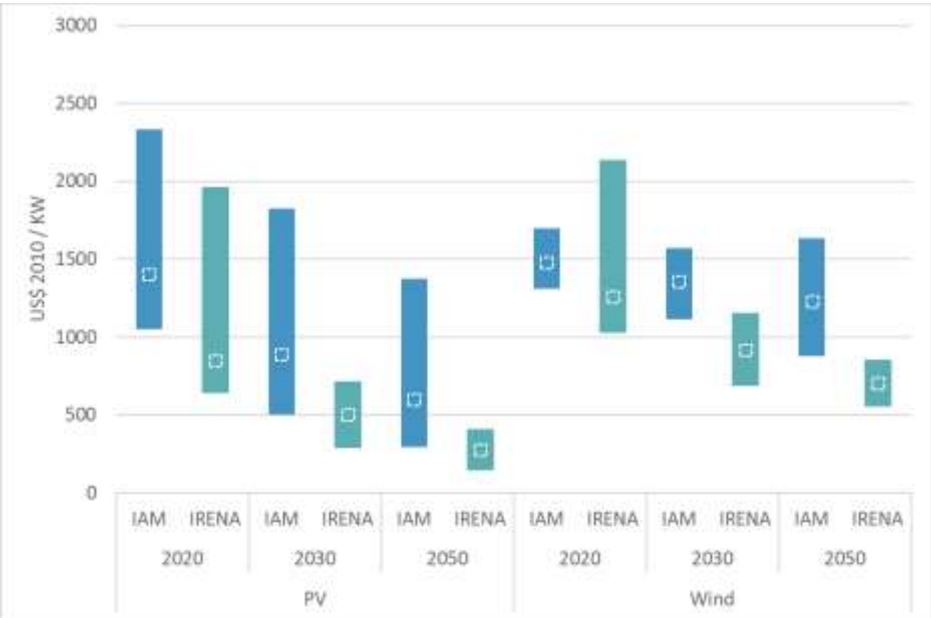


Figure 15.7: Cost assumptions IRENA and IAM for PV and Wind in 2020/2030/2050

Note: Current capital cost assumptions for 2020, 2030 and 2050, exemplary for solar PV and Wind onshore technologies based on the models comprised from the AR6 Integrated Assessment Model (IAM)

scenarios database (for end-of-the-century peak temperature range: 1.75°C-2.25°C) derived in chapter 3 and current world market prices as well as IRENA forecasts (<2°C).
Blue bars: Range of 15 IAMs. Green bars: Range of IRENA models. Square represent mean value IAM. No mean available for IRENA for 2030 and 2050, square represents the middle of min and max

Usually, standardised assumptions are applied on soft costs, like balance-of-system (BOS) costs and financing costs, and do not reflect the reality of developing renewable energy projects in many developing countries (IDB 2019). Ameli et al. (2021) flag the "climate investment trap" created by inappropriate assumptions on financing costs in developing countries. Applying significantly standardised assumptions can consequently not provide robust insights for specific country groups. While IAMs mostly discuss investment needs to achieve the Paris Agreement 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 15.2 and 15.3 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 identifying required transformations in the energy sector to reach specific long-term climate targets. However, reporting of investment needs outside the energy sector was scarce reducing the explanatory power of total in the context of overall investment needs. 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 (see "Annex C: Scenarios and modelling methods" for details). The presentation in Tables 15.2 and 15.3 focuses on the near-term (2023–2032) investment requirements in the energy sector and how this differ depending on temperature category (Table 3.6 in chapter 3 presents the data for the medium-term (2023-2052)). The results highlight both clear requirements for increased investments, and a shift from fossil generation and extraction towards renewable technologies and efficiency for more ambitious temperature categories. The substantial ranges within each of these categories reflect the existence of multiple pathways, differentiated by socio-economic assumptions, technology etc. 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. 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; Hirth and Steckel 2016).

Table 15.2: Global average yearly investments from 2023–2032 for Electricity supply, Energy Efficiency and Extraction

Peak Temp.	**Electricity**	of which … …Fossil	…Nuclear	…Storage	…T & D	…Renewables	of which … *…Solar*	*…Wind*	Fossil Extraction	**Energy Efficiency**
1.25–1.75	2574 (2080;3393) [31]	94 (50;99) [31]	141 (80;203) [35]	210 (58;252) [28]	812 (540;1011) [34]	1118 (793;1569) [35]	432 (336;800) [35]	460 (278;621) [35]	353 (241;546) [19]	277 (15;319) [9]
1.75–2.25	1663 (1025;2248) [49]	100 (70;121) [46]	118 (73;153) [42]	97 (33;167) [32]	491 (416;779) [34]	760 (526;1109) [42]	339 (267;384) [42]	220 (160;330) [42]	353 (284;608) [23]	245 (126;276) [3]
2.25–2.75	1535 (991;2228) [219]	103 (87;146) [206]	92 (74;138) [188]	91 (34;183) [136]	616 (360;803) [155]	692 (531;1025) [191]	298 (172;371) [191]	256 (161;372) [191]	375 (284;481) [96]	11 (8;12) [25]
2.75–3.25	1065 (644;1675) [63]	105 (96;149) [52]	59 (17;119) [46]	5 (5;31) [18]	335 (255;376) [34]	488 (218;526) [46]	158 (86;265) [46]	160 (67;206) [46]	422 (379;544) [42]	8 (8;10) [10]
3.25–3.75	745 (580;1444) [110]	102 (94;149) [91]	60 (13;109) [73]	6 (5;36) [26]	335 (297;389) [56]	462 (157;511) [76]	158 (49;260) [76]	151 (57;206) [76]	428 (419;600) [66]	8 (8;9) [14]
3.75–4.25	871 (573;1435) [50]	138 (110;186) [45]	47 (4;74) [44]	40 (5;94) [20]	397 (333;465) [34]	411 (221;511) [44]	154 (78;225) [44]	129 (64;206) [44]	427 (422;469) [26]	8 (8;8) [5]
4.25–4.75	1133 (708;1315) [71]	198 (147;254) [70]	61 (22;75) [71]	20 (9;41) [44]	440 (354;522) [64]	397 (271;446) [72]	142 (96;179) [72]	114 (72;160) [72]	526 (428;797) [34]	222 (8;236) [14]

Note: Global average yearly investments from 2023-2032 for Electricity supply and its subcomponents, and for Fossil Fuel Extraction (in billion USD 2015). Scenarios are grouped into common AR6 categories (vertical axis, C1-C7). The numbers represent medians across all scenarios within one category, and rounded brackets indicate inter-quartile ranges, while the numbers in squared brackets indicate number of scenarios.

This requires very fast shifts of investment as infrastructures in the power sector generally have long lifetimes of few decades. In the 1.5°C scenarios, investments into non-biomass renewables increase to over 1 trillion USD yr^{-1} in 2030, an increase by more than factor 3 over the values of around 250–300 billion USD yr^{-1} that has been relatively stable over the last decade (IEA 2019a). 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; Steckel and Jakob 2018; Hirth and Steckel 2016).

Table 15.3: Average yearly investments from 2023–2032 for Electricity Generation capacity by Regions

Peak Temp.	Asia		Latin America and the Caribbean		Middle East and Africa		Europe		North America		Others	
	Fossil	Renewables	Fossil	Renewables	Fossil	Renewables	Fossil	Renewables	Fossil	Renewables	Fossil	Renewables
1.25–1.75	69 (23;78) [24]	467 (431;1123) [24]	0 (0;3) [24]	95 (80;231) [24]	10 (9;25) [24]	125 (110;201) [24]	4 (4;5) [18]	139 (114;206) [24]	3 (2;3) [24]	210 (172;282) [24]	6 (5;22) [24]	78 (69;276) [24]
1.75–2.25	63 (43;80) [27]	338 (258;463) [27]	0 (0;1) [27]	70 (63;91) [27]	16 (10;29) [27]	61 (42;94) [27]	4 (3;9) [26]	99 (83;113) [27]	8 (4;18) [27]	133 (95;180) [27]	12 (8;14) [27]	45 (28;68) [27]
2.25–2.75	62 (37;85) [150]	299 (235;397) [148]	2 (0;8) [149]	71 (57;91) [148]	18 (10;32) [150]	60 (31;95) [148]	5 (4;15) [141]	103 (84;120) [148]	7 (4;19) [150]	138 (98;203) [148]	11 (7;28) [147]	50 (32;69) [145]
2.75–3.25	39 (26;47) [37]	163 (79;242) [36]	5 (4;9) [37]	41 (18;58) [36]	18 (11;40) [37]	27 (16;34) [36]	10 (7;16) [35]	76 (15;98) [36]	14 (6;17) [37]	80 (50;123) [36]	13 (9;40) [36]	30 (13;49) [35]
3.25–3.75	38 (25;40) [59]	123 (82;202) [58]	4 (4;10) [59]	27 (12;57) [58]	18 (15;44) [59]	20 (13;30) [58]	10 (7;16) [57]	44 (11;97) [58]	16 (12;19) [59]	62 (27;100) [58]	13 (9;30) [55]	21 (11;44) [54]
3.75–4.25	61 (39;110) [37]	120 (80;184) [36]	5 (3;9) [37]	44 (12;57) [36]	21 (16;28) [37]	24 (10;39) [36]	10 (4;16) [37]	46 (11;84) [36]	16 (10;20) [37]	73 (50;95) [36]	18 (11;27) [35]	14 (7;23) [34]
4.25–4.75	115 (73;146) [50]	144 (112;186) [47]	7 (4;19) [50]	54 (35;57) [47]	31 (25;43) [50]	30 (18;41) [47]	10 (6;17) [50]	77 (43;90) [47]	23 (14;40) [50]	66 (43;78) [47]	20 (16;29) [49]	13 (11;17) [46]

Note: Average yearly investments from 2023-2032 for Electricity Generation capacity, by aggregate regions (in billion USD 2015). The numbers represent medians across all scenarios within one category, and rounded brackets indicate inter-quartile ranges, while the numbers in squared brackets indicate number of scenarios. Renewable totals are energy supply investment of non-biomass renewables.

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 such as Asia, Latin America and Middle East and Africa, 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. This illustrates an important opportunity for ensuring the build-up of sustainable energy infrastructures in these regions, but also constitutes a risk of additional carbon lock-in if investments into fossil infrastructures especially coal-fired power plants continue.

Quantitative analysis of investment needs in energy generation and efficiency based on AR6 scenario database and IRENA data. According to IRENA, government plans in place today call for investing at least 95 trillion USD in energy systems over the coming three decades (2016–2050) (IRENA 2020b). Redirecting and increasing investments to ensure a climate-safe future (Transforming Energy Scenario) would require reaching 110 trillion USD by 2050, or around 2% of average annual GDP over the period. Of that total, over 80% need to be invested in renewables, energy efficiency, end-use electrification, and power grids and flexibility. If viewed in annual terms, 3.2 trillion USD needs to be invested in the global energy system every year to 2050. That compares to recent historical investment (2017–2019) in the energy system of around 1.8 trillion USD yr^{-1} (IEA 2020c), and 2.9 trillion USD yr^{-1} in a reference scenario (Planned Energy Scenario) based on governments' current energy plans and other planned targets and policies (as of 2019), including Nationally Determined Contributions under the Paris Agreement. While cumulative global energy investment by 2050 for a Transforming Energy Scenario would cost 15 trillion USD more than the Planned Energy Scenario (16% higher), its overall composition would shift decisively away from fossil fuels (Figure 15.8).

Planned Energy Scenario investments Transforming Energy Scenario investments

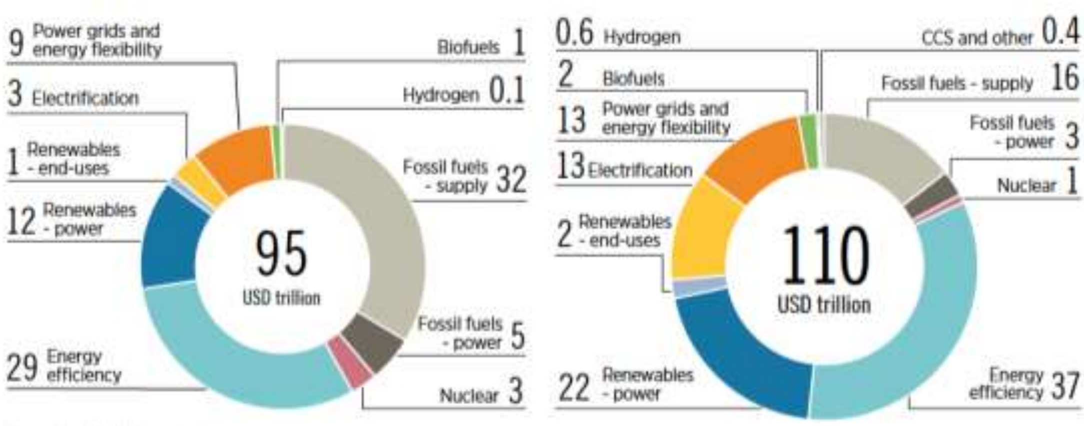


Figure 15.8: Cumulative Energy investments between 2016-2050
Note: Cumulative energy sector investments over the period between 2016 and 2050 for both scenarios. The 'gap' would be around 15 trillion USD, 'only' a 16% higher than expected / need to align IAM and IRENA data and explain differences if this chart should remain in. Numbers based on IRENA analysis (IRENA 2020). New investment priorities: renewables, efficiency and electrification of heat and transport.

Renewables and associated infrastructure account for nearly half of the difference in total investment, with energy efficiency and electrified transport and heat applications absorbing the rest. Investment to build up renewable power generation capacity needs to be twice as high as currently foreseen, reaching 22.5 trillion USD by 2050 (Figure 15.8). With solar and wind power on the rise, grid operators need new equipment to make the whole power system operate flexibly. Some of the solutions are market based, while others require investment in modern technology solutions. Quick-ramping thermal generation back-ups, pumped hydro, reinforced transmission and distribution grids, digital control equipment, vastly expanded storage capacity, and demand-side management through heat pumps, electric boilers and behind-the-meter batteries are just some of the areas for power system investment. Energy efficiency requires investments of 1.1 trillion USD yr^{-1}, more than four times the present level. Roughly in line with investment patterns over the last nine years, solar and wind technologies would lead the way in the transformation of the global electricity sector. In the context of total installed capacity by 2050, much greater capacity expansion would be needed for solar PV (8,000–9,000 GW) as compared to wind (5,500–6,000 GW). Overall, electricity generation investments increase considerably, reflecting the higher relevance of capital expenditures in decarbonised electricity systems.

Quantitative analysis of investment needs in other sectors. As described above investment needs in non-energy sectors tend to be ignored in many integrated assessment models with studies for individual countries or regions providing a more fragmented picture only. However, the quality of estimates is likely not to be less robust given the drawbacks of integrated assessment models.

For the transportation sector, OECD has presented the most comprehensive assessment of financing needs in the AR6 database based on IEA data with the annual average coming in at 2.7 trillion USD in the 2°C (66%) scenario. The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in our analysis. Financing needs for vehicles but also charging infrastructure are not reflected in these numbers. Current flows as reported by CPI include both, charging infrastructure and household investments in electric vehicles which became a major driver of increased private sector investments in mitigation in the last few year representing nearly 70% of private sector finance and 23% of total funding to the transport sector. The Food and Land use Coalition estimates additional investment needs for ten critical transitions for the global food and land use systems to achieve the LTGG and SDGs. Additional annual investment needs until 2030 add up to USD 300–350 billion USD. Considering the three of the ten transitions grouped under nature-based solutions only, annual investment needs would come in between 90–115 billion USD. However, given the strong interlinkage of the presented transitions and accumulated effects, climate change related investments can hardly be separated (The Food and Land Use Coalition 2019). Shakhovskoy et al. (2019) present an overview of financing needs of small-scale farmers globally, however, without focusing on the required climate related investments. According to their assessment 270 million smallholder farmers in South/South-East Asia, sub-Sahara Africa and Latin America face approximately 240 billion USD of financing needs, thereof 100 billion USD short-term agricultural needs, 88 billion USD long-term agricultural needs and 50 billion USD non-agricultural needs (ISF Advisors 2019). These numbers can only provide “an indication of the magnitude of the climate investments required in small-scale agriculture” (CPI 2019b). The Five-Year Assessment Report of the New York Forest declaration presents some key figures on financial needs to achieve deforestation-free economies and forest restoration. Besides support for training, policy development and implementation, institution building and infrastructure, the main cost component of the first element are economic opportunity costs in the range of 5–60 billion USD (NYDF Assessment Partners 2019). Based on global cost-per-hectare estimates of FAO and the Global Mechanisms of the UNCCD, financing needs to achieve the NYFD and its 350 million hectare goal amount to 837–1,208 billion USD until 2030 (NYDF report 2019; FAO 2015) and comes ins above the levels included in the estimates of the Food and Land use Coalition. Despite the 2020 goal of the New York declaration on Forests and the Bonn Challenge receiving sufficient pledges in 2017 (bonnchallenge.org), actual progress in restoration is much more limited with estimates ranging from just above 26–44 million hectares until 2019 (NYDF Assessment Partners 2020). Applying the average cost estimates, remaining annual financing needs in terms of restoration costs would come in around 81–84 billion USD.

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 2019a; UNEP 2018a). UNEP reports adaptation financing needs amounting to 140 to 300 billion USD yr^{-1} by 2030 and 280 to 500 billion USD yr^{-1} by 2050 (UNEP 2016). 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). There is increasing recognition of rising adaptation challenges and associated costs within and across Developed countries. Undoubtedly countries in the EU, the US, Canada and other are spending more on wide range of adaptation issues both as preventive measures and building resilience (greening infrastructure, climate proofing major projects and managing climate related risks) against the impacts of climate change extreme weather events (severe storms, flooding, drought, wild fires), (USGCRP 2018). Developed countries climate change adaptation spending coves areas such as federal insurance programmes, federal, state and local property and infrastructure, supply chains, water systems. The US President's 2017 Budget estimates that the US government incurred over 357 billion USD in direct costs because of weather-related disasters in the last decade[1]. The EU will be affected by heavy precipitation events and floods, more frequent heat waves, retreating glaciers and changing terrestrial ecosystems (European Parliament 2018). At EU level, there is a target of 20% for 2014 to 2020, Multi-annual Financial Framework for climate related expenditures and climate change adaptation actions are integrated into all the major EU spending Programmes (Climate ADAPT 2020)[2.] Since Paris Agreement and in alignment with SDGs, this target has been increase to at least 25% of expenditures contributing to climate objectives (2021–2027).

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 (UNISDR and WMO 2012; UN ESCAP 2017, World Bank 2019, OECD and World Bank 2016). Between 1978 and 1997, the direct economic losses from disasters were valued between 895 billion USD2017 and 1,313 billion USD2017 and between 1998 and 2017 direct economic

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FOOTNOTE [1] According to the US' Government Accountability Office (GAO), there is no accurate accounting of US expenditures on climate change (GAO 2018). Hence, these figures on US climate spending are only indicative. For example, GAO (2018) notes that the Office of Management and Budget reported that the federal government spent over USD154 billion on climate-related activities since 1993; however the report cautioned that not all of this addressed directly climate change nor its risks. The GAO report flagged that many were only secondarily related to climate change. It cited for example, nuclear energy program existed 'before serious concerns on climate change, but its budget was counted as climate. Of the six agencies reporting on climate change spending to OMB, 94% of this was not related to climate change, nor was new spending (GAO2018).

