WG III contribution to the Sixth Assessment Report

List of corrigenda to be implemented

The corrigenda listed below will be implemented in the Chapter during copy-editing.

CHAPTER 15

Document (Chapter, Annex, Supp. Material)	Page (Based on the final pdf FGD version)	Line	Detailed information on correction to make
Chapter 15	21	25	In 2019, global GFCF reached 23 trillion USD compared to 16.2 trillion USD in 2010, a 42% increase (Figure 15.2) Should be changed to: In 2019, global GFCF reached around 20 trillion USD2015 compared to around 14 trillion USD2015 in 2010, a more than 40% increase (Figure 15.2).
Chapter 15	35	17	higher total needs until 2030, around 1.8 trillion USD yr-1 in buildings and 1.7 trillion USD yr-1 in industry are needed in the 1.5-S and TES scenario. Should be changed to: higher total needs until 2030, around 1.8 trillion USD yr-1 in buildings and industry are needed in the 1.5-S.
Chapter 15	35	19	For the TES total EE investment needs until 2030 are stated at 29 trillion USD translating into an yearly average of around 1.8 trillion USD yr-1. Should be changed to: For the TES cumulative EE investment needs until 2030 are stated at 29 trillion USD translating into an yearly average of around 1.7 trillion USD yr-1, excluding transportation
Chapter 15	35	24	The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in our analysis amounting to 0.4 trillion USD on average until 2030. On a regional level, (Oxford Economics 2017) shows, that annual infrastructure investments between 2016 and 2040 vary widely. For all available countries (n=50) estimates counts close to 0.4 trillion USD, including 0.2 trillion USD for China. Based on available data for 9 African countries, investments in rail infrastructure range from 0.1 billion USD in Senegal to 1.6 billion USD in Nigeria. (Osama et al. 2021) highlights a 4.7 billion USD financing gap for African countries in the transport sector. In Latin America the report identifies Brazil as frontrunner of required rail investments with 8.3 billion USD, followed by Peru with 2.3 billion USD. Totally, developed countries mounting up to 117 billion USD yr-1 (n=14, mean=8.35bn USD) for rail infrastructure funding needs, succeeded by developing countries (excl. LDCs) with 26 billion USD yr-1 (n=28, mean=0.93bn USD, excluding China). Should be changed to: The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in this

			analysis. On a regional level Oxford Economics (2017) shows, that annual infrastructure investments between 2016 and 2040 vary widely. For all available countries (n=50) estimates counts close to 0.4 trillion USD yr-1, including 0.217 trillion USD yr-1 for China. Based on available data for nine African countries, investments in rail infrastructure range from 0.1 billion USD yr-1 in Senegal to 1.6 billion USD yr-1 in Nigeria. Osama et al. (2021) highlights a 4.7 billion USD financing gap for African countries in the transport sector. In Latin America Brazil requires rail investments of 8.3 billion USD yr-1, followed by Peru with 2.3 billion USD yr-1, and Chile with 2.1 billion USD yr-1. In total, developed countries mounting up to almost 120 billion USD yr-1 (n=15, mean=7.97bn USD yr-1) for rail infrastructure financing needs. Estimates for available developing countries adds up to almost 50 billion USD yr-1 (n=27, mean=1.78bn USD yr-1, excl. China and LDCs) (Oxford Economics 2017).
Chapter 15	36	8	derives average yearly investment needs of around 278 billion USD yr-1 until 2030 and 431 USD billion yr-1 in the next several decades, Should be changed to: and derives average yearly investment needs of around 278 billion USD yr-1 in the next several decades, including opportunity costs
Chapter 15	38	24	between 15.9% in 2035 (Oxford Economics 2017) and 32% (Arezki et al. 2016). Should be changed to: between 19% (Oxford Economics 2017) and 32% (Arezki et al. 2016)
Chapter 15	83	2	Individual and clubs of developed and developing countries currently provide public guarantees (ADB 2015; IIGCC 2015; Pereira Dos Santos 2018; GGGI 2019; PIDG 2019; AGF 2020; Garbacz et al. 2021). --> Individual and clubs of developed and developing countries currently provide public guarantees (ADB 2015, 2018; IIGCC 2015; Pereira Dos Santos 2018; GGGI 2019; Garbacz et al. 2021).
Chapter 15	84	42	LDCs are least likely to have active capital markets. Clubs of LDCs are partnering with AAA MDBs in aggregation approaches (AfDB 2020; GCF 2020b). --> LDCs supported by humanitarian entities are least likely to have active capital markets (ICRC 2020; IDFC 2020; Cao et al. 2021b). Clubs of LDCs are partnering with AAA MDBs in aggregation approaches (AfDB 2020; GCF 2020b).
Chapter 15	85	12	i) lack of aid and debt transparency (Moyo 2009; Mkandawire 2010; PWYF 2020) ii) mining-fossil fuels sector and illicit finance (Plank 1993; Sachs and Warner 2001; Hanlon 2017b)) iii) lack of developed country commitment to pledges (Nhamo and Nhamo 2016) iv) unregulated players as financial intermediaries in blended finance (Pereira 2017; Donaldson and Hawkes 2018; Tan 2019) v) weak accountability reflected in soft SDG data measurement and vi) burden of responsibility in mobilising resources for Paris and SDG to countries with historically soft institutional capacity (Hickel 2015; Donald and Way 2016;

			Scheyvens et al. 2016; Liverman 2018). --> i) multilaterals model, lack of transparency around aid and debt (Mkandawire 2010; Lee 2017; PWYF 2019; Bradlow 2021; Gianfagna et al. 2021) ii) illicit finance (Plank 1993; Sachs and Warner 2001; Hanlon 2017; US DoJ 2019)) iii) lack of developed country commitment to pledges (Nhamo and Nhamo 2016) iv) unregulated players as financial intermediaries in blended finance (Pereira 2017; Donaldson and Hawkes 2018; Attridge and Engen 2019; Tan 2019) v) weak accountability reflected in soft SDG data and vi) burden of responsibility in mobilising Paris and SDG resources falling to countries with historically soft institutional capacity (Hickel 2015; Donald and Way 2016; Scheyvens et al. 2016; Liverman 2018).
Chapter 15	33	16	Replace Table 15.3 - (Storage) see end of doc for revised version
Chapter 15		Figure 15.4	Replace Figure 15.4 see end of doc for revised version
Chapter 15	Front page	Review Editors	Remove Jean-Charles Hourcade as review editor
Chapter 15	21	16	almost 80 trillion USD in 2019), -> around 80 trillion USD2015 in 2019),
Chapter 15	21	25	In 2019, global GFCF reached 23 trillion USD compared to 16.2 trillion USD in 2010, a 42% increase (Figure 15.2) --> In 2019, global GFCF reached around 20 trillion USD2015 compared to around 16 trillion USD2015 in 2010, a more than 40% increase (Figure 15.2).