FOOTNOTE [2] Figure for climate spending from the EU, as with the U S, should be read with care. As noted by a EUP report, In line with the logic of mainstreaming the climate objectives into all EU policies, there are no dedicated budgetary chapters or lines allowing for the immediate identification of related expenditure (European Parliament 2018). The Commission has developed a methodology for tracking the climate-related expenditure, using existing international standards, such as those of the OECD, as a reference. It relies on the concept of indicators attributed to financial envelopes for specific programmes and policy areas according to their significant (100%), moderate (40%) or insignificant (0%) contribution towards climate change objectives. Based on the percentages attributed, the total amount spent on climate change can be then indicated. Implications and limitations of these methodology should be duly taken into account when using the resulting figures. For instance, the same expenditure may by tracked for more than one priority (e.g. both climate and biodiversity). Research by argues that made to disaggregate the EU funding for mitigation and adaptation (Forster et al. 2017). Based on the results, programmes focused on mitigation actions would correspond to 59% of the EU spending on climate, and those focusing on adaptation - to 41%.

losses were valued at 2,908 billion USD2017 (CRED and UNISDR 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 (CRED and UNISDR 2018). The real cost to the global economy over the last twenty years is 520 billion USD yr^{-1} and 26 million people impoverished (CRED and UNISDR 2018). Disaster preparedness, disaster risk reduction and building resilience are hence critical for sustainable development and allowing response to the effect for climate change.

Financing needs for mitigation and adaptation components of 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 calculating 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. 2020). Estimates for the implementation of renewable energy targets in NDCs point out to around 1.7 trillion USD will be needed by 2030, or on average almost 110 billion USD yr^{-1} (IRENA 2017). More than 70% of total investment needed (or 1.2 trillion USD) will have to be mobilised to implement the unconditional targets. A further 500 billion USD will be required in developing countries in the form of international finance to support the conditional targets. 50 non-Annex I countries have included financial data for adaptation, accumulating to more than 50 billion USD yr^{-1} 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.

Over 100 countries included adaptation component in their intended NDCs (INDCs) and approximately 25% of these referenced national adaptation plan (NAP) (GIZ 2017a). 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[3], 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.

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 2018a), 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

FOOTNOTE [3] 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).

presents 435 projects requiring 76.59 billion USD of funding in November 2020 (Green Climate Fund 2020).

15.5. Considerations on financing gaps and drivers

15.5.1. 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 and 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. It comprises short-termism (e.g. Robins and McDaniels 2016), high perceived risks for mitigation relevant technologies and/or regions (information gap through incomplete/asymmetric information, e.g. Clark et al. 2018), lack of carbon pricing effects (e.g. Best and Burke 2018), home bias (results in limited balancing for regional mismatches between current capital and needs distribution, e.g. Boissinot et al. 2016), and perceived high opportunity and transaction costs (results from limited visibility of future pipelines and policy interventions; + SME financing tickets and the 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 15.4.1, 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 Box 15.5 Measuring progress towards the 100 billion USD yr^{-1} 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).

15.5.2. Gaps identified with regard to sectors and regions

Against the background of multiple challenges with regard to the comparability of and level of detail provided in IAMs and sectoral studies, a detailed illustration on overall financing needs can have an indicative character only. Depending on the context, very different comparative analyses might be appropriate (see also Section 15.4.1). Therefore, the following chart (Figure 15.9) should only be read in connection with the key findings below:

Total funding for mitigation remains significantly below estimated needs by around five times with significant gaps existing across sectors and regions requiring compounded average growth rates of at minimum 15% to reach the average investment needs until 2025. However, financing needs in terms of required investments have any little explanatory power in terms of the magnitude of the challenge to mobilise funding. In addition to measurement challenges from different definitions and data gap, sectors and regions offer highly divergent financial risk-return profiles and economic costs as well as standardisation, scalability and replicability of investment opportunities as basis for private sector investment appetite. Moreover, soft costs and institutional capacity for enabling environment that can be prerequisite for addressing financing gap are ignored when focusing on investment cost needs.

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 photovoltaic and on-shore wind even without taking account the mitigation component (FS-UNEP Centre and BNEF 2019a; IRENA 2020a). This investment activity comes 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).

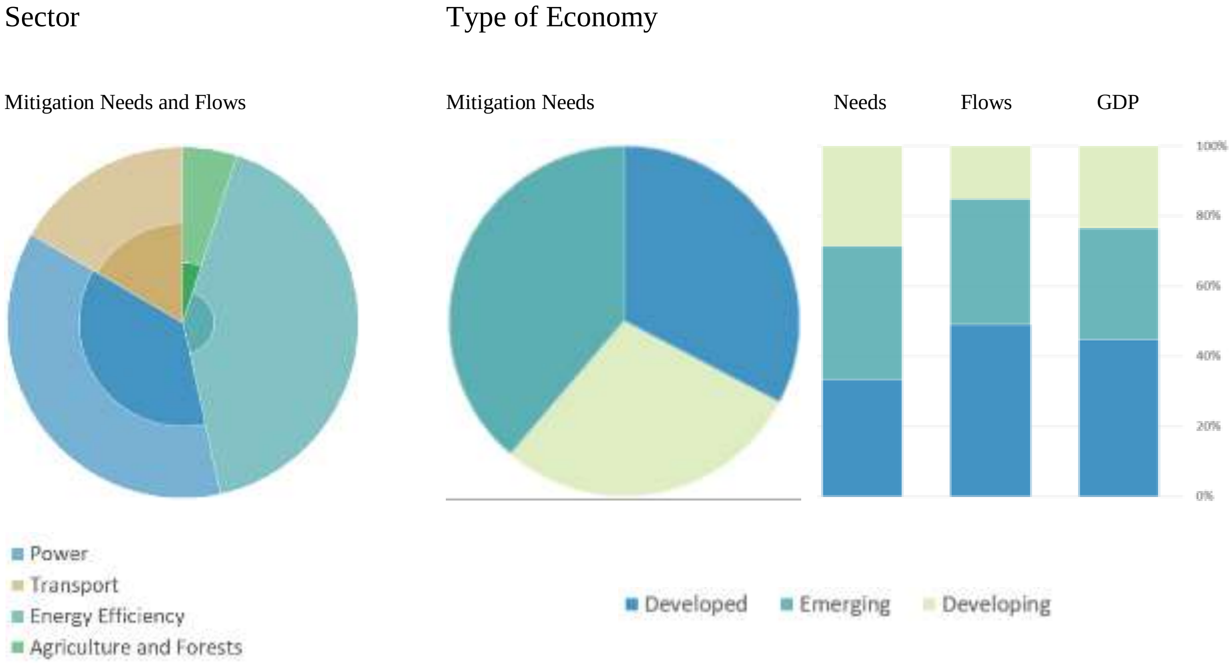


Figure 15.9: Breakdown of average investment needs until 2030
Left chart: Inner boundary represents current flows (mean average of 2017 and 2018), outer boundary represents average mitigation investment needs until 2030. Wing area in between represents resulting finance gaps by sectors. The existing gaps in terms of unmet investment needs are only a single indicator to

be used as part of a more comprehensive (and qualitative) assessment in order to understand the magnitude of the challenge to scale-up finance in sectors and regions. Agriculture and Forests (145 billion USD) based on The Food and Land Use Coalition adjusted for higher afforestation needs based on New Forest Declaration Progress Reports, Energy Efficiency needs (1,099 billion USD) based on IRENA (2020), Electricity sector needs (974 billion USD) based on AR6 IAM database with incremental T&D and Storage needs representing incremental investment needs for Temperature range of 1.75°C–2.25°C over the average of 3.0, 3.5, 4.0 (+/- 0.5C°). Transport needs (425 billion USD) based on estimates for new rail infrastructure of G20 Infrastructure Initiative, no estimates for new EVs available. Flows represent only mitigation pegged flows (incl. multiple objectives, which accounts around 2% of total flows) by sectors provided by CPI. Cross-sectoral flows such as Policy and national budget support & capacity building are excluded (2% of total non-Adaptation flows).

Right chart: Emerging represents BRICS countries. Developing and developed countries by IPCC country classification (UN M49). Flows: Mean average of 2017 and 2018 as per CPI breakdown, trans-regional and non-regional flows (approximately 20% of flows) allocated pro rata. Breakdown of needs for Agriculture and Forests based on current Bonn Challenge commitments due to lack of better data, afforestation needs represent >50% of total needs, Electricity sector by Type of Economy based on AR6 IAM database, Energy Efficiency needs based on IRENA data, Transport needs based on Global Infrastructure Outlook for Rail Infrastructure needs. Total GDP 2018 in constant 2017 international dollars, World Bank Indicator (NY.GDP.MKTP.PP.KD).

Comparing annual average total investments in global fuel supply and the power sector of approximately 1.61 trillion USD yr^{-1} in 2019 (IEA 2020c) to the investment in the Stated Policies Scenario (approximately 1.84 trillion USD yr^{-1}) and the Sustainable Development Scenario (approximately 1.91 trillion USD yr^{-1}) in 2030 underlines the required shift of existing capital investment rather than the need to massively increase sector allocations (McCollum et al. 2018; Granoff et al. 2016).

Ensuring access to the heavily regulated electricity markets is a key driver for an accelerated private sector engagement (REN21 2019; IFC 2016; FS-UNEP Centre and 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 and 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 standardised contract structures and the increased availability of risk mitigation instruments addressing political/regulatory risks and home bias constraints (IRENA 2020a; FS-UNEP Centre andBNEF 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 15.3) in which will have to change to accelerate renewable energy investment activity.

The intensive capital expenditure nature and limited dispatchability of renewable energy does not fit in a system where marginal costs drive the dispatch of electricity and are the main means to recover investment, both liberalised and regulated systems will be confronting this (IRENA 2020c). How generators of electricity and providers of flexibility services are rewarded conveys crucial information in both the short term ("Should we provide this service now?") and the long term ("Should we invest in this system and commission a new unit?"). The failure electricity market structures to deal with this and other transition requirements saddles users with additional costs and inhibits vital new investments, often because of inefficient regulatory adjustments. Changing electricity market structures, including a potential higher share of market pricing, will change business models (Pahle and Schweizerhof 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.

Despite significant tracking issues with regard to flows, the energy efficiency financing gap has likely widened with investment opportunities remaining untapped to a large extent. This holds true for all sub-segments. Sources of funding for energy efficiency projects could comprises are extremely wide with a strong role of businesses, governments and households. Green bonds have been used to finance EE improvement projects in buildings, transport and energy. Public sector investments in the transport sector have increased significantly in the past years reflecting the increased interest of capital markets in renewable energy and the efficient and corresponding reallocation of public funding. This inconsistency in methodologies at the level of needs versus current flows with regard to end user investments leads to an overstatement of current flows and a lower gap than actually given. However, the dynamics in EE spending at household levels provide some confidence that future financing needs can be addressed well. Provision of funding by capital markets for public transport infrastructure among others heavily depend suitable financing vehicles and increased funding for development of projects with a low level of standardisation (OECD 2015c).

Current funding of land-based mitigation options is less than 1 billion USD yr^{-1} representing only 2.5% of climate mitigation funding, significantly below the potential proportional contribution (CPI 2015). Funding needs include a scale up of REDD+ but not a full compensation of economic opportunity costs. Taking into account the rate of forest loss and limited progress made since its endorsement in 2014 (NYDF Assessment Partners 2019) higher levels of opportunity cost compensation as well as a stronger focus in deforestation-free value chain, including a stronger reflection in taxonomies and financial sector investment decision processes are necessary to meet the NYFD goals. Taking into account the specifics of land-based mitigation (in particular long investment horizons, strong dependency on monetisation 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). Agriculture is likely to develop more potential to mobilise private finance than forest sector given its strong linkage to food security and hunger and shorter payback periods. The significant gap in land-based mitigation finance also indicates the crucial lack of finance to the bottom of the pyramid.

Agricultural support is an important source of distortions to agricultural incentives in both rich and poor countries (Mamun et al. 2019) ranging from largest component of the support, market price supports, increased gross revenue to farmers as a result of higher prices due to market barriers created by government policies, to production payments and other support including input subsidy (e.g. fertiliser subsidy) (Searchinger et al. 2020). USD600 billion of annual governmental support for agriculture in the OECD database contributes only modestly to the related objectives of boosting crop yields and mitigating climate change in a just way (Searchinger et al. 2020). A review of (NDCs of 40 developing countries which submitted a NDC to the UNFCCC Interim NDC Registry by April 2017, and include within their NDC efforts to REDD+ via support from the UN-REDD Programme and/or World Bank Forest Carbon Partnership Facility) indicates that none of the countries reviewed mention fiscal policy reform of existing finance flows to agricultural commodity production or other publicly supported programmes that affect the direct and underlying drivers of land use conversion (Kissinger et al. 2019).

The analysis of gaps type of economy illustrates the challenge for developing countries. Estimated mitigation financing needs as percentage of constant GDP (constant intl. dollar) comes in at less than 2% for developed countries, and less than 3% for developing countries as well as BRICS. Section 15.6.2 elaborates on outlooks with regard to fiscal headspace and ability to tap capital markets. A robust analysis of financing needs by country rating can hardly be performed based on the available data points, it would provide a valuable indication of the magnitude of international public finance needed. 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 2019a), 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 urbanisation makes it imperative that institutional investors and policy-makers recognise 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, rivalling China, India, US and Europe, would be costly. Policies centred 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.

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, as well as information market failures. The 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 biggest challenge in climate finance is likely to be in developing countries, even in the presence of 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. 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 challenge 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.

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. 2020). 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 energy, transport and urban infrastructure. Delaying action on accelerating the energy transition will almost double the amount of stranded assets in fossil-fuel supply infrastructure (Tong et al. 2019). Already USD 11.8 trillion in assets will need to be stranded by 2050 for 2°C world. Moreover, further delaying action for another 10 years would result in an additional 7.7 trillion USD in stranded assets by 2050.

Finance for adaptation and resilience. While not covered in the quantitative analysis above, adaptation finance gaps continue to increase. The implementation of NAPs 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 multilateral funding under (Non-)UNFCCC[4] 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 2019b; 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

FOOTNOTE [4] 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.

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 2019b); blue bonds (or water bonds), (Holmes 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 2019b). Whereas it is about 10% of sovereign green bonds raised.

The implementation phase of NAPs will require 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. Multiple funds support of the implementation of the NAPs including the Adaptation Fund, the GCF and the Pilot Program for Climate Resilience, the MDBs and development banks. To date, the private sector has limited involvement in NAPs and adaptation projects and planning but can be involved through public-private partnership (discussed in Section15.6.2.2) and incentives by governments (NAP Global Network 2017; UNEP FI and FS 2016; Koh et al. 2016; Schmidt-Traub and Sachs 2015; UNEP 2016). Innovative private financing mechanisms such as green and blue bonds may also be important for the implementation of adaptation actions (Innovative Financing Initiative 2014; World Bank and PPIAF 2015; Holmes et al. 2014, Hurley and Voituriez 2016; UNFCCC 2019b). Nonetheless, adaptation financing is only about 2% of the share of green bond financing raised up to June 2019 (UNFCCC 2019b)[5] and about 10% of sovereign green bonds raised.

Financing for resilience is 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; UNEP FI 2014; Watson et al. 2015). While resilience financing is mainly grant-funding, 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.

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. Challenges related to financing residual climate-related losses and damages are particularly high for developing countries. Financing loss and damage from extreme

FOOTNOTE [5] According to climate bonds initiative, total green bond finance raised in 2018 was 168.5 billion USD across 44 countries (UNFCCC 2019b).

events requires rapid payouts; the cost of financing for many developing countries is already quite high; and the expense of risk financing is expected to increase as disasters become more frequent, intense and more costly not only due to climate change but also due to higher levels of exposure. Addressing both extreme and slow onset climate impacts requires designing adequate financial protection systems for reaching the most vulnerable. Moreover, some fraction of losses and damages, both material and non-material, are not commonly valued in monetary terms [non-economic loss] and hence financing requirements are hard to estimate. These non-market-based residual impacts include loss of cultural identity, sacred places, human health and lives (Serdeczny 2019; Paul 2019).

Urgency of climate action and timely provision of climate finance. In the case of the GCF, the time period until deployment is two-stepped. In the first step the time of submission to reach Board Meeting approval is on average 296 days (GCF 2020a). The second step between Board approval until contract effectiveness is on average 219 days (GCF 2020b). Determinants that are driving the time frame until disbursement are multi-folded and depending largely on regional circumstances. Considering, that co-financing projects are more complex in the financial architecture more time is needed for legal obligations. Indeed, the confirmation of disbursement with co-financiers has been identified as a major challenge that leading to delays for the start of implementation.

15.6 Approaches to address financing gaps

Near-term actions to shift the financial system over the next decade are critically important and possible with globally coordinated efforts. Taking into account the inertia of the financial system as well as the magnitude of the challenge to align financial flows with the long-term global goals, fast action is required to ensure the readiness of the financial sector as an enabler of the transition. The following subsections elaborate on key areas which can have a catalytic effect in terms of addressing existing barriers – besides political leadership and interventions discussed in other chapters of AR6.

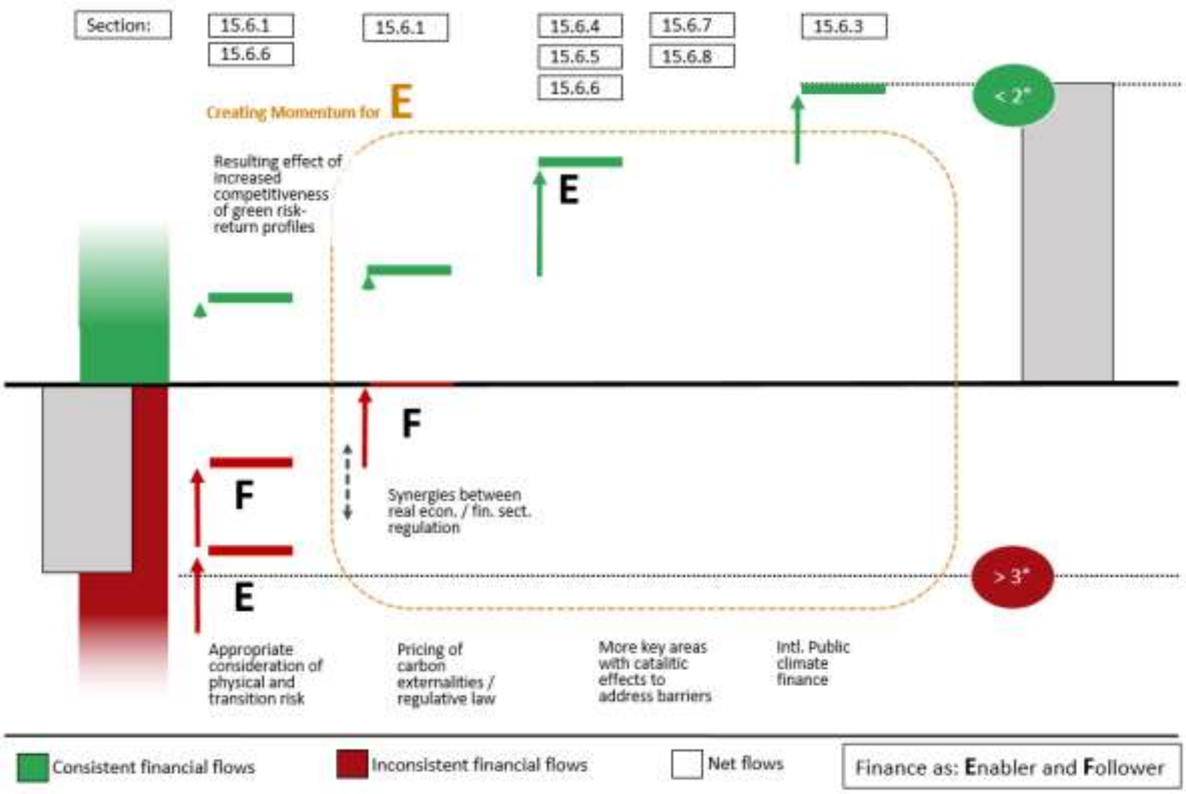


Figure 15.10: Visual abstract to address financing gaps in section 15.6

Addressing knowledge gaps with regard to climate risk analysis and transparency will be one key driver for more appropriate climate risk assessment and efficient capital allocation (15.6.1), efficient enabling environments support the reduction of financing costs and reduce dependency on public funding (15.6.2), a revised common understanding of debt sustainability, including also negative implications of deferred climate investments on future GDP, particularly stranded assets and resources to be compensated, can facilitate the stronger access to public climate finance, domestically and internationally (15.6.3), climate risk pooling and insurance approaches are a key element of financing of a just transition (15.6.4), the supply of finance to a widened focus on relevant actors can ensure transformational climate action at all levels (15.6.5), new green asset classes and financial products can attract the attention of capital markets and support the scale up of financing by providing standardised investment opportunities which can be well integrated in existing investment processes (15.6.6), a stronger focus on the development of local capital markets can help mobilizing new investor groups and to some extent mitigate home bias effects (15.6.7), new business models and financing approaches can help to overcome barriers related to transactions costs by aggregating and/or transferring financing needs and establish supply of finance for needs of stakeholder groups lacking financial inclusion (15.6.8).