Chapter 15	35	17	higher total needs until 2030, around 1.8 trillion USD yr-1 in buildings and 1.7 trillion USD yr-1 in industry are needed in the 1.5-S and TES scenario. For the TES total EE investment needs until 2030 are stated at 29 trillion USD translating into an yearly average of around 1.8 trillion USD yr-1. --> higher total needs until 2030, around 1.8 trillion USD2015 yr-1 in buildings and industry are needed in the 1.5-S. For the TES cumulative EE investment needs until 2030 are stated at 29 trillion USD2015 translating into an yearly average of around 1.7 trillion USD2015 yr-1, excluding transportation.
Chapter 15	35	24	The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in our analysis amounting to 0.4 trillion USD on average until 2030. On a regional level, (Oxford Economics 2017) shows, that annual infrastructure investments between 2016 and 2040 vary widely. For all available countries (n=50) estimates counts close to 0.4 trillion USD, including 0.2 trillion USD for China. Based on available data for 9 African countries, investments in rail infrastructure range from 0.1 billion USD in Senegal to 1.6 billion USD in Nigeria. (Osama et al. 2021) highlights a 4.7 billion USD financing gap for African countries in the transport sector. In Latin America the report identifies Brazil as frontrunner of required rail investments with 8.3 billion USD, followed by Peru with 2.3 billion USD. Totally, developed countries mounting up to 117 billion USD yr-1 (n=14, mean=8.35bn USD) for rail infrastructure funding needs, succeeded by developing countries (excl. LDCs) with 26 billion USD yr-1 (n=28, mean=0.93bn USD, excluding China). --> The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in this analysis. On a regional level Oxford Economics (2017) shows, that annual infrastructure investments in rail between 2016 and 2040 vary widely. For all available countries (n=50) estimates counts close to 0.4 trillion USD2015 yr-1, including 217 billion USD2015 yr-1 for China. Based on available data for nine African countries, investments in rail infrastructure range from 0.1 billion USD2015 yr-1 in Senegal to 1.6 billion USD2015 yr-1 in Nigeria. Osama et al. (2021) highlights a 4.7 billion USD financing gap for African countries in the transport sector. In Latin America, Brazil requires rail investments of 8.3 billion USD2015 yr-1, followed by Peru and Chile with 2.3 and 2.1 billion USD2015 yr-1. In total, developed countries mounting up to almost 120 billion USD yr-1 (n=15, mean=7.97 bn USD yr-1) for rail infrastructure investment needs. Estimates for available developing countries adds up to almost 50 billion USD yr-1 (n=27, mean=1.78bn USD yr-1, excl. China and LDCs), and available data for seven LDCs (mean=0.34 bn USD yr-1) shows data gaps for specific countries (Oxford Economics 2017).
Chapter 15	36	8	derives average yearly investment needs of around 278 billion USD yr-1 until 2030 and 431 USD billion yr-1 in the next several decades, -> derives average yearly investment needs of around 278 billion USD2015 yr-1 until 2030 rising to 431 USD2015 billion yr-1 over the next several decades, including opportunity costs

Chapter 15	38	24	between 15.9% in 2035 (Oxford Economics 2017) and 32% (Arezki et al. 2016). --> between 19% (Oxford Economics 2017) and 32% (Arezki et al. 2016)
Chapter 15	80	36	Although AAA-rated IFC blended finance fund was established in 2013, it took on seven of its eight institutional investors in 2017 with insurers AXA and Swiss Re investing 500 million USD each to bring the fund to 7 billion USD raised from eight global investors (Attridge and Gouett 2021). --> Although AAA-rated IFC blended finance fund was established in 2013, most investors joined in 2017 with insurers AXA and Swiss Re investing 500 million USD each to bring the fund to 7 billion USD raised from eight global investors (Atteridge and Gouett 2021)
Chapter 15		Figure 15.4 caption	Total Needs: See Table 15.4. Regional breakdown of needs: For Electricity based on IAM output for Non-Biomass renewable (mean C1:C3) plus incremental investment needs for T&D and Storage (mean C1:C3 less mean C5:C7) (see Table 15.2, 15.3., except C6 and C7). --> Total needs: See Table 15.4. Regional breakdown of needs: For Electricity based on IAM output for Non-Biomass renewable and Storage (mean C1:C3) plus incremental investment needs for T&D (mean C1:C3 less C5) (see Table 15.2, 15.3).
Chapter 15	23	Table 15.1	TSU: As discussed with Jim and Alaa, adding two lines with values deflated to USD2015 : see end of doc for revised version
Chapter 15	23	Table 15.1 Note	Note: Standing Committee on Finance (SCF). Numbers in current billion USD. Deflated to USD2015 in italic. Given the variations in numbers reported by different entities,
Chapter 15	23	Figure 15.3	Note: Numbers in billion USD. -> Note: Numbers in current billion USD. Deflated to USD2015 see Table 15.1 in italic.

Chapter 15	23	Figure 15.3	caption of figure 15.3 edits: remove the "0" in the legend and, and replace it with “no regional mapping” in the figure legend. see end of doc for revised version
Chapter 15	36	8	[cross-reference] -> remove
Chapter 15	36	Table 15.4	see end of doc for revised version
Chapter 15	36	Table 15.4	For AFOLU: Chapter 7 analysis, Section 7.4; The Food and Land use Coalition (Shakhovskoy et al. 2019) -> Chapter 7 analysis, Section 7.4; The Food and Land use Coalition (2019); Shakhovskoy et al. (2019)
Chapter 15	36	Table 15.4 Note	Note: Total range 2.4 trillion to 4,8 trillion USD yr-1. -> Note: Total range 2.3 trillion to 4.5 trillion USD yr-1.
Chapter 15	39	15	current climate finance flows -> recent climate finance flows
Chapter 15	42	11	Estimated mitigation financing needs as percentage of current GDP (USD2015) comes in at around 2-4% for developed countries, and around 5-10% for developing countries (see Figure 15.4) (high confidence). Climate finance flows have to increase by factor 4-8 in developing countries and 2-5 in developed countries. -> Estimated mitigation financing needs as percentage of mean 2017-2020 GDP in USD2015 comes in at around 2-4% for developed countries, and around 4-9% for developing countries (see Figure 15.4) (high confidence). Climate finance flows have to

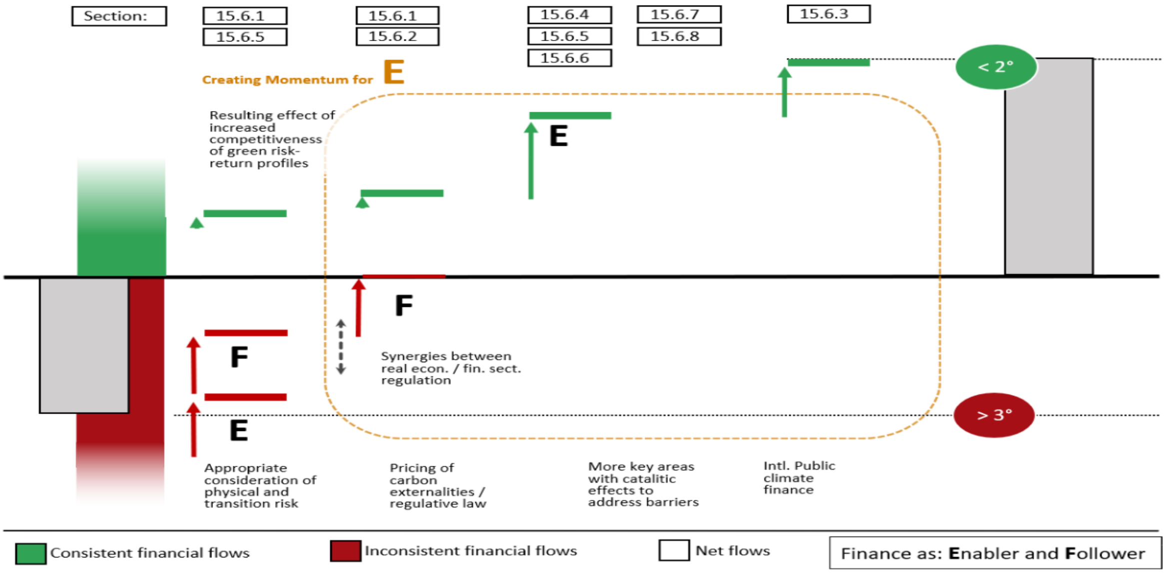
			increase by factor 4-7 in developing countries and 3-5 in developed countries.
Chapter 15	42	17	Flows to Eastern Asia, with its average flows of 269 billion USD being dominated by China (more than 95% of total mitigation flowsto Eastern Asia), would have to increase by a factor of 2-4, -> Flows to Eastern Asia, with its annual average flows (2017-2020) of 252 billion USD2015 being dominated by China (more than 95% of total mitigation flows to Eastern Asia), would have to increase by a factor of 2-4,
Chapter 15	42	33	Notably, climate finance flows to African countries might have even decreased by about one fifth for mitigation technology deployment -> Notably, climate finance flows to African countries might have even decreased for mitigation technology deployment
Chapter 15	26	8	in 2018 2018 (OECD 2020b). --> in 2018 (OECD 2020b).
Chapter 15	27	21	reached USD 687 billion --> reached 687 billion USD
Chapter 15	34	23	reaching on average around 1 USD trillion yr-1 (average until 2030) for electricity generation as well as grids and storage, increasing to above 2 USD trillion yr-1 (average until 2030) in the 1.5 scenario (IRENA 2021) --> reaching on average around 1 USD2015 trillion yr-1 (average until 2030) for electricity generation as well as grids and storage, increasing to above 2 USD2015 trillion yr-1 (average until 2030) in the 1.5 scenario (IRENA 2021)
Chapter 15	34	26	between 1.1 USD trillion yr-1 and 1.6 USD trillion yr-1 (average until 2030) --> between around 1.0 USD2015 trillion yr-1 and around 1.6 USD2015 trillion yr-1 (average until 2030)

Chapter 15	34	35	decrease from 5.0 trillion USD until 2030 yr-1 to 3.8 trillion USD yr-1 for 2030-2050 --> decrease from 5.0 trillion USD2015 until 2030 yr-1 to 3.8 trillion USD2015 yr-1 for 2030-2050
Chapter 15	34	37	remain flat at 2.2 trillion USD yr-1 through the coming three decades --> remain flat at 2.2 trillion USD2015 yr-1 through the coming three decades
Chapter 15	35	45	IEA indicates a total of around 0.6 and 0.8 trillion USD yr-1 for transport energy efficiency in the SDS and IEA scenario for the 2026-2030 period --> IEA indicates a total of around 0.6 and 0.7 trillion USD2015 yr-1 for transport energy efficiency in the SDS and IEA scenario for the 2026-2030 period
Chapter 15	35	15	For the 1.5-S average yr-1 needs until 2050 come in at 963 billion USD for buildings, 102 billion USD for heat pumps, and 354 billion USD for industry. Applying the relative share of these categories on higher total needs until 2030, around 1.8 trillion USD yr-1 in buildings and 1.7 trillion USD yr-1 in industry are needed in the 1.5-S and TES scenario --> For the 1.5-S average yr-1 needs until 2050 come in at 963 billion USD2015 for buildings, 102 billion USD2015 for heat pumps, and 354 billion USD2015 for industry. Applying the relative share of these categories on higher total needs until 2030, around 1.8 trillion USD2015 yr-1 in buildings and 1.7 trillion USD2015 yr-1 in industry are needed in the 1.5-S and TES scenario
Chapter 15	35	20	level at 0.6 and 0.8 billion USD yr-1 on average between 2026-2030 -> level at around 0.6 and 0.8 trillion USD2015 yr-1 on average between 2026-2030
Chapter 15	35	43	For the 1.5-S scenario, IRENA indicates average investment needs of 0.2 trillion USD yr-1 for electric vehicle infrastructure, 0.2 trillion USD yr-1 for transport energy efficiency and 0.3 trillion USD yr-1 for EV batteries (IRENA 2020d) (average until 2030). -->For the 1.5-S scenario, IRENA indicates average investment needs of 0.2 trillion USD2015 yr-1 for electric vehicle infrastructure, 0.2 trillion USD yr-1 for transport energy efficiency and 0.3 trillion USD2015 yr-1 for EV batteries (IRENA 2020d) (average until 2030).