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

Climate change as a source of financial risk. Achieving climate mitigation and adaptation objectives requires ambitious climate finance flows in the near-term, i.e. 5-10 years ahead. However, knowledge gaps in the assessment of climate-related financial risk are a key barrier to such climate finance flows. Therefore, this section discusses the main knowledge gaps that are currently being addressed in the literature and those that remain outstanding.

Climate-related financial risk is meant here as the potential adverse impact of climate change on the value of financial assets. A recent but remarkable development since AR5 is that climate change has been explicitly recognised by financial supervisors as a source of financial risk that matters both for financial institutions and citizens' savings (Bolton et al. 2020). Previously, climate change was mostly regarded in the finance community only as an ethical issue. The reasons why climate change implies financial risk are not new and are discussed more in detail below. What is new is that climate enters now as a factor in the assessment of financial institutions' risk (e.g. such as the European Central Bank or the European Banking Authority) and credit rating (see also Section 15.6.3) and, going forward, into stress-test exercises. This implies changes in incentives of the supervised financial actors, both public and private, and thus changes in the landscape of mitigation action by generating a new potential for climate finance flows. However, critical knowledge gaps remain. In particular, the underestimation of climate-related financial risk by public and private financial actors implies a reallocation of capital inconsistent with the mitigation objectives.

Physical risk. On the one hand, unmitigated climate change implies an increased potential for adverse socio-economic impacts especially in more exposed economic activities and areas. Accordingly, *physical risk* refers to the component of financial risk associated with the adverse physical impact of hazards related to climate change (e.g. extreme weather events or sea level rise) on the financial value of assets such as industrial plants or real estate. In turn, these losses can translate into losses on the values of financial assets issued by exposed companies (e.g. equity/bonds) and or sovereign entities as well as losses for insurance companies. The assessment of climate financial physical risks poses both challenges in terms of data, methods and scenarios. It requires to cross-match scenarios of climate-related hazards at granular geographical scale, with the geolocation and financial value of physical assets. The relationship between the value of physical assets (such as plants or real estate) and the financial value of securities issued by the owners of those assets is not straightforward. Further, the repercussion of climate related hazards on sovereign risk should also be accounted for.

Transition risks and opportunities. On the other hand, the mitigation of climate change, by means of a transition to a low-carbon economy, requires a transformation of the energy and production system at a pace and scale that implies adverse impacts on a range of economic activities, but also opportunities for some other activities. If these impacts are factored in by financial markets, they are reflected in the value of financial assets. Thus, *transition risks and opportunities* refer to the component of financial risk (opportunities) associated with negative (positive) adjustments in assets' values resulting directly or indirectly from the low-carbon transition.

The concepts of *carbon-stranded assets* (see e.g. Leaton and Sussams 2011), and *orderly* vs. *disorderly transition* (Sussams et al. 2015) emerged in the NGO community, have provided powerful metaphors to conceptualise transition risks and have evolved into concepts used also by financial supervisors (NGFS 2019) and academics. The term carbon stranded assets refers to fossil-fuel-related assets (fuel or equipment) that become unproductive. An *orderly transition* is defined here as a situation in which market players are able to fully anticipate the price adjustments that could arise from the transition. In this case, there would still be losses associated with stranded assets but it would be possible for market players to spread losses over time and plan ahead. In contrast, a *disorderly transition* is defined here as a situation in which a transition to a low carbon economy on a 2C° path is achieved (i.e. by about 2040), but the impact of climate policies in terms of reallocation of capital into low-carbon activities and the corresponding adjustment in prices of financial assets (e.g. bonds and equity shares) is large, sudden and not fully anticipated by market players and investors. Note the impact could be unanticipated even if the date of the introduction is known in advance by the market players. There are several reasons why such adjustments could occur. One simple argument is that the political economy of the transition is characterised by forces in different directions, including opposing interests within the industry, mounting pressure from social awareness of unmitigated climate risks. Politics will have to find a synthesis and the outcome could remain uncertain until it suddenly unravels. Note also that, in order to be relevant for financial risk, the disorderly transition does not need to be a catastrophic scenario in terms of the fabric of markets. It also does not automatically entail systemic risk, as discussed further down. Knowledge gaps in this area are related to emerging questions, including: What are, in detail, the transmission channels of physical and transition risk? How to assess the magnitude of the exposure to these risks for financial institutions and ultimately for people's savings? How do transition risk and opportunities depend on the future scenarios of climate change and climate policies? How to deal with the intrinsic uncertainty around the scenarios? To what extent, an underestimation of climate-related financial risk, could feed back on the alignment of climate finance flows and hamper the low-carbon transition? What lessons from the 2008 financial crisis are relevant here, regarding moral hazard and the trustworthiness of credit risk ratings? The attention of both practitioners and the scientific community to these questions has grown since the Paris Agreement. In the following we review some of the findings from the literature, but the field is relatively young and many of the questions are still open.[6]

Assessment of physical risk. Some estimates of losses on physical assets can be found in the literature. Significant cost increases have been observed related to increases in frequency and magnitude of extreme events (see Section 15.4.2 on financing needs). Economic losses from weather and climate-related extreme events 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

FOOTNOTE [6] In the context, while belonging to grey literature, reports from financial supervisors or non-academic stakeholders, can be of interest, for what they document in terms of changes in perception and incentives among the market players and hence of the dynamics of climate finance flows.

Nordic countries (FinansNorge et al. 2013). Damages from climate change are expected to escalate dramatically in Europe (Forzieri et al. 2018) and in some EU countries there is already some evidence that banks, anticipating possible losses on the their loan books, lend proportionally less to firms exposed to climate-related hazard (e.g. floods, (Faiella and Mistretta 2020)). 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). At the global level, the expected 'climate value at risk' (climate VaR) of financial assets has been estimated to be 1.8% along a business-as-usual emissions path (Dietz et al. 2016), with however, a concentration of risk in the tail (e.g. 99th VaR equals to 16.9%, or 24.2 trillion USD, in 2016). Climate-related impacts are estimated to increase the frequency of banking crises (up over 200% across scenarios) while rescuing insolvent banks could increase the ratio of public debt to gross domestic product by a factor of 2 (Lamperti et al. 2019). Further assessments of physical risk for financial assets, accounting also for the propagation of losses through financial networks, estimate global GDP losses at 7.1% (1.13%) in 2080, without adaptation (with adaptation). These correspond respectively to a 50 % and a 10-fold increase with respect to the mean present risk, which amounts to 0.76% of global GDP (Mandel et al. 2020). Finally, climate physical risk can impact on the value of sovereign bonds (one of the top asset classes by size), in particular for vulnerable countries (Stampe et al. 2020).

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).

Assessment of transition risk

Carbon stranded assets. 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). In relative terms, stranded assets of fossil-fuel companies amount to 82% of global coal reserves, 49% of global gas reserves and 33% of global oil reserves (McGlade and Ekins 2015). This suggests that only 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. The devaluation of fossil fuel assets imply financial losses for both the public sector (see Section 15.6.8) and the private sector (Coffin and Grant 2019). Global estimates of potential stranded fossil fuel assets amount to at least 1 trillion, based on ongoing low-carbon technology trends and in the absence of climate policies (cumulated to 2035 with 10% discount rate applied; 8 trillion USD without discounting (Mercure et al. 2018a). With worldwide climate policies 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).

Assets directly and indirectly exposed to transition risk. In terms of types of assets and economic activities, the focus of estimates of carbon stranded assets, tend to be on physical reserves of fossil fuel (e.g. oil fields) and sometimes financial assets of fossil-fuel companies (see van der Ploeg and Rezai under review). However, a precondition for a broader analysis of transition risks and opportunities is to go beyond the narrative of stranded assets and to consider a classification of sectors of all the economic activities that could be affected (Monasterolo 2020). This, in turn depends on their direct or indirect role in the GHG value chain, their level of substitutability with respect to fossil fuel and their role in the policy landscape. Moreover, such a classification needs to be replicable and comparable across portfolios and jurisdictions. One classification that meets these criteria is the Climate Policy Relevant Sectors (CPRS) (Battiston et al. 2017) which has been used in several studies by financial supervisors (EIOPA 2018; ESMA 2020; OeNB 2020; ECB 2019; EBA 2020). The CPRS classification builds on the international classification of economic activities (ISIC) to map the most granular level (4 digits) into a small set of categories characterised by differing types of risk: fossil-fuel (i.e. all activities whose revenues depends mostly and directly on fossil-fuel, including concession of reserves and operating industrial plants for extraction and refinement); electricity (affected in terms of input but that can in principle diversify they energy sources); energy intensive (e.g. steel or cement production plants), automotive manufacturing plants, which are affected in terms of energy cost but not in terms of the main input); transport and buildings (affected in terms of both energy sources and specific policies). All financial assets (e.g. bonds, equity shares, loans) having as issuers or counterparties firms whose revenues depends significantly on the above activities are thus potentially exposed to transition risks and opportunities. Further, investors' portfolios have to be part of the analysis since changes in financial assets values affect the stability of financial institutions and can thus feed back into the transition dynamics itself (e.g. through cost of debt for firms and through costs for assisting the financial sector). One outstanding challenge for the analysis of investors' exposure to climate risks is the difficulty to gather granular and standardised information on the breakdown of non-financial firms' revenues and capex in terms of low/high-carbon activities.

Given the magnitude of the assets that are potentially exposed, transition risk can have implications for financial stability both at the level of individual financial institutions, and at the macro-level. The concern that central would have to act as "climate rescuers of last resort" in a systemic financial crisis stemming from some combination of physical and transition risk has been raised (Bolton et al. 2020). Correspondingly, a concern of moral hazard arises, whereby some financial actors could have an incentive to downplay climate-related financial risk. For these reasons, several financial supervisors have conducted assessments of transition risk. For instance, the European Central Bank (ECB) reported preliminary estimates of aggregate exposures of financial institutions to CPRS relative to their total debt securities holdings, as ranging between 1% for banks to about 9% for investment funds (ECB 2019). The European Insurance and Occupational Pensions Authority (EIOPA) reported aggregate exposures to CPRS of EU insurance companies at about 13% of their total securities holdings (EIOPA 2018). Further analyses on the EU securities holdings indicate that among financial investments in bonds issued by non-financial corporations, EU institutions hold exposures to CPRS ranging between 36.8% for investment funds to 47.7% for insurance corporations; analogous figures for equity holdings range from 36.4% for banks to 43.1% for pension funds (Alessi et al. 2019). Another study indicates that losses on EU insurance portfolios of sovereign bonds could reach up to 1%, in conservative scenarios (Battiston et al. 2019).

Endogeneity of risk and multiplicity of scenarios. One fundamental challenge is that climate-related financial risk is endogenous. This means that the perception of the risk changes the risk itself, unlike most contexts of financial risk. Indeed, transition risk depends on whether governments and firms continue on a business-as-usual pathway (i.e. misaligned with the Paris Agreement targets) or engage on a climate mitigation pathway. But the realisation of the transition pathway depends itself on how, collectively, society, including financial investors and supervisors, perceive the risk of taking /not taking the transition scenario. The circularity between perception of risk and realisation of the scenarios implies first of all that multiple scenarios are possible, and that which scenario is ultimately realised can depend on policy action. In this context, probabilities of occurrence of scenarios are difficult to assess and this is important because risk vary widely across the different scenarios.

In this context a major challenge is the fat-tail nature of physical risk. One the one hand, forecasts of climate change and its impact on humans and ecosystems imply tail events (Weitzman 2014) and tipping points which cannot be overcome by model consensus (Knutti 2010). On the other hand, everything else the same, costs and benefits vary substantially with assumptions on agents' utility, productivity, and intertemporal discount rate, which ultimately depend on philosophical and ethical considerations (see (Nordhaus 2007; Nicholas Stern 2008; Pindyck 2013). Thus, more knowledge is needed on the interaction of climate physical and transition risk, the possible reinforcing feedbacks and transmission channels to the economy and to finance. Moreover, models need to account for compound risk, i.e. the interaction of climate physical and/or transition risk with other sources of risk such as pandemics, as the COVID-19.

Challenges for climate transition scenarios. The endogeneity of risk and its associated deep uncertainty implies that the standard approach to financial risk consisting of computing expected values and risk based on historical values of market prices, is not adequate for climate risk (Bolton et al. 2020). To address this challenge, a recent stream of work has developed an approach to make use of climate policy scenarios to derive risk measures (e.g. expected shortfall) for financial assets and portfolios, conditioned to scenarios of disorderly transition (Roncoroni et al. 2020; Battiston et al. 2017; Monasterolo and Battiston 2020). In particular, climate policy shocks on the output of low/high carbon economic activities are calculated based on trajectories of energy technologies as provided by large-scale Integrated Assessment Models (Kriegler et al. 2015; McCollum et al. 2018) conditioned to the introduction of specific climate policies over time. This approach allows to conduct climate stress-test both at the level of financial institutions and at the level of the financial system of a given jurisdiction.

In a similar spirit, recently, the community of financial supervisors in collaboration with the community of climate economics has identified a set of climate policy scenarios, based on large-scale IAM, as candidate scenarios for assessing transition risk (Monasterolo and Battiston 2020). These scenarios have been used for instance, in an assessment of transition risk conducted at a national central bank (Allen et al. 2020). This development is key to mainstreaming the assessment of transition risk among financial institutions, but the following challenges emerge. First, a consensus among financial supervisors and actors on scenarios of transition risk that are too mild could lead to a systematic underestimation of risk. The reason is that the default probability of leveraged financial institutions is sensitive to errors in the estimation of the loss distribution and hence sensitive on the choice of transition scenarios (Battiston and Monasterolo 2020). This in turn could lead to an allocation of capital across low/high carbon activities that is insufficient to cater for the investment needs of the low-carbon transition.

Second, IAM do not contain a description of the financial system in terms of actors and instruments and make assumptions on agents' expectations that could be inconsistent with the nature of a disorderly transition (Espagne 2018; Pollitt and Mercure 2018; Battiston et al. 2020b). In particular, IAMs solve for least cost pathways to an emissions target in 2100, while the financial sector's time horizon is much shorter and risk is an important factor in investment decision.

Third, the current modelling frameworks used to develop climate mitigation scenarios, which are based on large-scale IAM, assume that the financial system acts always as an enabler and do not account for the fact that, under some condition (i.e. if there is underestimation of climate transition risk) can also act as a barrier to the transition (Battiston et al. 2020a) because it invests disproportionately more in high carbon activities.

Macroeconomic implications of the technological transition. 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). 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). An example is the transport sector, which uses around 50% of oil extracted (Thomä 2018; IEA 2018). A rapid diffusion of electric vehicles (and other alternative vehicle types), poses an important risk of as it could lead to oil demand peaking before 2050 (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). 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).

International dimension of climate risk. Due to the predominantly international nature of fossil fuel markets, assets may be at risk from regulatory and technological changes both domestically and in foreign countries. 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). Since state-owned fossil fuel companies tend to enjoy lower production cost, privately-owned fossil fuel companies are more at risk (Thomä 2018). 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).

Main regulatory developments and voluntary responses to climate risk. Framing climate risk as a financial risk (not just as an ethical issue) is key for it to become an actionable criteria for investment decision among mainstream investors (TCFD 2019). Since 2015 financial supervisors and central banks (e.g. the Financial Stability Board, the G20 Green Finance Study Group, and the Network for Greening the Financial System (NGFS)) have played a central role in raising awareness and increase transparency of the potential material financial impacts of climate change within the financial sector (Bank of England 2018; Bank of England 2015a; TCFD 2019b). The NGFS initiative have engaged in particular in the elaboration of climate financial risk scenarios, as mentioned earlier.

Although disclosure has increased since the TCFD 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). 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).

There have been also similar initiatives at the national level (U.S. GCRP 2018; DNB 2017; UK Government 2017). In particular, 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 have been so far 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).

A key recent development is the EU Taxonomy for Sustainable Finance (TEG 2019), which provides a classification of economic activities that (among other dimensions) contribute to climate mitigation or can be enabling for the low-carbon transition. Indirectly, such classification provides useful information on investors' exposure to transition risk (Alessi et al. 2019; ESMA 2020).

Finally, many consultancies have stepped forward offering services related to climate risk. However, the methods are typically proprietary, non-transparent, or based primarily on carbon foot printing, which is a necessary but insufficient measure of climate risk. Further, ESG (environmental, social and governance) metrics can useful but are, alone, inadequate to assess climate risk.

15.6.2 Enabling environments

The Paris Agreement recognised for the first time the key role of aligning financial flows to climate targets. Key decision makers try to provide enabling environment for both public and private sectors to mobilise financial resources in order to tackle climate change.

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 incentivises long horizon green private investment, and facilitates optimal (from investor and environmental perspectives) exits from investment (Owen et al. 2018). Mapping 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). 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). Four types of interventions have been discussed by financial regulators and central banks in dealing with climate-related risks: developing methodologies and tools for a better understanding of risks and their implications, better disclosure of investors' exposure to climate-related risks, explicit consideration of these risks in setting financial regulations, and consideration of these risks in central bank's policy toolkit (Campiglio et al. 2018). 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 that includes policy reform to value environmental degradation, incentivise private investments, bridging finance gaps, and ensuring transparency (Clark et al. 2018). 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). 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), considering tax returns (Taghizadeh-Hesary and Yoshino 2019), improving green finance policy frameworks, developing information exchange channels, and strengthening the international cooperation in green financial system (Peng et al. 2018b).