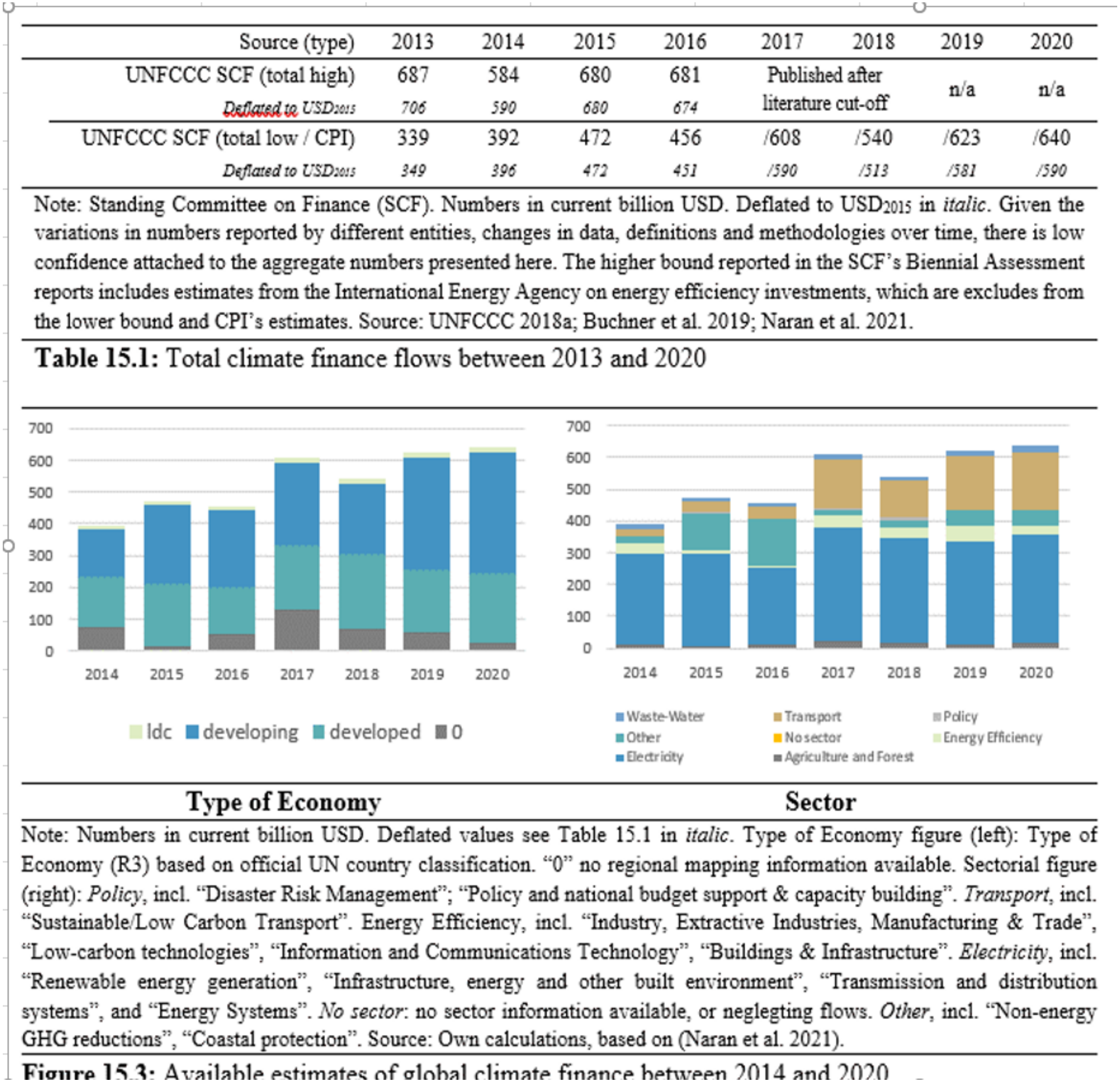
Chapter 15	23	10	with Brazil, India, China and South Africa accounting for 25% to 43% depending on -> with Brazil, India, China and South Africa accounting for around one-quarter to more than a third depending on
Chapter 15	24	17	between 90% and 95% between 2017 and 2020 -> consistently above 90% between 2017 and 2020
Chapter 15	9	40	385 billion USD yr-1 -> 385 billion USD(FOOTNOTE) yr-1 FOOTNOTE: In the chapter, USD units are used as reported in the original sources in general. Some monetary quantities have been adjusted selectively for achieving comparability by deflating the values to constant US Dollar 2015. In such cases, the unit is explicitly expressed as USD2015.
Chapter 15	13	42	countries of 40 billion USD -> countries of 40 billion USD(FOOTNOTE) FOOTNOTE: In the chapter, USD units are used as reported in the original sources in general. Some monetary quantities have been adjusted selectively for achieving comparability by deflating the values to constant US Dollar 2015. In such cases, the unit is explicitly expressed as USD2015.
Chapter 15	21	16	70 trillion USD2015 -> 70 trillion USD2015(FOOTNOTE) FOOTNOTE:In the chapter, USD units are used as reported in the original sources in general. Some monetary quantities have been adjusted selectively for achieving comparability by deflating the values to constant US Dollar 2015. In such cases, the unit is explicitly expressed as USD2015.
Chapter 15	34	0	Reference C5 category for T&D shown because it is used for calculation of incremental needs for Figure 4. -> (REMOVE) duplication in the caption
Chapter 15	40	27	approximately 1.61 trillion USD yr-1 -> approximately 1.61 trillion USD(FOOTNOTE) yr-1 FOOTNOTE: In the chapter, USD units are used as reported in the original sources in general. Some monetary quantities have been adjusted selectively for achieving comparability by deflating the values to constant US Dollar 2015. In such cases, the unit is explicitly expressed as USD2015.

Chapter 15	48	39	24.2 trillion USD, -> 24.2 trillion USD(FOOTNOTE), FOOTNOTE: In the chapter, USD units are used as reported in the original sources in general. Some monetary quantities have been adjusted selectively for achieving comparability by deflating the values to constant US Dollar 2015. In such cases, the unit is explicitly expressed as USD2015.
Chapter 15	4	5	The gaps represent a major challenge for developing countries, especially Least Developed Countries (LDCs), where flows have to increase by factor 4 to 8, -> The gaps represent a major challenge for developing countries, especially Least Developed Countries (LDCs), where flows have to increase by factor 4 to 7,

Corrected Ch 15 Figure 15.5



Corrected Ch 15 Figure 15.3



Source (type)	2013	2014	2015	2016	2017	2018	2019	2020
UNFCCC SCF (total high)	687	584	680	681	Published after literature cut-off		n/a	n/a
Deflated to USD2015	*706*	*590*	*680*	*674*				
UNFCCC SCF (total low / CPI)	339	392	472	456	/608	/540	/623	/640
Deflated to USD2015	*349*	*396*	*472*	*451*	*/590*	*/513*	*/581*	*/590*

Note: Standing Committee on Finance (SCF). Numbers in current billion USD. Deflated to USD2015 in *italic*. 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. Source: UNFCCC 2018a; Buchner et al. 2019; Naran et al. 2021.

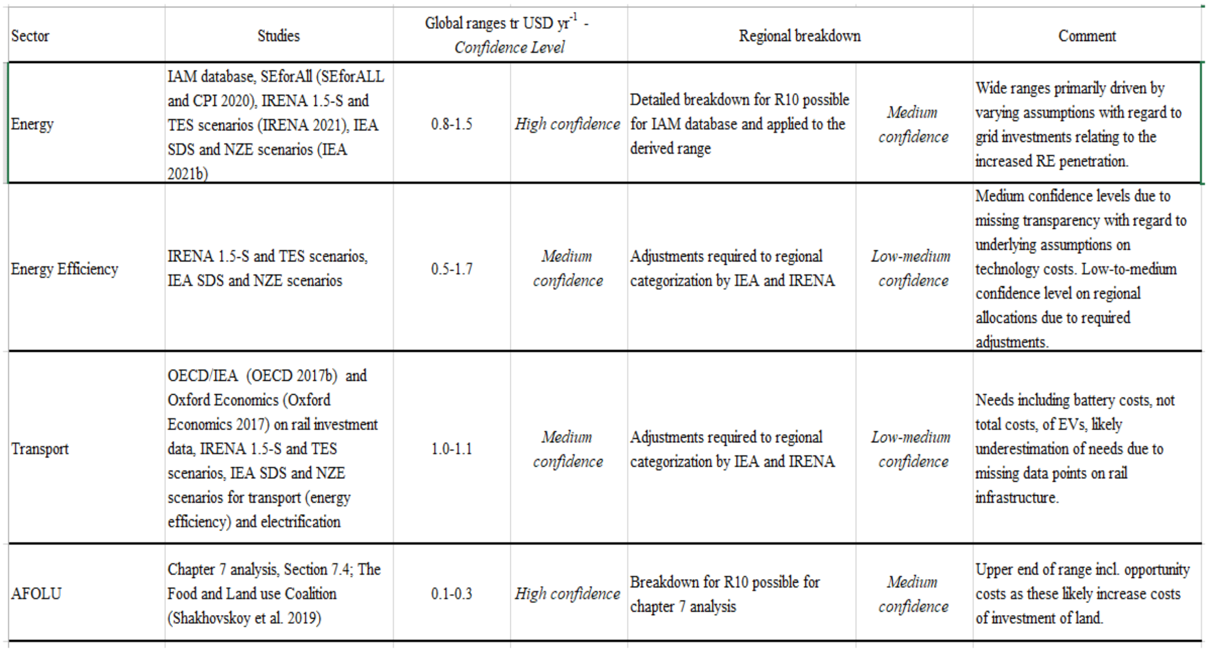
Table 15.1: Total climate finance flows between 2013 and 2020

Type of Economy **Sector**

Note: Numbers in current billion USD. Deflated values see Table 15.1 in *italic*. Type of Economy figure (left): Type of Economy (R3) based on official UN country classification. "0" no regional mapping information available. Sectorial figure (right): *Policy*, incl. "Disaster Risk Management"; "Policy and national budget support & capacity building". *Transport*, incl. "Sustainable/Low Carbon Transport". Energy Efficiency, incl. "Industry, Extractive Industries, Manufacturing & Trade", "Low-carbon technologies", "Information and Communications Technology", "Buildings & Infrastructure". *Electricity*, incl. "Renewable energy generation", "Infrastructure, energy and other built environment", "Transmission and distribution systems", and "Energy Systems". *No sector*: no sector information available, or neglegting flows. *Other*, incl. "Non-energy GHG reductions", "Coastal protection". Source: Own calculations, based on (Naran et al. 2021).

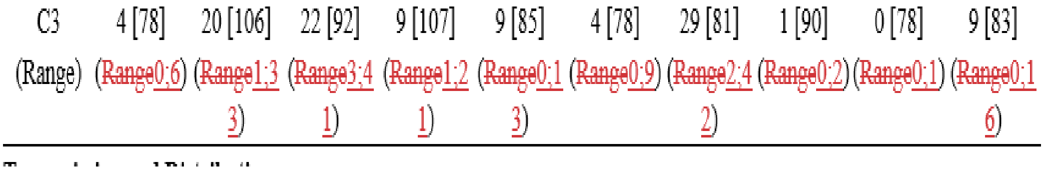
Figure 15.3: Available estimates of global climate finance between 2014 and 2020

Corrected Table 15.4



Sector	Studies	Global ranges tr USD yr^{-1} - *Confidence Level*		Regional breakdown		Comment
Energy	IAM database, SEforAll (SEforALL and CPI 2020), IRENA 1.5-S and TES scenarios (IRENA 2021), IEA SDS and NZE scenarios (IEA 2021b)	0.8-1.5	*High confidence*	Detailed breakdown for R10 possible for IAM database and applied to the derived range	*Medium confidence*	Wide ranges primarily driven by varying assumptions with regard to grid investments relating to the increased RE penetration.
Energy Efficiency	IRENA 1.5-S and TES scenarios, IEA SDS and NZE scenarios	0.5-1.7	*Medium confidence*	Adjustments required to regional categorization by IEA and IRENA	*Low-medium confidence*	Medium confidence levels due to missing transparency with regard to underlying assumptions on technology costs. Low-to-medium confidence level on regional allocations due to required adjustments.
Transport	OECD/IEA (OECD 2017b) and Oxford Economics (Oxford Economics 2017) on rail investment data, IRENA 1.5-S and TES scenarios, IEA SDS and NZE scenarios for transport (energy efficiency) and electrification	1.0-1.1	*Medium confidence*	Adjustments required to regional categorization by IEA and IRENA	*Low-medium confidence*	Needs including battery costs, not total costs, of EVs, likely underestimation of needs due to missing data points on rail infrastructure.
AFOLU	Chapter 7 analysis, Section 7.4; The Food and Land use Coalition (Shakhovskoy et al. 2019)	0.1-0.3	*High confidence*	Breakdown for R10 possible for chapter 7 analysis	*Medium confidence*	Upper end of range incl. opportunity costs as these likely increase costs of investment of land.