Central banks and climate change. Central banks in all economies will likely have to play a critical role in supporting the financing of fiscal operations in particular in a post-COVID world (quantitative easing (QE) to backstop public borrowing, especially for bonds at the long maturity end). This is much more likely in developed countries with recourse to greater financial market confidence, especially in the context of their 'exceptional privileges' as global reserve currencies. Instruments and institutional arrangements for better international monetary policy coordination will likely be paramount for success to spill over well beyond the borders of the developed economies, and an imperative for global success in the current context of growing external debt stress and negative credit rating pressures facing both emerging and low-income countries (with sixty negative sovereign credit actions by rating agencies and many more in banking and corporate sectors in 2020).

Because climate change might involve large disruptive risks, both in terms of physical and transition risks as described above, central bankers have started examining the implications, as part of their core mandate of managing the stability of the financial system. Climate related risk assessments and disclosure, both at the systemically important corporate levels and at the financial institution level are therefore becoming important, including stress testing assessments by central banks of climate change risks. This is an essential first step that many central banks are starting to increasingly look at (Rudebusch 2019), although such risk assessment by financial regulators and greater transparency and disclosure may not be enough by themselves to spur increased institutional low-carbon climate finance (Ameli et al. 2019)

Central banks' QE is created as temporary cyclical tools, but it is now being examined as a tool for enabling climate investments (Dafermos et al. 2018). A green QE program 'would have the benefit of providing large amounts of additional liquidity to companies interested' in green projects (Campiglio et al. 2018). Green QE would have positive effects, such as accelerating the development of green bond markets, encouraging investments and banking reserves, and reducing risks of stranded assets, while it might increase the income inequality and financial instability (Monasterolo and Raberto 2017)**.** While the short-term effectiveness would not be substantial, the central bank's purchase of green bonds could have a positive effect on green investment in the long run (Dafermos et al. 2018). However, green QE program by itself would not be an effective measure, other green fiscal policies, green finance policies, and regulatory interventions are suggested additionally to compliment the green finance measures. The use of green QE needs to be cautious on potential issues, such as undermining central bank's independence, affecting central bank's portfolio by including green assets with poor financial risk standards, and potential regulatory capture and rent seeking behaviours (Krogstrup and Oman 2019).

Policy instruments have hit the zero-lower bound of policy interest rates in the EU and the USA, quantitative easing has become increasingly necessary and resorted to, with central banks buying assets such as longer term treasury and high-grade corporate bonds to lower long-term interest rates. Although expected to be a cyclical and temporary in an economic downturn, how long these cycles might last is not known with certainty but have been much longer than anticipated (Fawley and Neely 2013). Central banks are now increasingly under pressure and not averse to correcting for this distortion by excluding fossil-fuel investments from future quantitative easing programs.

Green Quantitative Easing. A proposed 'green' QE goes further (Campiglio et al. 2018). Central banks explicitly conducting a program of purchases of low-carbon assets, either as a rising share of zero-bound quantitative easing monetary policies in economic downturns, or as part of changing the existing balance sheets of central banks assets in an extended phase with rising risks of climate instability. The latter may become even more important if central banks increasingly need to backstop treasuries bond purchases as part of a medium-term longer duration fiscal recovery program after COVID-19. Indeed, recent episodes of large-scale and long-lasting QE using 'extended period' language tend to suggest that central banks have not been averse to QEs that do not just deal with short-term liquidity needs but have explicitly had the objectives to facilitate longer duration economic recovery and the functioning of particular financial markets (Fawley and Neely 2013) and therefore a 'green' QE program to stimulate a structural redirection of economic recovery towards a low-carbon transition might have greater practice and precedence than commonly appreciated. There are also spill-overs of QE in advanced economies that are significant (Bhattarai et al. 2021) which might benefit emerging market central banks to also do so and gain from capital inflows, especially when the tapering of such QE programs is conducted cautiously.

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). However, it needs to consider trade-offs that might negatively affect the financial stability at the same time. For instance, green supporting factors, would have could support the productivity of green capital goods and encourage green investments in the short-term, but might cause financial instability by raising non-performing loans ratio of dirty investments and creating green bubbles (Dunz et al. 2019). The COVID-19 crisis has opened an opportunity to restructure the economy into climate-friendly form by aligning the COVID-19 response packages with the Paris Agreement. The key is to monitor and ensure that the public and private finance do not flow into companies and assets that do not comply with the Paris Agreement. The financial supervisors needs to implement stricter guidelines to overcome the greenwashing challenges (Caldecott 2020). After focusing on providing recovery packages in the short-term, the governments need to nurture renewable and energy efficient technologies and prepare the long-term strategies for restructuring of the economy through stimulus packages. In the long-term, it is necessary to design policies to prepare for future shocks (Steffen et al. 2020).

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. The theory 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 a weaker form of the efficient markets hypothesis may still apply (that given enough time, investors cannot do better than the market, even if the latter makes short-term errors). It is arguable 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. Banks and institutional investors are also progressively rebalancing their investment portfolios away from fossil-fuels and towards rising portfolios of low-carbon investments (IEA 2019b; Monasterolo and de Angelis 2020)**.** In the meantime, the world runs the risk of sharp adjustments, crises and irreversible 'tipping points' (Lontzek et al. 2015) sufficiently destabilizing climate outcomes. This 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). Disclosure requirements of risks and information in private settings remain mostly voluntary and difficult to implement (Monasterolo et al. 2017; Battiston et al. 2017a).

Nevertheless, financial markets are innovating in search of solutions. 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, bundling construction financing, debt financing , mezzanine financing, 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 case for efficient financial markets in developing countries 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), and high-risk aversion as most markets are rated as junk, or below/barely investment grade (Hanusch et al. 2016). Other constraints such as limited long-term financial instruments and underdeveloped domestic capital markets, absence of significant domestic bond markets for investments other than sovereign borrowing, and inadequate term and tenor of financing, make the efficient markets thesis practically inapplicable for most developing countries. Local governments effort to de-risk might turn out negative and encourage privatisation of public services (Gabor 2019). The developing of local capital markets and robust domestic financial systems is a priority however is a long term strategy for low and middle income countries and regions, with capacity - that choose to pursue that path using the technical assistance programmes available (see Section 15.6.7). More pro-active interventions, such as publicly organised and supported low-carbon infrastructures through resurrected national development banks may 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). Especially in developing countries with insufficient traditional de-risking measures, 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, can be beneficial to enhancing financial resilience of risk bearers, especially the most vulnerable communities and their governments (Linnerooth-Bayer and Hochrainer-Stigler 2015).

Markets: Public theory, finance, and creative destruction. The extension of the case for public policy support to developing 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 but the scale and urgency of change might force options of change to occur faster, supported by state policy because excessive financialisation 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). (Mercure et al. 2016) suggested 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. 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). Grafström and Lindman (2017) suggest that public R&D support did not necessarily induce significant effects on invention/patents, there were large cross-border knowledge spill-overs (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 (10-25 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 (+50 countries) by reducing market risks in financing and stability in project revenues (Menanteau et al. 2003; Jacobsson et al. 2009).

Outside of RE, scattered but numerous examples are available on the role of innovative public policy to spur and create new markets and technologies, including the procurement of LEDs and bulks in India (2014–2018), earlier energy-efficient lighting with standardisation and quality assurance, direct procurement, stakeholder 'involvement' and 'demonstrations' in Sweden (1991–2000) (Arent et al. 2017), energy efficiency schemes at the city and state levels in the USA, working with private sector and financial markets. 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 and 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 weatherisation programs in US (Fowlie et al. 2018), while political economy changes brought a decline in offshore wind opportunities in Norway. The energy performance contracting (EPC) is widely accepted, and effective mechanism used for improving energy efficiency. EPC is a win-win business model between an energy service company (ESCO) and energy user. Generally, the ESCO will take on the technical risks involved with the project and make profit only after the performance target is reached, while the energy user will benefit from infrastructure improvements but take up the business risks. Based on the general concept, different variations of the EPC business models are established, such as the share savings, guaranteed savings, energy-cost trust, and finance lease (Qin et al. 2017). Despite the advantages of EPC, the main concern related to EPC is that the allocation of risk and profit between various stakeholders is complex (Guo and Zhang 2020). Government guarantees are an important financial instrument that plays an important role in expanding climate finance, especially from the private sector, with scarce public finance, by reducing the risk profile of the investment opportunities. Investment guarantees 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). Risk-sharing allows participants to increase the amount and number of resources and participants, to leverage scarce public finance to maximise the impacts, and to take shared and common approaches among financial actors (UNEP 2011).

Support of climate action via carbon pricing, taxes, and 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). 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). Nonetheless, durable carbon pricing in economic and political systems must be implemented and approached combining related elements to both price and quantity (Grubb 2014).

The introduction of fiscal measures, such as carbon tax, or market-based pricing, such as emission trading scheme, to reflect carbon pricing have benefits and drawbacks that policymakers need to consider both country-specific conditions and policy characteristics. Carbon tax can be a simpler and easier way to implement carbon pricing, especially in developing countries, because countries can utilise the existing fiscal tools and do not need a concrete enabling conditions as market-based frameworks. The reallocation of revenues from carbon taxes is an important measure. It can further shift towards low-carbon investments as well as reduce negative impacts of taxes by reducing the conventional tax burdens (High-Level Commission on Carbon Prices 2017). In combination with other policies, such as subsidies, public R&Ds on resource-saving technologies, properly designed carbon taxes can facilitate the shift towards low-carbon, resource-efficient investments (Bovari et al. 2018; Naqvi and Stockhammer 2018; Dunz et al. 2020). While carbon taxes have negative effects on GDP, which can be alleviated from using the revenues of carbon taxes, it would raise the price of carbon-intensive products as well as increase production costs of carbon-intensive firms (Dunz et al. 2020)**.**

Emission trading systems (ETS) has been considered as an effective instrument for achieving emissions reductions. For example, (Barragán-Beaud et al. 2018) recommended that ETS is the most appropriate mechanism with better political feasibility and cost-effectiveness in the Mexican electricity market. China had achieved emissions reductions and energy conservations through its pilot ETS between 2005 and 2015 (Hu et al. 2020; Zhang et al. 2019). However, ETS is 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).

The effectiveness and results of carbon pricing 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 still a weak relationship between changes to the tax rate and changes to emissions that the level of the existing carbon taxes are not strong enough to yield a significant emissions reduction. However, the presence of carbon taxes can promote low-carbon technologies and investments (Best and Burke 2018), and price signals, including carbon taxation, provide powerful and efficient incentives for households and firms to reduce CO_2 emissions (IMF 2019). Theoretical discussions usually portray carbon taxes and ETSs as alternatives but in practice jurisdictions often implement both instruments to address emissions by different sources (Haites 2018)**.** Institutional learning, administrative prudence, appropriate carbon revenue management and stakeholder engagement are identified as key ingredients for successful ETS regimes (Narassimhan et al. 2018). While the carbon pricing policies are increasingly adopted in both developed and developing countries, (Finon 2019) argued the role of the non-carbon price instruments, such as command-and-control, mandate and obligations on technologies or sectors, and subsidies on efficient equipment, especially in developing countries. While the carbon pricing provides information in establishing climate policies, non-carbon price instruments can be more effective in developing countries where market and regulatory failure and political economy constraints are more prevalent. To date, 64 carbon pricing initiatives were implemented or scheduled for implementation, and covered only 22% of global GHG emissions (World Bank Group 2020b). While the carbon pricing was suggested by many economists and researchers (Nordhaus 2015; Pahle et al. 2018), overcoming the political and regulatory barriers would be necessary for the further implementation of an effective carbon pricing nationally and internationally. Without the strong political support, the effectiveness of carbon pricing would be limited to least-cost movements (Meckling et al. 2015).

Role of domestic funding sources. Efforts to address climate change can be scaled up through the mobilisation of domestic funds (Fonta et al. 2018). However, several barriers need to be overcome by the state investment banks (SIBs) to efficient allocate the public funding. The SIBs should effectively take up the following roles to address these issues. First, SIBs should take up a capital provision role to assist with overcoming financial barrier when there are economic downturns or with projects requiring huge upfront capital cost. Second, SIBs can attract the private investors to low-carbon projects by taking up a de-risking role. Third, education is another key role of SIBs as they not only develop the capacities of their employees but also, educate investors and developers disseminating new information and knowledge throughout the sector. Fourth, SIBs are required to co-finance with other investors for large projects; thus, SIBs can signal and direct the investments towards green projects. Lastly, SIBs can also act as a first mover by investing in new and innovative technologies or business models (Geddes et al. 2018).

BOX 15.6 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 2019a). For example, in 2018, solar PV LCOEs for utility-scale projects came in between 0.04 USD kWh^{-1} and 0.35 USD kWh^{-1} with a global weighted average of 0.085 USD kWh^{-1}. 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 (Steffen 2019; Geddes et al. 2018). 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 et al. (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% (PV) 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).

15.6.2.1 The public-private and mobilisation narrative and current initiatives

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. 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.

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 (CBI 2019) which is hardly recognised as private sector involvement in the current debate. 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). It remains key that the private sector mobilisation 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).

Limited comparative research is available on the efficiency of mobilisation 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 prioritisation and agreement on prioritisation 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 overemphasise 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).

15.6.3 Considerations on availability and effectiveness of public sector funding

The gap analysis as well as other considerations presented in this chapter illustrate the critical role of increased volumes and efficient allocation of public finance to reach the long-term global goals, both nationally and internationally.

Higher public spending levels driven by the impacts of COVID-19 and related recovery packages. Higher levels of public funding represent a massive chance but also a substantial risk. A missing alignment of public funding and investment activity with the Paris Agreement (and sustainable development goals) would result in significant carbon lock-ins, stranded assets and thus increase transition risks and ultimately economic costs of the transition. Using IMF data for stimulus packages, Andrijevic (2020) estimated that COVID-19 related fiscal expenditure had surpassed 12 trillion USD by October 2020 (80% in OECD countries), a third of which being spent in liquidity support and healthcare. Total stimulus pledged to date are ten times higher than low-Paris-consistent carbon investment needs from 2020–2024 (Vivid Economics 2020; Andrijevic et al. 2020). Overall, stimulus packages launched include 3.5 trillion USD to sectors directly affecting future emissions, with overall fossil-fuel investment flows outweighing low-carbon technology investment (Vivid Economics 2020).

Lessons from the global financial crises show that although deep economic crises create a sharp short-term emission drop, and green stimulus is argued to be the ideal response to tackle both the economic and the climate crises at once, disparities between regional strategies hinder the low carbon transition. Indeed, inconsistent policies within countries can also counterbalance emission reductions from green stimulus, as well as a lack of transparency and green spending pledged not materialised (Jaeger et al. 2020). Also, aggressive monetary policy as a response to the global financial crisis, including quantitative easing that did not target low-carbon sectors, has been heavily criticised (Jaeger et al. 2020). The COVID-19 crisis recovery, in contrast, benefits from developments which have taken place since, such as an emerging climate-risk awareness from the financial sector, reflected in the call from the Coalition of Finance Ministers for Climate Action (2020), which reunites 50 countries' finance ministers, for a climate-resilient recovery. The steep decrease in renewable electricity prices since 2010 also represents a relevant driver for a low carbon recovery (Jaeger et al. 2020). Many more sectors are starting to show similar opportunities for rapid growth with supportive public spending such as low-carbon transport and buildings (IEA 2020d). Expectations that the package will increase economic activity rely on the assumption that increased credit will have a positive effect on demand, the so-called demand-led policy (Mercure et al. 2019). Boosting investment should propel job creation, increasing household income and therefore demand across economic sectors. A similar plan has also been proposed by the incoming US administration.

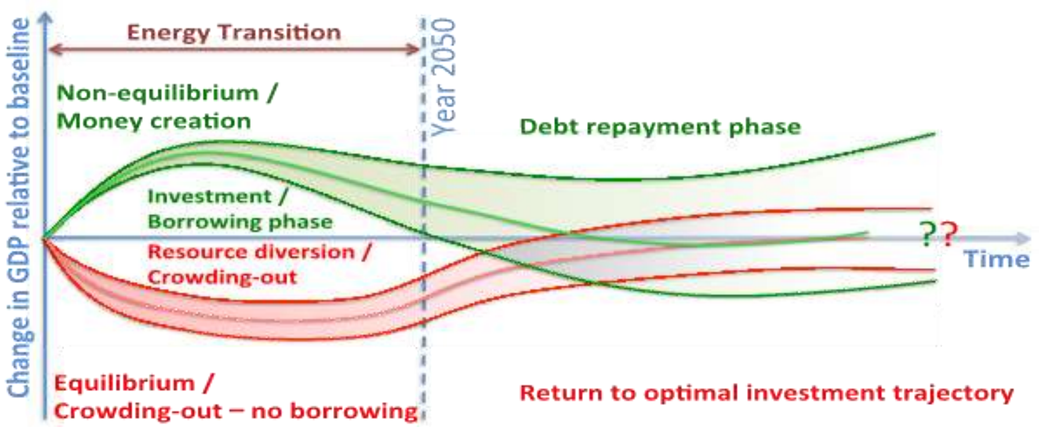
Nevertheless, three uncertainties remain. First, only those countries and regions with highest credit-ratings (AAA or AA) with access to deep financial markets and excess savings will be able to mount such counter-cyclical climate investment paths, typically high-income developed economies. In more debt constrained countries have and lower access to global savings pool countries because of higher risk perceptions and lower credit ratings (BBB or less), exacerbated by COVID-19 and already leading to credit downgrades and defaults (Kose et al. 2020) and have long tended to be fiscally pro-cyclical (Mcmanus and Ozkan 2015). These include the general class of virtually all major emerging and especially low-income developing countries, to which such demand-stimulating counter-cyclical climate consistent borrowing path is likely To access such funds, these countries would need globally coordinated fiscal policy and explicit supporting cross-border instruments, such as sovereign guarantees, strengthening local capital markets and boosting the 100 billion USD annual climate finance commitment (Dasgupta et al. 2019).

Second, a strong assumption is that voters will be politically supportive of extended and increased fiscal deficit spending on climate on top of COVID-19 related emergency spending and governments will overcome treasury biases towards fiscal conservatism (to preserve credit ratings). Evidence strongly suggests that voters (and credit rating agencies) tend to be fiscally conservative(Peltzman 1992; Lowry et al. 1998; Alesina et al. 2011; Borge and Hopland 2020) especially where expenditures involve higher taxes in the future and do not identifiably flow back to their local bases (the 'public good' problem). Such mistrust has been a reason for abortive return to fiscal austerity often in the past (most recently during global financial crisis) and may benefit for political support by consistently reframing the climate expenditures in terms of job creation benefits (Bougrine 2012), effectiveness of least-cost fiscal spending on climate for reviving private activity, and the avoidance of catastrophic losses (Huebscher et, al. 2020) from higher carbon emissions. A new understanding of debt sustainability including negative implications of deferred climate investments on future GDP has not yet been mainstreamed (see more on the debt sustainability discussion below (e.g. Buhr et al. 2018; Fresnillo 2020). In addition, implications on the availability of international public finance flow are not yet clear with announcement of additional funding being linked to emergency healthcare support rather than an increase of predictable mid/long-term financial support. Heavy investment needs for recovery packages in developed countries on the one hand and their international climate finance commitments might be perceived to compete for available "perceived as appropriate" budgets.

BOX 15.7 Macroeconomics and finance of a Post-COVID-19 green stimulus economic recovery path

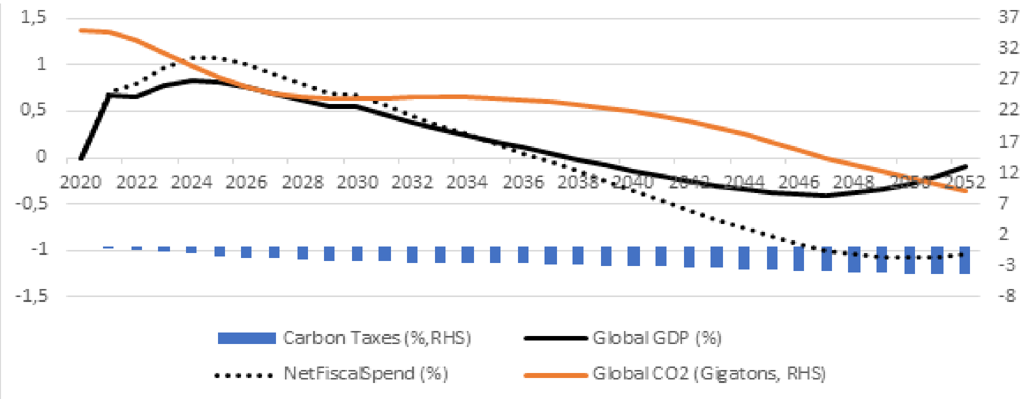
Financial history suggests that capital markets may be willing to accommodate extended public borrowing for transient spending spikes (Barro 1987) when macroeconomic conditions suggest excess savings relative to private investment opportunities (Summers 2015) and when public spending is seen as timely, effective and productive, with governments able to repay when conditions improve as economic crisis conditions abate. A surge in global climate mitigation spending in the post-pandemic recovery may be an important opportunity, which global capital markets are signalling (Global Investor Statement 2019). The standard 'neo-classical' macroeconomic model is often used in integrated energy-economy-climate assessments (Nordhaus 2018; Balint et al. 2016). This class of Computable General Equilibrium (CGE) models, however, have a limited treatment of the financial sector and assume that all resources and factors of production are fully employed, there is no idle capacity and no inter-temporal financial intermediation (Pollitt and Mercure 2018). Investment cannot assume larger values than the sum of previously determined savings, as a fixed proportion of income. Such constraint, as stressed by Mercure et. al (2019), implies that investment in low-carbon infrastructure, under the equilibrium assumptions, necessarily creates a (neo-Ricardian) crowding-out effect that contracts the remaining sectors. The graphic below shows the implications (in the red-shaded part of Figure 1). Higher investment in low-carbon activities in the near-and-medium-term (2020-50) energy transition must involve diverting resources and crowding-out of other investments that lowers output growth relative to the baseline and slowly recovers back to the optimal path.

Post-Keynesian demand-side macroeconomic models, with financial sectors and supply-side effects, in contrast, allow for the reality of non-equilibrium situations: persistent short to medium term underemployed economy-wide resources and excess savings over investment because of unexpected shocks, such as COVID-19. In these settings, economic stimulus packages allow a faster recovery with demand-led effects: "Economic multipliers are near zero when the economy operates near capacity. In contrast, during crises such as the GFC, economic multipliers can be high (Blanchard and Leigh 2013; Hepburn et al. 2020). The expected results are opposite to the standard supply-led equilibrium models as a response to investment stimulus (the green-shaded part of Box 15.7, Figure 1), as intended by 'green-stimulus' packages such as proposed by the EU (Mercure et al. 2019; Balint et al. 2016).



Box 15.7, Figure 1: Two Worlds – Energy transition outcomes under alternative model assumptions (Keynesian vs General Equilibrium)

Even if demand-led models work better in depressions, the question nevertheless is whether the additional public borrowing for such 'green stimulus' can be undertaken by market borrowings given already high public debt levels and recovered in the future from taxes as the economy revives. Moreover, we need to understand how big the size of the stimulus would have to be to achieve the desired rate of carbon emissions reduction (and not crowd out private activity) and whether there is a path of (carbon) taxes that can stimulate the desired energy transition path and provide confidence to financial markets. The results of recent macroeconomic modelling work (IMF 2020a) represented by 10 major countries/regions, including oil exporters suggests answers (Box 15.7, Figure 2). It uses a non-standard macroeconomic framework, with financial and labour market rigidities and fiscal and monetary rules (McKibbin and Wilcoxen 2013), that have Keynesian features and allow an examination of the effects of climate mitigation policies on carbon emissions and short, medium and long-term macroeconomic dynamics. First, a global 'green stimulus' of about an average of 0.8% of GDP annually in additional fiscal spending between 2020-30 would be required to accelerate the emissions reduction path required for a 1.5°C transition. Second, such a stimulus would also accelerate the global recovery by boosting GDP growth rates by about 0.6% annually during the critical post-COVID period. Third, the optimal tax policy would be to backload the carbon taxes to later in the macroeconomic cycle, both because this would avoid dampening near-term growth while pre-announced carbon tax plans would incentivise long-term private energy transition investment decisions today and provide neutral borrowing. This macroeconomic modelling path thus replicates the 'green stimulus' impacts expected in theory (Box 15.7, Figure 1). There are also some other additional features of the modelled proposal: (a) fiscal stimulus—needed in the aftermath of the pandemic—can be an opportunity to boost green and resilient public infrastructure; (b) green research and development 'subsidies' are feasible to boost technological innovations; and (c) income transfers to lower income groups are necessary to offset negative impacts of rising carbon taxes.



Box 15.7, Figure 2: Global macroeconomic path of Post-COVID-19 climate consistent recovery
Note: Post-COVID Green Stimulus Recovery Path. Global CO_2 Emissions, GDP Growth and Fiscal Stimulus (Deviations from Baseline), and Later Carbon Taxes. Source: WEO database, IMF (2020)

Considerations on global debt levels and debt sustainability as well as implications for climate finance. The Paris Agreement marked the consensus of the international community that a temperature increase of well below 2 degrees needs to be achieved and the SR1.5 has demonstrated the economic viability of 1.5°C. As such, the question on "How much can we afford" versus "Whatever it takes and what is the most appropriate and robust set-up and framework for that" should have been answered. However, in terms of increase of supply of in particular public finance, often the debate is still driven by the question on affordability, considerations around financial debt sustainability and budgetary constraints against the background of macroeconomic headwinds – even more in the (post-)COVID-19 world. For example, Maastricht Treaty ceilings (3% of GDP government deficit and 60% of GDP (gross) government debt) are somehow artificial hurdle rates not considering economic costs of deferred climate action as well as economic benefits of the transformation.

Robust studies on the economic costs and benefits in the short- to long-term of reaching the LTGG exist for only few countries and/or regions, primarily in the developed world e.g. (e.g. BCG 2020; McKinsey 2020a). With many studies underpinning the strong economic rationale for high investments in the short-term (McKinsey 2020a), regional differences are significant highlighting the need for extensive cooperation and solidarity initiatives.

For many developing countries, the focus of debt sustainability discussions is on the negative effect of climate change on the future GDP and the uncertainty with regard to short-term effects of climate change and their economic implications. 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. The latter 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.

Debt levels globally but particularly in developing and vulnerable countries have significantly increased over the past years with current and expected climate change impacts further burdening debt sustainability. For low and middle income countries, 2018 marked a new peak of debt levels amounting to 51% of GDP; between 2010 and 2018, external debt payments as a percentage of government budget grew by 83% in low- and middle-income countries, from an average of 6.71% in 2010 to an average of 12.56% in 2018 (Eurodad 2020). COVID-19 has further reduced the fiscal space of many developing governments and/or increased the likelihood of debt stress. With many vulnerable countries already being burdened with higher financing costs, this limited fiscal head space further shrinks their ability to actively steer the required transformation (Buhr et al. 2018)**.**

Considering the need for responses to short-term liquidity issues and long-term fiscal space, current G20/IMF/World Bank debt service suspension initiatives are focused the liquidity issue her than underlying problems of more structural nature of many low-income (Fresnillo 2020). In order to ensure fiscal space for climate action in the coming decade a mix between debt relief, deferrals of liabilities, extended debt levels and sustainable lending practices including new solidarity structures need to be considered in addition to higher levels of bi/multilateral lending to reduce dependency on capital markets and to bridge the availability of sustainably structured loans for highly vulnerable and indebted countries. More standardised debt-for-climate swap, a higher share of GDP linked bonds or structures ensuring (partial) debt cancellation in case countries are hit by physical climate change impacts/shocks appear possible. The collective action clause might be a good example of a loan/debt term which became market standard. Definition of triggers is likely the most complex challenge in this context.

With public funds becoming scarcer, 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).

Stranded assets. The debate around stranded assets focuses strongly on the loss of value to financial assets for investors (see Section 15.6.1), however, stranded asset and resources in the context of the transition towards a low emission economy "are expected to become a major economic burden for states and hence the tax payer" (EEAC 2016). Assets include not only financial assets but also infrastructure, equipment, contracts, know-how, jobs as well as stranded resources (Bos and Gupta 2019)**.** Besides financial investors and fiscal budgets, consumers remain vulnerable to stranded investments. Against the background of the frequent simultaneousness of losses occurring the for financial investors on the one hand and negative employment effects as well as regional development and fiscal effects, negotiations about compensations and public support to compensate for negative effects of phasing out of polluting technologies often remain interlinked and compensation mechanisms and related redistribution effects un-transparent.

Recent phase-out deals tend to aim for a (partial or full) compensation rather than no relief for losses. In contrast to the line of argument in the tobacco industry, the backward looking approach and a resulting obligation of compensation by investors in polluting assets can be observed rarely with the forward looking approach of compensations by future winners for current losers dominating – despite the high level of awareness about carbon externalities and resulting climate change impacts among polluters for many years (van der Ploeg and Rezai 2020). In particular, transactions in the energy sector show a high level of investor protection also against much needed climate action which is also well illustrated by share of claims settled in favour of foreign investors under the Energy Charter Treaty and investor-state dispute settlement (Bos and Gupta 2019)**.**

Late government action can delay action and consequently strengthen the magnitude of action needed at a later point in time with implications on employment and economic development in impacted regions requiring higher level of fiscal burden. This has also be considered in the context of global climate cooperation with prolonged support for polluting infrastructure resulting heavy lock-in effects and higher economic costs in the long-run (Bos and Gupta 2019)**.** With a significant share of fossil resources which need to become stranded in developing countries to reach the LTGG, REDD remains a singular example for compensation for stranded resources.

15.6.4 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 4210 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 yr^{-1} losses) (Aon Benfield UCL Hazard Research Centre 2019). In the period 2017–2018, natural catastrophe losses total approximately 219 billion USD (Bevere 2019). 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[7], (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). The World Bank estimated that 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. 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).

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). Commercial insurability is heavily driven by the predictability of losses and the resulting ability to calculate insurance premium levels properly. Climate change has become a major factor of increasing uncertainty. The previously strong reliance on historic data in calculation of premium levels is inappropriate in the case of climate change and requires significant adjustments of internal decision-making processes. Different risk perceptions between policyholders and insurers will create contrary assessments on premium levels and consequently underinsurance. McKinsey (2020) also stresses the systemic effect of climate change on insurers' business models and resulting availability of appropriate insurance products.

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 a trend towards 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

FOOTNOTE [7] 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).

also increasingly appealing to the business sector, particularly MSMEs, in developing countries (Schaer, C., Kuruppu, N. (2018), MEFIN Network and GI RFPI Asia. (2016) and Woods (2016).

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 bilateral donors such as the USAID and DfID, and the multilateral development banks, 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 seems relatively 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 and disbursement is rapid and there are also fewer transaction costs(Lucas 2015: World Bank 2014). 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).

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 organisations 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 coordination challenges, limited scope, de-stabilisation due to exit of one or more members as premiums risk, inadequate attention to permanent and non-economic losses (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 in 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 (Schaeffer et al. 2014; Lucas 2015). 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 growing popularity of parametric insurance and climate risk pooling, there are very ambitious attempts to expand this approach on several fronts (Scherer 2017). Schoenmaker and Zachmann (2015) have proposed a global climate risk pool to help the most vulnerable countries. The pathway to this includes capacity building in underdeveloped financing sectors of developing countries. They argue that as climate extreme become more normalised, 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 (2015) 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 (2015) call for international risk pooling as the only sensible strategy. They proposed a global risk pool that builds 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. Kreft and Schäfer (2017) offer a three-step process for how the G20 can cement their agenda in advancing risk pooling instruments. First, address the major gaps in climate risk insurance for poor and vulnerable communities. Second, 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 utilised in many G-20 countries, where individual risk pool may exist. (Kreft and Schäfer 2017). Importantly, existing regional mechanisms, while they perform very well, only cover a portion of climatic hazards.

Other gaps and challenges flagged by Kreft and Schäfer (2017) 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 recognise the work of ARC's Africa Risk for not only providing the infrastructure to trigger disbursement but for also promoting national risk analysis. Another important gap in the landscape of climate risk pooling is lack of attention to financial institutions' lending portfolio that is vulnerable to weather shocks. In this regard 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 has 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 and the Vulnerable Group of 20 States,). 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).

In the literature there are two attempts at systematic evaluation or comprehensive assessment of regional climate risk pools: The 2015, UK Department of International Development funded long term-Independent Evaluation of the ARC; and a comprehensive study by Scherer (2017). Overall, none of these studies draw adverse conclusions about regional climate risk pooling initiatives/mechanisms. According to Scherer (2017) ‘it appears that insurances work in principle and there is certainly successes’ and ’initial experiences demonstrates regional climate risk insurances works’. The author cited the 28 payouts to 16 countries of 106 million USD arguing that it provides cash-starved countries with much needed cash (Scherer 2017). The DFID a ten- year long evaluation (2015-2024) examines the uptake of ARC (ARC 2020) and its impact on reducing vulnerability to disasters. It notes that there is scarce literature on disaster risk insurance mechanism in terms of impacts. In its current sample of 20 countries as of November 2017, it noted that 4 are projected to experience food security crisis (IPC Level 3) but are not signatories to the ARC which may signal that ARC is not attractive to all food insecure countries and that there is no overwhelming appetite for ARC among poorer countries. Additionally, Panda and Surminski (2020), research on the importance of indicators and frameworks for monitoring the performance and impact of CDRI make no final assessment of any of the regional climate risk pool. However, they propose mechanisms to improve the transparency and accountability of the system. Scherer (2017) , Forest (2018) and Panda and Surminski (2020), seem to indicate that there is enthusiasm to support and scale up regional climate risk insurance (Scherer 2017). Examples of this support include, the Germany Ministry for Economic Cooperation and Development (BMZ) has provided 5.9 million USD for WFP to protect 1.2 million vulnerable African framers with climate risk insurance, through ARC Replica, and the G7, InsuResilience Vision 2025, which has committed to ensuring 400–500 million poor persons are covered against disaster shock by pre-arranged finance and insurance mechanism by 2025, some of this will be through ARC (World Food Programme 2020). Of course, this does not mean that risk pools are without challenges or are not failing on specific sets of metrics. Forest (2018) flags three failing areas: policy holder and hazard coverage, the cost of premium and risk transfer parameters and the use of payout, which in most cases are up to the government. Here, ARC is flagged among the three regional Risk pools, as the only one with contingency plan requirement that can support effective use of pay-outs. Other research explores climate risk pool and its impact flag lack of transparency around payout, premium or risk transfer parameters. Ultimately, climate risk pools are not full insurance; they offer only limited coverage. Entities such as the UK Anti-Corruption Help desk is exploring how to mitigate potential corruption with regard to climate risk insurance.

15.6.5 Widen the focus of relevant actors: Role of communities, cities and sub-national levels

There is an urgency and demand to meet the financial needs of the climate change actions not only at the national level but also at the subnational level, to achieve low-carbon and climate-resilient cities and communities (Barnard 2015; C40 Cities Finance Facility and CDP and Global Covenant of Mayors 2018). Scaling up subnational climate finance and investment is a necessary condition to achieve climate change mitigation and adaptation action (Ahmad et al. 2019). Many countries have established decentralised and devolved climate finance systems to support subnational climate change actions (Sharma et al. 2015; IIED 2017).

The importance of exploring effective subnational climate finance. Stronger subnational climate action is indispensable to adapt cities to build more sustainable, climate-positive communities (Kuramochi et al. 2020). It has transformative potential as a key enabler of inclusive urban economic development through the building of resilient communities (Floater et al., 2017a; Ahmad et al. 2019;

Colenbrander et al. 2018). Yet the significant potential of many subnational climate finance mechanisms remains unfulfilled. Policy frameworks and choices at higher levels underpin subnational climate investments (Colenbrander et al. 2018; Hadfield and Cook 2019). To scale climate investment, a systematical understanding of the preconditions to mobilizing high-potential financing instruments at the national and subnational levels is necessary.

Subnational climate finance needs and flows. Subnational climate finance covers financing and funding mechanisms reaching or utilising subnational actors to develop climate positive investment in urban areas. The fragility of interconnected national and subnational finances affects subnational finance flows, including the impact of the social-economic crisis (Canuto & Liu, 2010; Ahrend et al., 2013). The effect of deficit in investment for global infrastructure towards the growing subnational-level debt also creates pressure on subnational finances and constrains future access to financing (Smoke 2019).

IFC (2018) estimates a cumulative climate investment opportunity of 29.4 trillion USD across six urban sectors in emerging market cities to 2030. The investment needed to make urban infrastructure sustainable is in the range of 0.4–1 trillion USD annually (CCFLA 2015). Low-carbon investment brings a compelling economic case for cities, estimated to generate 16.6 trillion USD net savings in 2015–2050 (Gouldson et al. 2015). However, the Institute for Environment and Development estimates that out of the 17.4 billion USD total investments in climate finance, less than 10% (1.5 billion USD) was approved for locally-focused climate change projects between 2003 and 2016 (Soanes et al. 2017). This includes adaptation and mitigation-dedicated locally-based projects, such as local climate-compatible infrastructure, climate-sensitive policy frameworks for local level, and climate change relevant community-based projects.

Subnational climate public and private finance. Urban climate finance and investment are prominent among the subnational climate finance landscape (CCFLA 2015; CPI 2019). Finance mechanisms that can support climate investment for the urban sector include public-private partnerships (PPPs); international finance; national investment vehicles; pricing, regulation, standards; land value capture; debt finance; and fiscal decentralisation (Granoff et al. 2016; Floater et al. 2017a; Gorelick 2018; White and Wahba 2019). Among these mechanisms, PPPs, debt finance, and land value capture have the potentials to mobilise private finance (Ahmad et al. 2019) (see PPP discussion in Section 15.6.6.1).

PPPs are particularly important in cities with mature financial systems as the effectiveness of PPPs depends on appropriate investment architecture at scale and government capacity. Such cities can enable its infrastructure such as renewable energy production and distribution, water networks, and building developments to generate consumer revenue streams that incentivise private investors to purchase equity as a long-term investment (Floater et al. 2017b). Shanghai shows that cities can employ direct funding, such as grants and subsidies, to conduct climate mitigation projects. If well-designed and cost effectively implemented, direct funding can be an attractive option in managing low-carbon transition as it fills the gap between the policy intentions and the policy outcomes (Peng and Bai 2020).

National-level investment vehicles can provide leadership for subnational climate financing and crowd in private finance by providing early-stage market support to technologies or local evidence related to asset performance and costs-benefits. When they do not exist or have limited capacity, international finance facilities such as multilateral development banks, multilateral climate funds, and ODA have substantial potential to drive subnational climate investment and blend different sources of finance. The use of carbon pricing is increasing at the subnational level along with regulation and standards on negative externalities, such as pollution, to steer investment towards climate financing (World Bank 2019a). Land value capture can benefit from robust regulatory frameworks as a powerful tool for funding large urban projects, particularly in transportation and land use sector to incentivise low-carbon mobility (Floater et al. 2017b). Where capacity at the subnational level and political will at the national level exist, fiscal decentralisation provides subnational governments with revenue through the property and other forms of taxation (Sow and Razafimahefa 2014).