Corrected table 15.3



C3	4 [78]	20 [106]	22 [92]	9 [107]	9 [85]	4 [78]	29 [81]	1 [90]	0 [78]	9 [83]
(Range)	(~~Range~~0;6)	(~~Range~~1;13)	(~~Range~~3;41)	(~~Range~~1;21)	(~~Range~~0;13)	(~~Range~~0;9)	(~~Range~~2;42)	(~~Range~~0;2)	(~~Range~~0;1)	(~~Range~~0;16)

Chapter 15: Investment and Finance

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Executive summary

Finance to reduce net greenhouse gas (GHG) emissions and enhance resilience to climate impacts represents a critical enabling factor for the low carbon transition. Fundamental inequities in access to finance as well as its terms and conditions, and countries exposure to physical impacts of climate change overall result in a worsening outlook for a global just transition *(high confidence).* Decarbonising the economy requires global action to address fundamental economic inequities and overcome the climate investment trap that exists for many developing countries. For these countries the costs and risks of financing often represent a significant challenge for stakeholders at all levels. This challenge is exacerbated by these countries' general economic vulnerability and indebtedness. The rising public fiscal costs of mitigation, and of adapting to climate shocks, is affecting many countries and worsening public indebtedness and country credit ratings at a time when there were already significant stresses on public finances. The COVID-19 pandemic has made these stresses worse and tightened public finances still further. Other major challenges for commercial climate finance include: the mismatch between capital and investment needs, home bias[1] considerations, differences in risk perceptions for regions, as well as limited institutional capacity to ensure safeguards represent. {15.2, 15.6.3}

Investors, central banks, and financial regulators are driving increased awareness of climate risk. This increased awareness can support climate policy development and implementation *(high confidence).* Climate-related financial risks arise from physical impacts of climate change (already relevant in the short term), and from a disorderly transition to a low carbon economy. Awareness of these risks is increasing leading also to concerns about financial stability. Financial regulators and institutions have responded with multiple regulatory and voluntary initiatives by to assess and address these risks. Yet despite these initiatives, climate-related financial risks remain greatly underestimated by financial institutions and markets limiting the capital reallocation needed for the low-carbon transition. Moreover, risks relating to national and international inequity – which act as a barrier to the transformation – are not yet reflected in decisions by the financial community. Stronger steering by regulators and policy makers has the potential to close this gap. Despite the increasing attention of investors to climate change, there is limited evidence that this attention has directly impacted emission reductions. This leaves high uncertainty, both near-term (2021-30) and longer-term (2021-50), on the feasibility of an alignment of financial flows with the Paris Agreement (*high confidence*). {15.2, 15.6}

Progress on the alignment of financial flows with low GHG emissions pathways remains slow. There is a climate financing gap which reflects a persistent misallocation of global capital *(high confidence).* Persistently high levels of both public and private fossil-fuel related financing continue to be of major concern despite promising recent commitments. This reflects policy misalignment, the current perceived risk-return profile of fossil fuel-related investments, and political economy constraints (*high confidence*). {15.3}

Estimates of climate finance flows – which refers to local, national, or transnational financing from public, private, multilateral, bilateral and alternative sources, to support mitigation and adaptation actions addressing climate change – exhibit highly divergent patterns across regions and sectors and a slowing growth. {15.3}

When the perceived risks are too high the misallocation of abundant savings persists. Investors refrain from investing in infrastructure and industry in search of safer financial assets, even earning low or negative real returns. {15.2, 15.3}

FOOTNOTE [1] Most of climate finance stays within national borders, especially private climate flows (over 90%). Reasons are national policy support, differences in regulatory standards, exchange rate, political and governance risks, to information market failures.

Global climate finance is heavily focused on mitigation (more than 90% on average between 2017-2020). This is despite the significant economic effects of climate change's expected physical impacts, and the increasing awareness of these effects on financial stability. To meet the needs for rapid deployment of mitigation options, global mitigation investments are expected to need to increase by the factor of 3 to 6 (*high confidence*). The gaps represent a major challenge for developing countries, especially Least Developed Countries (LDCs), where flows have to increase by factor 4 to 8, for specific sectors like AFOLU, and for specific groups with limited access to-, and high costs of-, climate finance (*high confidence*). {15.4, 15.5}

The actual size of sectoral and regional climate financing gaps is only one component driving the magnitude of the challenge, with financial and economic viability, access to capital markets, appropriate regulatory frameworks and institutional capacity to attract and facilitate investments and ensure safeguards being decisive to scale-up financing. Financing needs for the creation and strengthening of regulatory environment and institutional capacity, upstream financing needs as well as R&D and venture capital for development of new technologies and business models are often overlooked despite their critical role to facilitate the deployment of scaled-up climate finance *(high confidence)*. {15.4.1, 15.5.2}

The relatively slow implementation of commitments by countries and stakeholders in the financial system to scale up climate finance reflects neither the urgent need for ambitious climate action, nor the economic rationale for ambitious climate action. ***(high confidence).*** Delayed climate investments and financing – and limited alignment of investment activity with the Paris Agreement – will result in significant carbon lock-ins, stranded assets, and other additional costs. This will particularly impact urban infrastructure and the energy and transport sectors *(high confidence)*. A common understanding of debt sustainability and debt transparency, including negative implications of deferred climate investments on future GDP, and how stranded assets and resources may be compensated, has not yet been developed *(medium confidence)*. {15.6}

The greater the urgency of action to remain on a 1.5°C pathway the greater need for parallel investment decisions in upstream and downstream parts of the value chain. Greater urgency also reduces the lead times to build trust in regulatory frameworks. Consequently, many investment decisions will need to be made based on the long-term global goals. This highlights the importance of trust in political leadership which, in turn, affects risk perception and ultimately financing costs *(high confidence).* {15.6.1, 15.6.2}

There is a mismatch between capital availability in the developed world and the future emissions expected in developing countries. This emphasizes the need to recognize the explicit and positive social value of global cross-border mitigation financing. A significant push for international climate finance access for vulnerable and poor countries is particularly important given these countries' high costs of financing, debt stress and the impacts of ongoing climate change *(high confidence).* {15.2, 15.3.2.3, 15.5.2, 15.6.1, 15.6.7}