Debt financing via municipal bonds and borrowing is another essential tool for raising upfront capital. The share of municipal, sub-sovereign, and sovereign bonds could grow over time, given efforts to expand the creditworthiness and ensure a sufficient supply of own-source revenue to reduce the default risk. As of now, subnational and sub-sovereign bonds are constrained by public finance limits and the fiscal capacities of governments. Green municipal bonds can attract investors who do not typically buy municipal bonds, e.g., ESG investors, and fostering greater cross-agency collaboration because of the process of structuring and issuing a green bond requires cooperation within a city bringing together various departments responsible for finance, sustainability, infrastructure, and planning (Saha and D'Almeida 2017). However, it is prone to reputation externalities, which suggests caution about the existence of high specific demand for green bonds or the willingness of investors to 'pay for green'(Karpf and Mandel 2018). The process of issuing green municipal bonds incurs extra transaction costs due to the level of disclosure and reporting required.

Key challenges of subnational climate finance. Across all types of cities, four key challenges constrain the flow of subnational climate finance: (i) difficulties in mobilizing and scaling-up private financing (Granoff et al. 2016); (ii) deficient existing architecture in providing investment on the scale and with the characteristics needed, including lack of adequate project preparation facilities and resource supports (Anguelovski and Carmin 2011; Brugmann 2012); (iii) political-economic uncertainties, primarily related to innovation and lock-in barriers that increase investment risks (Unruh 2002; Cook and Chu 2018; White and Wahba 2019); (iv) the deficit in investment for global infrastructure affects the growing subnational-level debt, which putting pressure on subnational finances and constraining future access to financing (Canuto and Liu 2010) and; (v) lack of positive value capture (Foxon et al. 2015). 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 internalizing the valuation of positive social and environmental externalities (Foxon et al. 2015; Granoff et al. 2016).

Different finance challenges between rich and poor cities. Access to capital markets has been one of major sources for subnational financing is generally limited to rich cities, and much of this occurs through loans. Different challenges accessing capital markets associated with wealthy and poorer 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 decarbonisation across carbon markets (Silver 2015), and (iii) the policy and jurisdictional ambiguity in urban public finance institutions (Cook and Chu 2018; Padigala and Kraleti 2014). In poorer cities, these differing features continue to be inhibited by contextual characteristics of municipal finance, including gaps in domestic and foreign capital (Meltzer 2016), the mismatch between investment needs and available finance (Gorelick 2018), weak financial autonomy, lack of financial maturity, investment-grade credit ratings in local debt markets (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).

The depth and character of the local capital market also affect cities differently in generating bonds. Challenges facing developing bond market cities, e.g., India, include a lack of in-house capacity or trained professionals for managing bond issuances, and the abundance of existing state funds to meet capital needs, thus, lowering any interest or need for entering the bond market in general, or green bond market, in particular (GIZ 2017b). Johannesburg and Cape Town are successful examples of cities in the developing countries that have issued green municipal bonds that have been readily absorbed by the market (Gorelick and Walmsley 2020). In the mature bond market, e.g., the US, one of the biggest challenges to green municipal bonds is the lack of bankable green projects or project pipelines. Green projects and project pipelines are generally smaller in scale than the bond markets typically like to see come to market (Saha and D'Almeida 2017).

Climate investment and finance for communities. The literature on community finance is very limited, and there is a lack of evidence that which financing schemes contribute to climate change mitigation and adaptations at community level. There is growing interest in the linkages between microfinance and adaptation with particular focus on the agriculture sector (Agrawala and Carraro 2010; Fenton et al. 2015; Chirambo 2016; Dowla 2018; Climate Investment Funds 2018), the finance for community-based adaptation actions (Sharma et al. 2014; Fenton et al. 2014), and the relations between remittances and adaptation (Le De et al. 2013). However, the limits to which microfinance can facilitate adaptation are unknown as limited evidence exists regarding the extent of internal climate-proofing operations of microfinance institutions (Fenton et al. 2015).

There is less discussion on community finance for mitigation aside from the benefits of community finance and village funds in contributing to close investment gaps and community-based mitigation in the renewable energy and forest sectors (Ebers Broughel & Hampl, 2018; Bauwens, 2019; Watts et al., 2019). The full potential and barriers of the community finance model are still unknown and research needs to expand understanding of favourable policy environments for community finance (Bauwens, 2019; Watts et al., 2019). More literature in linking community climate change mitigation and adaptation actions and various financing instruments is needed, such as community development credit, community development loan/venture capital, local financing through cooperatives, public-private community partnership, community investment, village banking, crowdfunding, and community-based trust funds.

Implications for the transformation pathway. Subnational climate financial systems need to be sensitive to shadow systems influencing organisational 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 (Mansuri and Rao 2013) and continuing political injustice (Barrett 2013). Only a 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 contexts (Padigala and Kraleti 2014; Colenbrander et al. 2018a; Cook and Chu 2018; Zhan and Jong 2018; White and Wahba 2019). 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 an additional burden to disadvantaged groups (Steele et al. 2015).

15.6.6 Support the development of new asset classes

Investor demand in innovative financial products. Since AR5, innovative financial products such as environmental, social and governance (ESG) indices and sustainability and green labelled financial products have proliferated (see financial stock estimates in Section 15.3.2.1). These financial products are not necessarily 'new' in terms of financial design but are packaged or labelled in an innovative way to attract responsible and impact-oriented institutional investors.

The growth and diversity of the green bond market illustrates how innovative financial products can attract both public and private investors. Demand for green financial products initially stemmed from public sector pension funds, such as the Swedish pension funds, which resulted in pioneering efforts in climate and green bonds by the European Investment Bank and the World Bank in 2007-2008. Responsible or impact investors constitute over 50% of the investor base for green bonds (CBI 2020a). Since AR5, labelled green bonds have grown significantly, exceeding 160 billion USD in 2017–2018, up from 37–51 billion USD in 2014–2015 (CBI 2019). Commercial, financial institutions and corporates (e.g. in real estate, retail, manufacturing, energy utilities) now represent the largest volumes (CBI 2019). Municipal green bond issuance has also been strong in certain countries such as Sweden (see further discussion on municipal green bonds in section 15.6.6 on local actors). Beyond green bonds, additional products such as green loans, green commercial paper and sustainability-linked loans have also been introduced in the market (CBI 2019).

The financial crisis associated with COVID-19 has put increased pressure on debt issuers, but as of yet literature has not been identified that explores the extent to which the increase in indebtedness for sovereigns and corporates has been financed via climate-related labelled debt products. Further, at this time there is no identified literature assessing the degree to which international versus domestic investors are financing sovereign green debt in developing countries (for further discussion on attracting different types of investors through the development of local capital markets see section 15.6.7) However, continued steady growth in issuance has been observed in sustainability-labelled bonds (which include both social and green project types) since the COVID-19 crisis, whereas green bond issuance did not grow as fast in the first half of 2020 as it had the previous year, showing a greater slow-down in emerging than developed country markets (CBI 2020b).

Index providers and exchanges can also play a role in supporting the development of innovative financial products for climate action. Low-carbon indices have proliferated in recent years, with varying approaches including reduced exposure to fossil, best-in-class performers within a sector, and fossil-free (UN PRI 2018) (see discussion on ESG index performance that follows in this section). Exchanges can also play a supporting role to the uptake of green financial products through transparent listings and requirements to improve credibility of green labelling. The number of green or sustainability bond listing segments tripled from five in 2016 to 15 in 2018 (SSE 2018a). Green security listings can also be used to enhance local capital markets, see Section 15.6.7 for further discussion.

Potential for and challenges of a continued growth in innovative financial products. Despite recent growth and diversification, green bonds face several challenges in scaling up. Issuance of green-labelled bonds (257 billion USD in 2019) constitutes approximately 3.5% of the global bond market issuance in that year (Ehlers et al. 2020; CBI 2020a). Potential exists to increase issuance amongst corporates, for instance, and across a broader regional scope (although subject to limitations of local capital markets). Yet there remain several challenges to growing the green bond market, including *inter alia* the potential for greenwashing and limitations in application to developing countries (see discussion in next part of this section) (Banga 2019; Shislov et al. 2018).

Labels such as green, sustainable, transition and ESG have overlapping applications, and the degree to which they are climate relevant depends on underlying criteria and how they are applied. There is no universal definition of green bonds and varied definitions of eligible green activities are evolving across regional bond markets, including e.g. in China and India. There are related concerns of 'greenwashing' or labelling a financial product green when it is not climate-aligned (Shislov et al. 2018). Regulatory efforts in the EU focused on disclosure of climate risk (see section 15.6.1) aim to clarify definitions and guard against greenwashing (TEG 2019). The proposed EU Green Bond Standard would require transparency on the degree of alignment with the detailed taxonomy of sustainable activities, but it is too early to understand the potential market implications of the forthcoming regulation. For some investors, this could provide more assurance against greenwashing, but at the same time could place an additional transaction burden on issuers of green and sustainable products in the EU. A further check on greenwashing, although insufficient on its own, is the fear of reputation risk on behalf of investors, issuers and intermediaries in the age of social media (Hoepner et al. 2017).

Green bonds have been primarily targeting mitigation projects. In 2019, green bonds financed projects in the energy (32%), transportation (20%), buildings (30%) and water (9%) sectors (Climate Bonds

Initiative 2019). Agriculture and forestry projects, including adaptation projects, have been less suited to be financed in a bond structure, in part due to the more disaggregated nature of the projects and in part due to project 'bankability' or ability to contribute steady streams of financing to pay back the terms of a bond.

While the green bonds have the potential to further support financial flows to developing countries, local capital market deficiencies continue to hinder green finance flows (see also Section 15.6.7 on local capital markets for peer-learning examples and de-risking opportunities) (Banga 2019). Since 2007, 43% of green bonds and sukuks (Islamic finance instruments) have been issued by multilateral and bilateral development institutions to finance climate action in developing countries (Clapp and Pillay 2017). In addition, there have been some notable examples of issuance by emerging market institutions such as the city of Johannesburg in South Africa, Yes commercial bank in India and Nafin development finance institute in Mexico. Some of these issuances attracted a significant percentage of investors from abroad, e.g. 79% of the investors in the Korean Export Import Bank green bond were from the US and Europe, although the degree to which they have attracted international investors is largely not known (CICERO and CPI 2015). The Yes Bank green bond illustrates an example of mitigating some of the credit risk, whereby the Indian commercial bank sold its green bond to the IFC, which in turn resold the bond on the London Stock Exchange under its higher credit rating (Torvanger et al. 2016).

Green financial products and cost of capital. One indicator of the potential uptake of green financial products is the willingness of investors to pay a premium for the green label to reduce their exposure to climate risk. Investors face a systematic under-pricing of climate risk in financial markets (Kumar et al. 2019; Krogstrup and Oman 2019). Green bonds are on example of a financial product where investors, in certain parts of the market, may be starting to pay a premium or so-called "greenium" for reduced climate risk.

There is mixed evidence of a premium, or lower yields, for green bonds in certain parts of the market (*low agreement, medium evidence*). 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, some studies show a positive premium for green bonds is emerging (Baker et al. 2018; Karpf and Mandel 2018), or emerging only in the secondary market (Partridge and Medda 2020), while others find no evidence of a premium (Hyun et al. 2019; Larcker and Watts 2020). Several studies also show a recent emergence of a premium and oversubscription for some green labelled bonds denominated in EUR (CBI 2020a) in some cases for both USD or EUR (Ehlers and Packer 2017) green bonds, with a wide variation in the range of the observed difference in basis points focusing on the secondary market (Nanayakkara and Colombage 2019; Zerbib 2019; Gianfrate and Peri 2019), with financial institution and corporate green bonds trading marginally tighter than their non-green comparisons (Hachenberg and Schiereck 2018).

Spill over effects of green bonds may also impact equity markets and other financing conditions. Stock prices have been shown to positively respond to green bond issuance (Tang and Zhang 2020), while enhanced 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 spill over 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, but potentially with the distribution of wealth concentrated in the credit sector (Monasterolo and Raberto 2018). For sustainability-labelled indices, there is mixed evidence with some studies showing improved financial performance over non-labelled indices (Jain et al. 2019). On a credit 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) (see also discussion on ESG data gaps in Section 15.6.1).

Considerations on measurable environmental impact of green financial products. 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. Further, new products must be coupled with tightened climate policy and a reduction in investments associated with GHG-emitting activities to make a difference on the climate (See section 15.3.3.2 for further discussion on reduction of financial flows to emitting activities). While investors are increasingly paying attention to climate change, there is not yet evidence that this leads to climate-aligned portfolios (see discussion on voluntary initiatives in Section 15.6.1). According to one assessment, financial assets in many investors' portfolios indirectly support a temperature increase well above 2°C (2° Investing Initiative 2017). 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 to allocate 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 some avoided emissions (Glomsrød and Wei 2018) there is contested evidence about the amount of direct impact from divestment.

It is challenging to link specific emission reductions with green bonds. Data challenges point to an inability to link emission reductions at the organisation or firm level with green bond issuance (Ehlers et al. 2020), although one paper cited evidence of emission reductions at the corporate level following green bond issuance (Flammer 2020). There is also a lack of impact reporting requirements in the green bond market. In the proposed EU Green Bond Standard, the only reporting required is on annual allocation, not on impact reporting (European Commission 2020). Nor is impact reporting required for green bond listings at specific exchanges at this time, however this could change in future if investors apply pressure.

Green-labelled products may not necessarily result in increased financial flows to climate projects, although there can be benefits from capacity building with issuing institutions. Green bonds can be used to finance new climate projects or refinance existing climate projects, and thus do not necessarily result in finance for new climate projects constituting additional GHG reductions (a framing used in the Clean Development Mechanism). The labelling process itself may not necessarily lead to additional financing (Dupre et al. 2018; Nicol et al 2018), however recent studies illustrate a willingness of investors to pay a premium for green bonds that could shift the additionality discussion in future (see discussion earlier in this section). In addition, the labelling process has merit in contributing to building capacity within issuing institutions on climate change (Schneeweiss 2019), which could support identification of new green projects in the pipeline.

BOX 15.8 The role of fintech in supporting innovative instruments and climate investment

Fintech can enhance climate investment in innovative financial products and build trust through data, but also presents some challenges. Financial technology or 'fintech' applies to data-driven technological solutions that aims to improve financial services (Dorfleitner et al. 2017; Schueffel 2016; Lee and Shin 2018). Blockchain is a key fintech that secures individual transactions in a distributed system, which can have many applications with high impact potential but is also associated with uncertainty (World Energy Council 2017) (OECD, 2019) Applications of fintech include aggregating transactions, verifying data, and matching investors to projects to support greater access to capital for renewable energy and agriculture resiliency projects and aggregated information to support carbon markets and green financial instrument investments (Box 15.8, Table 1).

Box 15.8, Table 1: Clustered fintech applications relevant to climate finance change

Sustainable development	Energy sector	Carbon credits	Green financial instruments
Tracking assets in supply chains across sectors such as forestry, fisheries, or energy (Nassiry 2018)	Blockchain supported grid transactions, renewable energy financing, and electric vehicles (Livingston et al. 2018)	Emissions accounting from the project level throughout the value chain across regions and commodity markets (World Bank 2018b)	Distributed ledger technology (digital system for recording asset transactions) for green Asset-Backed Securities (ABS) (Knuth 2018)
Credit scoring, using 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 (Livingston et al. 2018)	Data support to enhance formation and liquidity of carbon emission reduction trading markets (Cen and He 2018)	Transparency and verification for green financial instruments via green wallets for investors (Kyriakou et al. 2017)(Stockholm Green Digital Finance 2017)
Digital insurance for agricultural crops can support farmers to build resilience to weather-related shocks (Kramer and Ceballos 2018)	PAYGO (pay as you go) systems support decentralised electricity markets, flexible energy supply/demand (UNEP Inquiry 2016b)	Monitoring, Reporting and Verification (MRV) systems using standard units for carbon accounting (World Bank 2018b)	Sustainability rating schemes for climate-smart infrastructure via data aggregation on investment value chains (van Der Lugt 2018)

Fintech can potentially circumvent the need for trusted intermediaries such as banks (Nassiry 2018) and thus limit the power of local elites (Schmidt and Sandner 2017). Small-to-medium enterprises (SMEs) in developing countries can benefit from fintech solutions that bring entrepreneurs closer to their funders and diversify the types of funding (UNEP Inquiry 2017). However, there are several challenges with fintech in supporting climate investment. High energy consumption is associated with the decentralised nature of blockchain to secure cryptocurrency ledgers, such as bitcoin (Mora et al. 2018). While 60% bitcoin verification processes target electricity consumption, they also emit 33.5 $MtCO_2$-eq yr^{-1} according to one study (Mora et al. 2018). Further, blockchain and digital currency applications are not covered by a governance system (Tapscott and Kirkland 2016; Nassiry 2018). This could lead to problems with security (Davidovic et al. 2019) and trustworthiness of green financial data or privacy of individual information. Further changes in licensing and prudential supervision frameworks could impact new fintech business models.

15.6.7 Development of local capital markets

Situational Context. Regionally, the current focus of the global climate investment policies and opportunities tends to be on the big four (China, USA, EU-28 and India) and the G-20 generally (UNEP 2019b). But attention must accelerate on developing countries and in particular vast low-income Africa (African Union Commission 2015; IEA 2019c; Sweerts et al. 2019; Mandelli et al. 2014; Briceño-Garmendia et al. 2009; Eberhard and Shkaratan 2012; Gujba et al. 2012). The scale of investments required for energy access and low-carbon infrastructure in Africa and LDC developing country regions requires access to long term capital over and above what public sector governments of developing countries and private sector commercial banks have available. The 2015 UN Addis Ababa Agenda Financing for Development (UN 2015) Article 14 estimates that to bridge the global infrastructure gap including the 1 to 1.5 trillion USD annual gap in developing countries requires both enhanced financial and technical support. Section 15.4.2 elaborates on average mitigation funding needs of developing countries of almost 800 billion USD or approximately 3% of current GDP until 2030. Developing countries will not only need to mobilise technical support and partnership, but all diverse sources of funds – domestic, international, public, private including climate finance as well as technical assistance pledged under the Paris Agreement and Copenhagen Accord. IEA estimates for Africa power sector alone at 120 billion USD, exceeds the 100 billion USD climate finance Copenhagen Accord for all developing countries (IEA 2019c). It is widely recognised that developing countries have under-developed local capital markets to different degrees – with bond markets still very much at a nascent stage in many countries particularly in Africa (Mu et al. 2013; Berensmann et al. 2015; Essers et al. 2016; Du and Schreger 2016; Dafe et al. 2017). Policies centred 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 assessed in literature as crucial options. These offer opportunities in terms of a greater diversification of funding sources, access to local currency funding and in some scenarios addressing home bias effects in financing costs.

Mobilising long term capital. Institutional investors are being seen as a source of long-term capital with investment portfolios built typically around bonds and equities with an investment horizon often tied to long-term nature of their liabilities such as pension benefits provided at retirement and life insurance pay-outs. Local and international institutional investors such as pension funds and insurance companies with sizeable and growing assets estimated to be between 20–100 trillion USD worldwide, are increasingly seen as one possible source of additional capital to fill the financing gaps (EIB 2012; Arezki et al. 2016; Kaminker et al. 2013). Africa's largest pension fund – the South Africa Government Pension Fund (GEPF) holds about two trillion South African Rands Assets Under Management (AUM) (exchange rate on 8 Jan 2021: USD 0.065/Rand representing more than 130 billion USD) (GEPF 2019). Other large sub-Sahara Africa pension funds with sizeable 2019 AUM include Nigeria (33 billion USD), Kenya (13 billion USD), Namibia (12 billion USD) and Botswana (9 billion USD) (PWC 2015; Irving 2020). Bagus et al. (2020) analysis values Africa's insurance industry as the eighth largest in the world at about 68 billion USD in terms of Gross Written Premium and growing - although this is not equally distributed across the continent. Institutional investors in Latin America and the Caribbean reportedly hold just over 1 trillion USD AUM, or about 20% of GDP (Cavallo and Powell 2019; Serebrisky et al 2020). Pension funds in Australia and Canada are seen as the leaders in direct investment in infrastructure, allocating about 5 % of total AUM to infrastructure investment (Inderst and Della Croce 2013). Sovereign wealth funds (SWFs) are estimated to have around 5 trillion USD AUM and expected to double in size in the next decade providing significant potential for green bond investment. Markowitz (2020) estimates Africa SWFs to hold about 80 billion USD. Institutional investors' asset allocation to direct infrastructure investments in general remains small with less than 1% for OECD pension funds. Green investment component remains even more limited (Kaminker et al. 2013). In an assessment to barriers to investment – suitable standardised investment vehicles of scale, lack of national infrastructure road maps to give investor confidence in government commitments to developing investable projects and perception of complex risks are cited as example impediments. Kaminker et al. (2013) argue that one of the elements to increasing institutional investor allocation to green infrastructure is a competitive risk-return basis over different time horizons, to accommodate the varying risk appetites, investment preferences, and constraints. In their analysis they point to institutional investors with fiduciary responsibilities not making investments purely because these are green but taking account green labelling (Section 15.6.6). Risk-return is said to be an important consideration for pensions funds and insurers in considerations of security, profitability, liquidity and quality (Aviva 2019; Asgari 2019). In terms of asset allocation – non-government bonds are said to provide diversification and attractive yields, especially developing country markets with limited supply of bond instruments and a high concentration of investments in government securities. Institutional investors are reported as looking for opportunities that mitigate the risks arising from climate change as they integrate environmental, social and governance (ESG) factors into the investment process. The UN Principles for Responsible Investment (PRI), the largest global network of institutional investors committed to the integration process of ESG, as of 31 March 2020 has 3,038 members representing 103 trillion USD (UN PRI 2020). A coalition of investors including UN PRI published COVID-19 recovery plans and a briefing paper urging policy makers to accelerate the Paris Agreement signalling readiness to invest in climate solutions (IIGCC 2018, 2020). In other collaborations; Africa and US regional institutional investors formed a partnership platform - Mobilising institutional investors to Develop Africa's Infrastructure (MiDA) to explore investments including energy access and low carbon (MIDA 2017; Mercer 2018) whilst Japan's GPIF and Norway's KBN launched a partnership promoting green bonds (GPIF Japan 2020). Another potential long-term external finance source: diaspora remittances flows to low-and middle countries rose from under 100 to 530 billion USD during 1990-2018 although challenges remain in pooling to achieve country-regional level scale. Diaspora bond issuance being deployed for mitigation and adaptation projects including securitisation of remittances and their use as collateral for infrastructure bonds are discussed in literature (World Bank 2019b; Ketkar and Ratha 2010; Akkoyunlu and Stern 2012; Mensah 2019). The international development finance club comprising of 26 national and regional banks refers to 4 trillion USD combined assets including 150 billion USD climate finance (IDFC 2020). These literature studies point to the diverse multi-stakeholder nature of players in development of local capital markets and mobilising long term capital.

De-risking in the different phases of long-term project financing. Decarbonisation in developing countries will need to be across diverse energy systems with access to finance for projects ranging from short-term loans for innovative clean cooking solutions, decentralised energy systems such as stand-alone units and mini-grids, to affordable long term capital for intra-country power stations and regional power pools and associated energy distribution network infrastructure (IRENA 2020b; IEA 2020e). Ehlers et al. (2014) highlights three project financing phases 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 and strategies to manage the risks and cost of financing. A 2018 ODI survey of global project preparation facilities showed high failure rates in the early project preparation phases (ODI 2018). The early *concept phase* often requires de-risking through grants and technical assistance to get the right projects going. Credit enhancement solutions such as local currency bond support, multi-country guarantees through export credit agencies are part of the mix. The early project financing phase is characterised by short-term bank loans in the high risk 2-5 years project construction phase. The bank loans are paid back by issuing bonds once the construction phase is over. This bond refinancing over say 15-25 years, in the low risk mature project phase provides a lower cost of capital over long term horizons particularly important in developing countries. Bond refinancing allows banks to recycle loans to new projects. Countries such as South Africa, Kenya, Nigeria with bond market development at varying stages have issued Special Purpose Vehicles (SPV) infrastructure project bonds with tenors up to 15 years and mobilised local institutional investors (Mathews and Kidney 2012; Kaminker and Stewart 2012; Ng and Tao 2016; CBI 2015; Moody's Investors Service 2016; Mbeng Mezui and Hundal 2013).

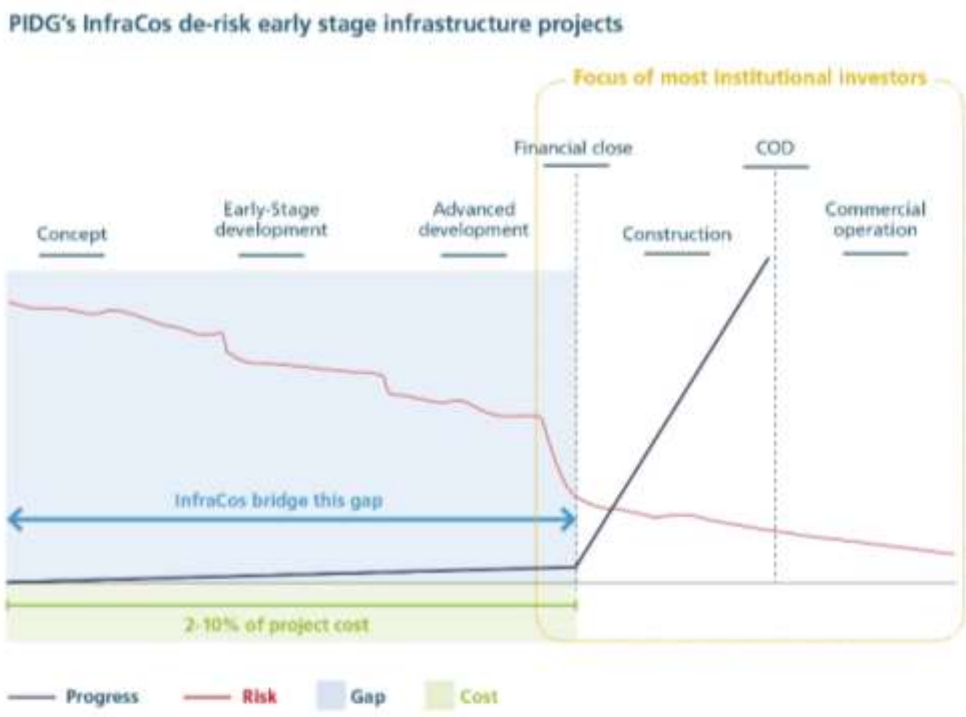


Figure 15.11: Bond refinancing mobilises institutional investors in mature project phase
Source: (PIDG 2019)

Several analysts propose standardised infrastructure project bonds and funds with scale to raise appeal to institutional investors. Pereira dos Santos and Kearney (2018) point to the MDBs business model imposing significant limitations on use of guarantees. Ketterer and Powell (2018) propose refinancing through standardised national infrastructure style bonds with MDB's facilitating project development and credit enhancements. Cavallo and Powell (2019) analysis proposes country level SPV infrastructure funds issuing bonds after the construction phase (see Figure 15.10). Arezki et al. (2016) points to the need for co-ordination and co-operation within the existing platforms to create a global supra-infrastructure institution that provides guarantees to mitigate project risks and make use of securitisation techniques on underlying assets. Interventions such as the multi-government funded Private Infrastructure Development Group (PIDG), UNEP Seed Capital Assistance Facility (SCAF 2021) and Climate Investor One or the Europe Project Bond Initiative offer support in the critical areas stated above. Cross-border partnership mechanisms led by entities such as national investment authorities, national banks, regional MDBs, infrastructure funds and institutional investors are said to bring the technical expertise to structure investment vehicles for large regional power pools projects (Chen et al 2020; Juvonen et al. 2019; Oseni and Pollitt 2016). Developing countries due to under-developed local capital markets, do not always have government bond benchmarks with long tenors important for pricing discovery and liquidity. The discussion below provides a context of technical assistance programmes available to support developing countries with capacity in development of local bond markets (IMF and World Bank Group 2016, 2017, 2018; IMF 2020d; IATFD 2020).

Development of bond markets and market design. The G20 working group made up of international organisations World Bank Group, IMF, regional development banks (ADB, AfDB, IADB, EBRD, OECD, BIS with support from the Deutsche Bundesbank) have 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 for countries that have capacity and choose to pursue that path. Development of local capital markets forms part of the UN (2015 and 2019) blueprints for financing SDG development. The G20 action plan is centred around improving co-ordination of technical assistance, using a common diagnostic framework to support technical advice as well as improving the data sharing in supporting the development of regional local bond markets (IMF 2020d; IMF and World Bank Group 2017, 2018). For appropriate country contexts, the plan acknowledges the development of local currency funding in reducing the reliance on foreign currency borrowing and exchange rate risks particularly important in long term project financing. The plan acknowledges the opportunity to strengthen local domestic savings given the growth potential with burgeoning populations in the developing country universe. The diagnostic tool draws on the experience of IMF, World Bank, OECD, EBRD alongside the yearly stocktake of developments and trends in regional bond markets. The tool allows regions and developing countries that choose to prioritise and pursue bond development to be supported in conducting evaluation of the status and efficiency of local currency bond markets as appropriate to country context. Amongst other factors, the assessment includes the general preconditions and support with regulatory and legal frameworks to the benefit of the developing country.

Building a government yield curve. The issuance of government bonds with different maturities can be an important policy objective specifically targeting development of local bond markets to provide local currency funding and long-term capital (Aglietta and Maarek 2007; World Bank and IMF 2001; Ng and Tao 2016). Such a government bond yield curve provides a pricing benchmark for bonds at different maturities important to investors in many ways as private placements or through public listing on exchanges- across a variety of bonds: green, blue, social, project, sustainability, water of GDP-linked bonds depending on underlying project profile. Countries can receive technical and financial assistance – in building the yield curve benchmark through risk-reduction and risk sharing using partial credit guarantees, anchor investments and securitisation assistance (IATFD 2016; GISD 2020; ICMA 2020c) which facilitate the issuance of long-term bonds. The yield curve benchmark issued at different maturities provide pricing discovery. The extension to long tenors are important in reducing the cost of capital for long term project financing (EIB 2017; AfDB 2017; EIB 2019; IATFD 2016). A full yield curve across different maturities with issuances from sovereign/quasi-sovereign entities such as national treasuries, municipalities, national transport entities mobilises local currency investors including public pension funds, sovereign wealth funds, public sector treasuries, national climate change and infrastructure funds (LSEG 2018). Where a country is open to foreign investors, as part of a sequenced reform process the yield curve mobilises green bond investor communities that include sovereign wealth funds, asset managers and investment banks, foundations and endowments, faith-based investors, corporations, insurers and public pension funds often with a minimum threshold for green investments and looking for developing country opportunities (Duru and Nyong 2016; LSEG 2018). As the market develops, a deep and liquid secondary market contributes to the reduction of liquidity risk by providing an exit mechanism for investors in long-term government securities. The role of the institutional investor South African pension fund (GEPF) in development of local capital markets and provision of long-term financing is illustrated through a range of activities which include investment in good quality local financial institutions, local currency bond markets at both domestic and regional Africa. The GEPF allocation includes long term low carbon investments using investment grade SPV (GEPF 2019).

There are market volatility considerations for countries when creating and deepening local bond markets as part of sequencing reform measures to minimise costs as liquidity and market depth improves. Each country has to consider the benefits and costs as part of broader policy agenda to enhance the economy's resilience to shocks by providing outlets for domestic savings and additional tools to effectively manage assets and liabilities on balance sheets (IMF 2020d; IMF and World Bank Group 2016, 2018). The universe of developing countries is diverse. Some low-income countries in Africa and Asia, do not have capacity in local capital markets nor do they have local institutional investors and rely on regional initiatives (UN ESCAP 2015). The 2018 African Continental Free Trade Area (AfCTA) agreement for regional integration and co-operation is said to be creating the world's largest free-trade with an estimated combined GDP of 2.5 trillion USD when fully implemented and operationalised (Fofack 2018; Abrego et al 2020). Regional instruments, such as Asia Pacific Project Facility, Africa Project Development Facility, World Bank's Global Infrastructure Facility reflect a sample of evolving regional instruments to mobilise resources including technical support and project preparation facilities (UN 2015). Early efforts in bond development focus on building and strengthening the short paper end of the yield curve - developing market transparency through publication of issuance calendars, communication with market players and standardisation of instruments (IMF and World Bank Group 2018). The process of bond development helps developing countries build market infrastructure through a robust payment, settlement system, development of legal frameworks including collateral and bankruptcy laws. The market-based pricing mechanisms – supports transparent capital market pricing and funding allocations to attract diverse investors, securities issuers and generally boost confidence. Developing the money markets is critical at the initial stage of bond development to anchor the short end of the yield curve and build market liquidity (Goodfriend 2011; World Bank and IMF 2001). Once short-term instruments are well established, the longer end of the yield curve could be introduced gradually along with widening the investor base, paying attention to considerations on whether to allow foreign participation in the local market as part of sequencing and wider policy programme. The G20 diagnostic action plan provides a framework for countries to be supported in evaluating at what point in the sequencing reforms to allow foreign participation (IMF 2016, 2017, 2020d). Amongst other factors, the assessment includes the general preconditions, key components such as market infrastructure, exchange rates as well as the constraints to successful local currency bond market development taking into account economic size, financing needs, costs, economic vulnerabilities, investor base, primary/secondary market structures, regulatory and legal frameworks, stage of economic development before any country embarks on any bond market development.

Fiscal incentives and role of securities exchanges in development of local capital markets. In their review of Africa bond markets - Mu et al. (2013) acknowledge the 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 project financing. Ng and Tao (2016b) 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; Tuhkanen and Vulturius 2020) 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 projects. Section 15.3.2 refers 123.8 trillion USD bonds outstanding in August 2020. (Amundi IFC 2019a) points to 168 billion green bonds outstanding at the end of 2019 – suggesting market potential for green bonds. Developing countries have been using different types of fiscal incentives and grants to support and jump-start the development of local capital markets through green bond markets (Agliardi and Agliardi 2019; IFC 2020; LSEG 2018). Some developing countries have used exchanges in listing of local currency green bonds to provide visibility of issuances to local institutional investors; others have introduced grant schemes as support to cover the costs of mandatory external bond reviews while others have used philanthropy schemes to subsidise and certify eligible projects by the local assurance agency (SBN 2018; Project Bond Initiative 2012; Banga 2019).

The literature review points to the costs of bond issuance being too high for developing countries due to soft creditworthiness. Developing country bond issuers require support in the form of credit enhancement such as guarantees and grants to improve credit-worthiness and lower the cost of borrowing for issuers. Philanthropy institutions increasingly play an important role in providing grants to cover the additional transaction costs associated with green bond issuances. Public credit enhancement, such as guarantees, subordinated debt and insurance form part of de-risking strategies in improving credit profile and bringing down the costs. The Overseas Private Investment Corporation, for example offers a specific green credit enhancement programme that provides guarantees to green bond issuances (LSEG 2018). MDBs/DFIs have credit enhancement schemes to lower the costs of borrowing for developing country issuers. 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 to lower the cost of borrowing from sub-investment grade BBB to AA+ investment grade making it attractive to institutional investors (Agarwal and Singh 2018). As part of mobilising all sources of funding, SIDs nation Fiji worked in partnership with the World Bank-IFC technical assistance for green bonds under the three year capital markets development project supported by the Australian government. The technical support enabled Fiji to be the first developing country to issue a sovereign green bond with five and thirteen year tenors in the process establishing its green government yield curve (Ministry of Economy Fiji 2020). Tranches of the bond were denominated in both local currency and hard-currency. Most of the proceeds were utilised for climate adaption projects with the sovereign bond mobilising both local and international investors through listings on the London Stock Exchange. Other private-public partnerships in supporting the development of local capital markets include the collaboration between IFC and asset manager Amundi which raised 1 billion USD from institutional investors. The fund is said to increase the capacity of developing country banks to fund climate-smart investments and purchases green bonds they issue (Amundi IFC 2019b,a). In another partnership, Financial Sector Deepening Africa (FSD Africa), a specialist development agency for building and strengthening financial markets across sub-Sahara Africa work in partnership with stock exchanges, NGO World Wide Fund in developing local currency green bond programmes (FSD-CBI 2020). Municipalities in Johannesburg and Cape Town made use of use of technical assistance from NDBs and DFIs in achieving credit enhancement and local currency green bond structuring with extended bond maturity and stock exchange listing (for Cape Town only) (Cities Alliance 2018; Gorelick 2018; Gorelick and Walmsley 2020). A 2017 UN Sustainable Stock Exchange Initiative report (SSE 2018b), representing a coalition of developed and developing nations highlighted opportunities including for 29 Africa stock exchanges, highlights green finance opportunities for supporting development of local capital markets through promotion of bond listings and enhanced disclosures to mobilise institutional investors.

New Asset Class of Carbon Remediation & Retail Investment Products. The possibility also arises of establishing a new asset class of carbon remediation investments in low carbon investments 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 centralised cooperative carbon remediation asset (CRA) institution (Hourcade et al 2015; Dasgupta et al. 2019) could implement this among its members and 'crowd-in' funding (see Section 15.6.2) 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 which are otherwise increasingly severely affected by growing debt burden and macro-prudential risks due to accelerating climate investments.

Debt Transparency. Most of the low carbon investment is required in developing country contexts which include Fragile and Conflict affected nations that have an existing debt burden. The COVID-19 pandemic has brought developing country debt management into focus (see Section 15.2.3). NGO activism literature is replete with calls for debt transparency as part of public finances delivering improvements in SDG impacts after 60 years of development finance. UK NGO Publish What You Fund established a DFI transparency initiative (Publish What You Fund 2019; Economist 2019). Mkandawire (2010) cites DFIs transparent reporting inside developing countries which they currently circumvent. UK NGO War on Want (2016) analysis of 101 energy and mineral resources companies controlling trillion USD in sub-Sahara Africa points to mining sector debt and revenue transparency in bolstering domestic resources for infrastructure development and curbing illicit finance. A 2018 ODI analysis (ODI 2018) documents the need for new transparency approaches around blended finance in the poorest countries. Oxfam (2018b) analysis argues for transparency in the use of MDBs financial intermediaries in lending. Oxfam (Oxfam 2020) refers to additional debt burden from climate finance. . As part of long term debt management - NGO Jubilee Debt (Economist 2019) propose changes to international lending architecture to introduce publicly accessible, transparent, mandatory reporting registry of all loans and debts. Other analysts (Stiglitz et al. 2020; Stiglitz 2020b) refer to a centralised UN debt restructuring option as part of UN Build Back Better (section 15.2.4). Some have pointed to measures such as SWF technical support, national statistical systems that embed international reporting standards for all entities including DFIs and NGOs (ICEAW 2012; UK NGO EITI; Norway GPFG 2019; Kenya FRACCK 2018).