Ambitious global climate policy coordination and stepped-up (public) climate financing over the next decade (2021–2030) can help address macroeconomic uncertainty and alleviate developing countries' debt burden post-COVID-19. It can also help redirect capital markets and overcome challenges relating to the need for parallel investments in mitigation and the up-front risks that deter economically sound low carbon projects. ***(high confidence)*** Providing strong climate policy signals helps guide investment decisions. Credible signalling by governments and the international community can reduce uncertainty for financial decision-makers and help reduce transition risk. In addition to indirect and direct subsidies, the public sector's role in addressing market failures, barriers, provision of information, and risk sharing (equity, various forms of public guarantees) can encourage the efficient mobilisation of private sector finance *(high confidence).* {15.2, 15.6.1, 15.6.2}

The mutual benefits of coordinated support for climate mitigation and adaptation in the next decade for both developed and developing regions could potentially be very high in the post-Covid era. Climate compatible stimulus packages could significantly reduce the macro-financial uncertainty generated by the pandemic and increase the sustainability of the world economic recovery. {15.2, 15.3.2.3, 15.5.2, 15.6.1, 15.6.7}

Political leadership and intervention remains central to addressing uncertainty as a fundamental barrier for a redirection of financial flows. Existing policy misalignments – for example in fossil fuel subsidies – undermine the credibility of public commitments, reduce perceived transition risks and limit financial sector action *(high confidence).* {15.2, 15.3.3, 15.6.1, 15.6.2, 15.6.3}

Innovative financing approaches could help reduce the systemic underpricing of climate risk in markets and foster demand for Paris-aligned investment opportunities. Approaches include de-risking investments, robust 'green' labelling and disclosure schemes, in addition to a regulatory focus on transparency and reforming international monetary system financial sector regulations *(medium confidence).* Green bond markets and markets for sustainable finance products have grown significantly since AR5 and the landscape continues to evolve. Underpinning this evolution is investors' preference for scalable and identifiable low-carbon investment opportunities. These relatively new labelled financial products will help by allowing a smooth integration into existing asset allocation models. *(high confidence)* Green bond markets and markets for sustainable finance products have also increased significantly since AR5, but challenges nevertheless remain, in particular there are concerns about 'greenwashing' and the limited application of these markets to developing countries. New business models (e.g. pay-as-you-go) can facilitate the aggregation of small-scale financing needs and provide scalable investment opportunities with more attractive risk-return profiles. Support and guidance for enhancing transparency can promote capital markets' climate financing by providing quality information to price climate risks and opportunities. Examples include sustainable development goals (SDG) and environmental, social and governance (ESG) disclosure, scenario analysis and climate risk assessments, including the Task Force on Climate-Related Financial Disclosures (TCFD). The outcome of these market-correcting approaches on capital flows cannot be taken for granted, however, without appropriate fiscal, monetary and financial policies. Mitigation policies will be required to enhance the risk-weighted return of low emission and climate resilient options, and - supported by progress in transparent and scientifically based projects' assessment methods - to accelerate the emergence and support for financial products based on real projects, such as green bonds, and phase out fossil fuel subsidies. Greater public-private cooperation can also encourage the private sector to increase and broaden investments, within a context of safeguards and standards, and this can be integrated into national climate change policies and plans. {15.1, 15.2.4, 15.3.1, 15.3.2, 15.3.3, 15.5.2, 15.6.1, 15.6.2, 15.6.6, 15.6.7, 15.6.8}.

The following policy options can have important long-term catalytic benefits *(high confidence).* (i) Stepped-up both the quantum and composition of financial, technical support and partnership in low-income and vulnerable countries alongside low-carbon energy access in low-income countries, such as Sub-Saharan Africa, which currently receives less than 5% of global climate financing flows; (ii) continued strong role of international and national financial institutions, including multilateral, especially location-based regional, and national development banks; (iii) de-risking cross-border investments in low-carbon infrastructure, development of local green bond markets, and the alignment of climate and non-climate policies, including direct and in-direct supports on fossil fuels, consistent with the climate goals; (iv) lowering financing costs including transaction costs and addressing risks through funds and risk-sharing mechanisms for under-served groups; (v) accelerated finance for nature-based solutions, including mitigation in the forest sector (REDD+), and climate-responsive social protection; (vi) improved financing instruments for loss and damage events, including risk-pooling-transfer-sharing for climate risk insurance; (vii) phasing-in carbon pricing and phasing out fossil fuel subsidies in a way that addresses equity and access; and (viii) gender-responsive and women empowered programs {15.2.3, 15.2.4, 15.3.1, 15.3.2.2, 15.3.3, 15.4.1, 15.4.2, 15.4.3, 15.5.2, 15.6, 15.6.2, 15.6.4, 15.6.5, 15.6.6, 15.6.7, 15.6.8.2}.

15.1 Introduction

15.1.1 Climate finance - key concepts and elements of scope

Finance for climate action (or climate finance), environmental finance (which also covers other environmental priorities such as water, air pollution and biodiversity), and sustainable finance (which encompasses issues relating to socio-economic impacts, poverty alleviation and empowerment) are interrelated rather than mutually exclusive concepts (UNEP Inquiry 2016a; ICMA 2020a). Their combination is needed to align mitigation investments with multiple SDGs, at a minimum, minimize the conflicts between climate targets and SDGs not being targeted. From a climate policy perspective, 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 2018a). However, as pinpointed in the AR5, significant room for interpretation and context-specific considerations remain. Further, such definition needs to be put in perspective with the expectations of investors and financiers (see Box 15.2).

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 15.1), stocks or flows, gross or net (the latter taking into account reflows and/or depreciation), and domestic or cross-border, public or private (see Box 15.2). 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). One should even consider the investments decided for reasons unrelated with climate objectives but contribute to these objectives (hydroelectricity, rail transportation).

'START BOX 15.1 HERE'

Box 15.1 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 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 encompass capital expenditures (CAPEX or upfront investment value leveraged over the lifetime of a project) operating and maintenance expenditures (OPEX), as well as financing costs. Note that some projects e.g. related to technical assistance 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. For financial investors, physical and intangible assets take the form of financial assets such as bonds or stocks which are expecting to provide income or be sold at a higher price later. In practice, investment decisions are motivated by a calculation of risk-weighted expected returns that takes into account all expected costs, as well as the different types of risks, discussed in Section 15.6.1, that may impact the returns of the investment and even turn them into losses.

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 auto-financing through retained earnings), as well as on grants and subsidies

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.