15.6.8 Facilitating the development of new business models and financing approaches

This section focuses on new finance approaches and business opportunities in three areas: i) service-based business models and finance approaches in energy and transport sectors, ii) nature-based solutions and iii) gender-responsive climate finance. New business models and financing approaches can help to overcome barriers related to transactions costs by aggregating and/or transferring financing needs and establishing supply of finance for needs of stakeholder groups lacking financial inclusion, particularly in areas that have been underfunded.

15.6.8.1 Service-based business models in the energy and transport sectors

Innovative business models have emerged as a key component for the global clean energy transition Some of which focus on empowering the customer (e.g. energy-as-a-service, mobility-as-a-service, aggregators and peer-to-peer electricity trading), while others focus on enabling directly in increasing the deployment of renewable energy supply (community-ownership models and pay-as-you-go models).

Energy-as-a-service. Energy-as-a-service (EaaS) is a business model whereby customers pay for an energy service without having to make any upfront capital investment (Hamwi and Lizarralde 2017) (Cleary and Palmer 2019). The underlying business model of EaaS can be different and will vary depending on scope, rationale, basis for competition, and source of earnings of the energy service provider and its role in the energy sector value chain (PWC 2014). Energy service providers can opt for a variety of revenue models ranging from a subscription-based model (fixed revenue contracts) to performance-based contracts (variable revenue contracts). Performance-based contracts can also be a form of "creative financing" for capital improvement that makes it possible to fund energy upgrades from cost reductions (JRC 2020; KPMG 2015). Innovation in EaaS has started for energy utilities at the household level (Chasin et al. 2020), where smart meters using real-time data are used to predict peak demand levels. In the United Kingdom the estimated average peak reductions with EaaS models is between 3-10% (with time-of-use-tariffs) (Government of UK 2016). Smart meter global market size estimated a revenue of USD 20.7 billion by 2020, growing to USD 28.6 billion by 2025, at a compound annual growth rate of 6.7% (Bloomberg 2020). Smart meter penetration (% of meters that are smart meters) was globally: 14% (Scully 2019), in China: 70% (Research and Markets 2019), in the US: 70% (98 million smart meters) in 2019 (IEI 2020) and in the EU-28: 44% in 2018, growing to 71% by 2023 (Kochanski et al. 2020). Investments made in EaaS models amount to USD 14.3 billion (Smart Energy International 2018).

Transport sector business models. Transport sector business models. The transport sector is one of the most challenging sectors in decreasing carbon emissions. Achieving the green mobility agenda in a transformational scenario, requires active policies (e.g. in the aviation sector) to phase-out fossil fuel usage by 2050, widely powered by renewable energy. The development of Information and Communication Technology (ICT) innovations have the potential to make transport, and mobility in general, more-efficient, cleaner and supporting the transformation towards a net-zero economy. Overall, there are three innovation driven trends, that foster the development of new business models: i) EVs and electric powertrains (e.g. smart charging for EVs are offering the field for new business models, aim to integration of renewable energy sources (IRENA 2019c), ii) Connected, autonomous vehicles (e.g. more efficient, less traffic congestion, accelerating of alternative fuel (Jones and Leibowicz 2019) and iii) Mobility-as-a-Service (MaaS). MaaS offers a wide range of applications to establish new mobility concepts and improve or even disrupt traditional mobility models (e.g. privately-owned cars). MaaS is a business model, whereby customers pay for a mobility service without having to make any upfront capital investment (e.g. buying a car). MaaS tends to deliver significant urban benefits in all regions (e.g. cleaner air, less pollution), and brings in efficiency gains in the use of resources. However, the switch (from e.g. traditional minibuses in Jakarta, Indonesia to on-demand motorcycle taxis) hardly improves the carbon footprint and further tempted on-demand mobility is likely to nurture carbon emissions (Suatmadi et al. 2019). These side-effects should be taken into consideration early in the process of developing new transport business models to achieve climate objectives and not isolating transport from other climate-related sectors

Aggregators. An aggregator is a grouping of agents in a power system (i.e., consumers, producers, prosumers or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to the operator (MIT 2016). An aggregator can help in better integration of renewable energy resources by providing both demand- and supply-side flexibility services to the grid. Demand-side flexibility is provided by aggregating demand-response resources or energy storage units. Managing demand-response of heat systems (micro CHP and heat pumps) in the Netherlands showed that peak demand can be reduced by 30 % to 35 % (TNO 2016). This makes a business case for deferred investments in distribution grid reinforcements and transmission grid infrastructure. Supply-side flexibility is provided by aggregators through dispatchable power generation (Ma et al. 2017). Aggregators can use operation optimisation platforms based on data on historical and forecasted data on demand, generation and price, to provide real-time operating reserve capacity and a range of balancing services to integrate higher shares of variable renewable energy (VRE), also known as a Virtual Power Plant (VPP). VPP balancing services have been estimated at a cost of USD 70 to US 100 per kW (Enbala 2018). In Australia, the South Australian government and Tesla are developing a network of 50 000 household solar PV units connected into an aggregator. This is expected to meet around 20% of South Australia's average daily power demand and could reduce the wholesale electricity price by around USD 8/MWh, or around USD 90 million yr^{-1} across all South Australian customers, which means 30 % of the total energy bill (Economics 2018). VPP global market value amounted to USD 762 million in 2016; expected to reach USD 4 597 million in 2023 (compound annual growth rate of 25.9 % from 2017 to 2023) (Research and Markets 2017). Countries with established regulatory frameworks allowing VPP trading are Australia, Austria, Belgium, Germany, Denmark, France, Netherlands, UK and the US (IRENA 2019d).

Peer-to-peer electricity trading. In Peer-to-peer (P2P) electricity trading, prosumers are able to directly trade electricity with other consumers in an online marketplace to achieve a win-win by seeking a better outcome compared to the relatively high tariffs and the relatively low buy-back rates of traditional utilities (IRENA 2020d) (Liu et al. 2019). Also, P2P models trading with distributed energy resources reduce transmission losses and congestion. Around 41.1% of the typical electricity cost goes towards managing and maintaining distribution (Auroraenergy 2020). Data from both producers and consumers need to be collected and analysed to check the reliability of the power system. Smart meters, broadband communication infrastructure, network remote control and automation systems are thus fundamental enablers of the P2P electricity trading model (IRENA 2019d). Examples of P2P projects can be found in Malaysia (SEDA 2020), Bangladesh (UNFCCC 2020), Germany (Lumenaza 2020; Sonnen 2020), the United Kingdom (Centrica 2018; Piclo 2016) and the United States (Mengelkamp et al. 2018).

Community-ownership models. Community-ownership models refer to the collective ownership and management of energy-related assets, usually distributed energy resources. Through cost-sharing, community-ownership models enable individual participants to own assets with lower levels of investment (projects vary in size but are often between 5 kilowatts (kW) and 5 megawatts (MW)) (Gall 2018). The innovative aspect of community-ownership business models lies in the role of the community and its participants going beyond renewable energy generation into heating systems and energy-related services (e.g. storage, charging electric vehicles, energy trade with surrounding communities); enabling energy efficiency programs (e.g. investment in building retrofits); and providing flexibility to the entire power system (e.g. through retailers that trade wholesale electricity produced by community-owned electricity generation plants) (Bisello et al. 2018) (IRENA 2018) (Singh et al. 2019). However, community-ownership projects may need large upfront investments, and communities' equity contributions might prove insufficient. Access to commercial financing is often difficult owing to the lack of clarity on long-term revenues generated by community-ownership projects. These challenges can be addressed if the community can partner with local businesses or developers to fill the funding gaps and increase the creditworthiness of the projects. The European Federation of Renewable Energy Co-operatives (REScoop) is attempting to mitigate such development risks by investing in community energy start-ups and selling its ownership to community members and other investors once the project is up and running (Rescoop 2020). Further, providing microcredit to communities can also be used as a mechanism to kick start community energy projects. For instance, in Latin America, Africa and South Asia, microcredit has been used to initiate community energy projects (REN21 2016).

Payment method: PayG. Pay-as-you-go (PayG) business models emerged to address the energy access challenge and to provide electricity generated from renewable energy sources at affordable prices, using available technologies to facilitate payment by instalments (IRENA 2019e). This business model has been used mostly for solar energy, and an energy service provider rents or sells solar PV systems in exchange for regular payments through mobile payment systems (IRENA 2019e). PayG helps rural electrification in off-grid areas, enables the low-income households to access clean energy systems and removes the high up-front barrier, and flexible mode as it can accommodate different levels of payments and usage level preferred by consumers (C40 Cities 2018). However, PayG has the technology and product risk, requires a financial viable and large customer base, and the system supplier must provide a significant portion of the finance and requires a substantial equity and working capital (C40 Cities 2018). Although PayG offers the potential to deliver a positive impact with regard to increasing access to clean affordable energy, both the technology and business models are more complex than current alternatives (Barrie 2017). The published and grey literature on PayG has not provided any comprehensive grounded picture of how PayG contributes in achieving sustainability transformations (Ockwell et al. 2019), and their effects of climate change mitigation and adaptation is unclear. Between 2015 and 2020, around 8 million people gained energy access with PayG models, PayG solar system sales by location (2016 data) in East Africa: 730,000 units, West Africa: 30,000 units, Latin America: 10,000 units, and South Asia: 20,000 units (IRENA 2019e). Market potential is 772 million or ~64% of off-grid consumers have access to mobile networks (2016 data) (IRENA 2019e). The PayG model has demonstrated success particularly in East African countries such as Kenya, Tanzania and Rwanda where the emergence of the PayG finance approach has accelerated access to basic electricity (Yadav et al. 2019).

15.6.8.2 Nature-based solutions including REDD+

Nature-based solutions are '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). Nature-based solutions consist of a wide range of measures including ecosystem-based mitigation and adaptation. The concept of the nature-based solutions is still new, and studies on the finance of nature-based solutions is still very limited. However, finance for one of the nature-based solutions, emission reductions 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, with lessons from finance for REDD+ being available.

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 2019; Griscom et al. 2020). 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).

Although nature-based solutions have large potential to address climate change and other sustainable development issues, existing finance and investment do not meet the needs. Nature-based solutions are undercapitalised and the lack of finance is widely recognised as one of the main barriers to the implementation and monitoring of nature-based solutions (Seddon et al. 2020). Finance and investment models that generate their own revenues or consistently save costs are necessary to reduce dependency on grants (Wamsler et al. 2020; Schäfer et al. 2019).

REDD+. REDD+ can significantly contribute to climate change mitigation and also produce other co-benefits like climate change adaptation, biodiversity conservation, and poverty reduction, if well-implemented (Morita and Matsumoto 2018). Currently, various financial sources are financing REDD+ activities, including bilateral and multilateral, public and private, and international and domestic sources, with linking with several finance mechanisms/approaches including carbon markets and results-based finance. However, finance is limited for REDD+ implementation. Since AR5, active discussion on financing mechanisms for REDD+ and analysis on challenges and opportunities of REDD+ financing have been made in the literature. With regard to the opportunities of mobilizing private 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). In the voluntary carbon markets, the volume of offsets generated through Forestry and Land Use activities increased 264% between 2016 and 2018, growing from 13.9 $MtCO_2$-eq. to 50.7 $MtCO_2$-eq., and within the Forestry and Land Use category, volume from REDD+ projects, focused on forest conservation, increased 187%, from 10.6 $MtCO_2$-eq. in 2016 to 30.5 $MtCO_2$-eq. in 2018 (Forest Trends' Ecosystem Marketplace 2019).

Current overall challenges of REDD+ finance include institutional fragmentation such as limited coordination in REDD+ financing both the supply and demand sides, lack of predictable funding for REDD+ , and uncertainty in effectiveness of the use of REDD+ finance such as REDD+'s results-based payment approach does not guarantee an effective REDD+ (Well and Carrapatoso, 2017; Recio, 2019 McFarland 2015; Atmadja et al. 2018; Lujan and Silva-Chávez 2018; Wong et al. 2019). Furthermore, there is a number of reasons that makes difficult to engage more the private sector in REDD+ finance. For example, the risk and factors necessary to create an enabling environment for private sector investments in REDD+ in many developing countries have yet to be sufficiently explored including carbon rights, tenure security, clear regulatory framework and law enforcement (Dixon and Challies 2015; Laing et al. 2016; Atmadja et al. 2018; Ehara et al. 2019; Streck 2020). Moreover, some characteristics of REDD+ makes it difficult to involve the private sector, such as insufficient returns on investment that low carbon prices cannot close the gap (World Bank 2017); the evolution of REDD+ to focus on national approaches has discouraged projects, and REDD+ could be losing out on an investment vehicle that some private sector actors are familiar with (Lujan and Silva-Chávez 2018). Third is the challenges related to forest carbon certification such as non-permanence risk, and uncertainty of monitored values and high costs of precise monitoring (Grimault et al. 2018). Although REDD+ has many challenges to mobilise more private finance, there is discussion on exploring other finance opportunities for the forestry sector, such as building new blended finance models combining different funding sources like public and private finance (Streck 2016; Rode et al. 2019), and developing enhanced bonds for forest-based actions (World Bank 2017).

Private finance opportunities for nature-based solutions. Nature-based solutions, including REDD+ are likely to be one of the most difficult sectors to attract private finance. The development of nature-based solutions face barriers that relate to the value proposition, value delivery and value capture of nature-based solutions business models and sources of public/private finance to tap into (Toxopeus and Polzin 2017). However, the demand of establishing new finance and business models to attract both public and private finance to nature-based solutions is increasing (Toxopeus and Polzin 2017; European Investment Bank 2019; Toxopeus 2019), not only under the discussion of finance for nature-based solutions, but also under the similar concepts like landscape finance and conservation finance. Furthermore, the recognition of the needs of financial institutions to identify the physical, transition and reputational risks resulting from not only the climate change but also loss of biodiversity is gradually increasing (De Nederlandsche Bank and PBL Netherlands Environmental Assessment Agency 2020).

Nature-based solutions deliver different benefits to different stakeholders, and the level of finance and business models needed for different types of nature-based solutions varies (Toxopeus and Polzin 2017; Toxopeus 2019). Current discussion on business models for nature-based solutions mainly focuses on nature-based solutions in the urban areas. Sustainable business model archetypes of nature-based solutions in urban areas include buildings, facades and roofs; urban green spaces, parks and urban forests; allotments and community gardens and blue spaces (Toxopeus and Polzin 2017). One of the key opportunities in implementing urban nature-based solutions is coordinating between different actors to realise a nature-based solution, and coordinate these actors and to mix and match business models for different parties (Toxopeus 2019). Furthermore, the innovation in financial instruments is necessary, such as capturing land value uplifting using tax schemes, creating public-private partnerships by using financing schemes based on crowdfunding or bitcoins, shifting the risks to reach social and environmental milestones from tax payers to private bondholders by using social impact bond schemes (Toxopeus and Polzin 2017).

15.6.8.3 Exploring 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). Examples of initiatives, framework and new models to enhance women's access to finance, including climate finance are the 2017 G20 Financial Inclusion Action Plan (GPFI) (GPFI 2017) and the Alliance for Financial Inclusion (AFI) (AFI 2017). The concept of a gender dividend is also attractive to governments and institutions. 'Gender dividend is the increased economic growth that could be realised with investments in women and girls (PRB 2019) (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 and multilateral development banks, and with bilateral and other national flows (Schalatek and Nakhooda 2013; Schalatek 2015; 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 multilateral climate funds (Green Climate Fund 2017b; GGCA 2015; Schalatek 2015; and Williams 2015). The OECD flags that only about 3% of bilateral climate ODA had gender equality as a principal objective, while 28% integrated gender equality as a secondary objective (OECD DAC 2016). It also argues that 'Gender equality is better integrated in adaptation than in mitigation activities with 46% of bilateral ODA to adaptation targeting gender equality, as compared to 28% to mitigation (OECD DAC 2016). At the same time, 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 programmes 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 where the review found that 'almost half of the analysed sample of 70 climate projects were 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 targeted to women's project on the ground, nor is there as yet an evaluation as to how 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, with a total 1.3 billion USD in assets). Investors in this stream include institutional investors, private equity/venture capital, and private debt funds)/Gender based social impact investing (SRI)/gender lens portfolio strategy, pink and green bonds etc./Parity portfolio/Matterhorn group (which 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) and Gender oriented crowdfunding.

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 et al. 2015; GIZ et al. 2017). Despite improvements in the substantive gender sensitisation 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-owned 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).

Frequently Asked Questions

FAQ 15.1 What's the current status of global climate finance and the alignment of global financial flows with the Paris Agreement?

Climate finance covers both mitigation and adaptation finance. Annual global climate finance flows have been on an upward trend since the fifth Assessment Report, reaching a yearly average all time high estimate of almost 600 billion USD in 2017/2018, with almost 95% allocated to mitigation activities and more than 50% in renewable energy generation, followed by low carbon transport (approx. 25%). However, current climate finance flows come in significantly below average needs across all regions and sectors to reach the long-term goals of the Paris Agreement. Global yearly needs are estimated at around 6 trillion USD yr^{-1} and [more to come]

Significant progress has been made in the commercial finance sector with regard to the awareness of climate risks resulting from inadequate financial flows and climate action. However, a more consequent investment and policy decision making that enables a rapid redirection of financial flows is needed. Regulatory support as a catalyser is an essential convey of such redirections.

Dynamics across sectors and regions vary with some being better positioned to close financing gaps and to benefit from an enabling role of finance in the short-term. The investment flows in the global power and fuel sector - accounting for approximately USD 1.62 trillion USD in 2019 – only slightly exceed the investment needs for attaining the sustainable development scenario [IPCC xx] - accounting for approx. 1.91tr USD yr^{-1} between 2023 and 2032.

FAQ 15.2 What's the role of climate finance and the finance sector for a transformation towards a sustainable future?

The Paris Agreement has widened the scope of relevant financial flows from climate finance only to the full alignment of finance flows with the long-term goals of the Paris Agreement. While climate finance relates historically to the financial support of developed countries to developing countries, the Paris Agreement and its Article 2.1(c) has developed on a new narrative that goes beyond traditional flows and relates to all sectors and actors. Climate-related financial risk is still massively underestimated by financial institutions, financial decision-makers more generally, and also among public sector stakeholders, limiting the sector's potential of being an enabler of the transition.

The private sector has started to recognise climate-related risks and consequently redirect investment flows. Dynamics vary across sectors and regions with the financial sector being an enabler of transitions in only some selected (sub-)sectors and regions. Consistent, credible, timely and forward-looking political leadership remains central to strengthening the financial sector as enabler.

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

Difference between current flows and average needs until [2030] by sector/region and/or type of financing to meet the long-term goals of the Paris Agreement driven by various barriers (Market and non-market failures) inside (short-termism, information gaps, home bias, limited visibility of future pipelines) and outside (e.g. missing pricing of externalities) of the financial sector. Major reason for financing gaps are […] [Numbers to come…]. Unmet financing needs are mostly discussed as a demand-side challenge. However, understanding challenges for deploying funds is critical as well - with a significant role remaining for public finance to close viability gaps and close funding gaps for preparatory action to increase absorptive capacity for commercial investments.

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