‘END BOX 15.1 HERE

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. (UNDP 2015; Hainaut and Cochran 2018)), international flows (e.g. (OECD 2016; AfDB et al. 2018)), global flows (UNFCCC 2018a; Buchner et al. 2019)), the financial system (e.g. (UNEP Inquiry 2016a) or specific financial instruments such as bonds (e.g. (CBI 2018)). Common frameworks, reporting transparency are, however, necessary in order to identify overlaps, commonalities and differences between these different measurements in terms of scope and underlying definitions. In that regard, the developments of national and international taxonomies, definitions and standards can help, as further discussed in Section 15.6. and Chapter 17 in WGII (TSU please confirm).

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Box 15.2 International climate finance architecture

International climate finance can flow through different bilateral, multilateral, and other channels, involving a range of different types of institutions both public (official) and private (commercial) with different mandates and focuses. In practice, the architecture of international public climate finance is rapidly evolving, with the creation by traditional donors of new public sources and channels of over the years (Watson and Schalatek 2019), as well as emergence of new providers of development co-operation, both bilateral (see (Benn and Luijkx 2017)) and multilateral (e.g. Asian Infrastructure Investment Bank), as well as of non-governmental actors such as philanthropies (OECD 2018a).

The operationalisation of the Green Climate Fund (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, such as the GCF, the Global Environment Facility (GEF) and the Adaptation Fund (AF).

The multiplication of sources and channels of international climate finance can help address growing climate-related needs, and partly results from increased decentralisation as well financial innovation, which in turn can increase the effectiveness of finance provided. There is, however, also evidence that increased complexity implies transaction costs (Brunner and Enting 2014), in part due to bureaucracy and intra-governmental factors (Peterson and Skovgaard 2019), which constitutes a barrier to low carbon projects and are 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; Gallagher et al. 2018; Humphrey and Michaelowa 2019), as well as risks of fragmentation of efforts (Watson and Schalatek 2020) which slows down coordination with international providers, national development banks and other domestic institutions.

'END BOX 15.2 HERE'

Beyond the need to scale up levels of climate finance, the Paris Agreement provides a broad policy environment and momentum for a more systemic and transformational 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 formulation is a recognition that the mitigation and resilience goals cannot be achieved without finance, both in the real economy and in the financial system, being made consistent with these goals (Zamarioli et al. 2021). It has in turn contributed to the development of the concept of alignment (with the Paris Agreement) used in the financial sector (banks, institutional investors), businesses, and public institutions (development banks, public budgets). As a result, since AR5, in addition to measuring and analysing climate finance, an increasing focus has been placed on assessing the consistency or alignment, as well as respectively the inconsistency or misalignment, of finance with climate policy objectives, as for instance illustrated by the multilateral development banks joint framework for aligning their activities with the goals of the Paris Agreements (MDBs 2018).

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 investments and financing for 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 (see Section 15.3.2.3). As a result, any meaningful assessments of progress requires implies the use of different shades to assess activities based on their negative, neutral ("do no harm") or positive contributions, e.g. (CICERO 2015; Cochran and Pauthier 2019; Natixis 2019). Doing so in practice requires the development of robust definitions, assessment methods and metrics, an area of work and research that remained under development at the time of writing. A range of financial sector coalitions, civil society organisations as well as commercial services providers to the financial industry have developed frameworks, approaches and metrics, mainly focusing on investment portfolios (Raynaud et al. 2020; IIGCC 2021; TCFD Portfolio Alignment Team 2021; U.N.-Convened Net-Zero Asset Owner Alliance 2021),and, to a lesser extent for real economy investments (Micale et al. 2020; Jachnik and Dobrinevski 2021).

Key findings from AR5 and other IPCC publications

For the first time the IPCC in AR5 (Clarke et al. 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 Sections 15.2 and 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, 2018a) 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, resilience and loss and damage financing needs cannot be entirely separated because of structural relationships, synergies, trade-offs and policy coherence requirements between these sub-categories of climate finance (Box 15.1).

'START BOX 15.3 HERE'

Box 15.3 Mitigation, adaptation and other related climate finance merit joint examination

Mitigation finance deals with investments that aim to reduce global carbon emissions, while adaptation finance deals with the consequences of climate change (Lindenberg and Pauw 2013). Mitigation affects the scale of adaptation needs and adaptation may have strong synergies and co-benefits as well as trade-offs with mitigation (Grafakos et al. 2019). 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 and the benefits of stronger adaptation responses may be high (Markandya and González-Eguino 2019). If adaptation investments build greater resilience, they might even moderate mitigation financing costs. Similar policy coherence considerations apply to disaster risk reducing financing, the scale of which depends on success with both adaptation and mitigation (Mysiak et al. 2018). The same financial actors, especially governments and the private sector, decide at any given time on their relative allocations of available financing for 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 parts of this chapter. Climate finance versus the financing of other Sustainable Development Goals (SDGs) faces a similar issue. A key agreement was that climate financing should be 'new and additional' and not at the cost of SDGs. 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 additionality of climate financing is thus essential (Brown et al. 2010). Policy coherence is also the reason why mitigation finance cannot be separated from consideration of spending and subsidies on fossil fuels. Climate change may additionally cause the breaching of physical and social adaptation limits, resulting in climate-related 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 are related to the overall quantum of mitigation, adaptation, and disaster risk reduction finance available (Frame et al. 2020). All categories of climate finance thus need to be considered together in discussions around climate finance.

'END BOX 15.3 HERE'

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 (95% of total) went towards mitigation, which nevertheless underfinanced and adaptation even more so. Measurement of progress towards the commitment by developed countries to provide 100 billion USD yr^{-1} by 2020 to developing countries, for both mitigation and adaptation (Bhattacharya et al. 2020) – a narrower goal than overall levels of climate finance – continued to be a challenge, given the lack of clear definition of such finance, although there remain divergent perspectives (see Section 15.2.4). 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 annual), both public and private, 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 2018a) 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 for the former, and for the latter, 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 600 billion USD (mean 2017/2020), with a slowing in the most recent period 2014 to 2017, the gap in financing was reported to have widened considerably (see Section 15.4 and 15.5). 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, although the absence of alternative financing and access to low carbon energy is a complicating factor.

Adaptation financing needs, meanwhile, were rising rapidly. The Adaption Gap Report 2020 (UNEP 2021) reported that the current efforts are insufficient to narrow the adaptation finance gap, and additional adaptation finance is necessary, particularly in developing countries. The gap is expected to be aggravated by COVID-19 (*high confidence)*. It reaffirmed earlier assessments that by 2030 (2050) the estimated costs of adaptation ranges between 140-300 billion (280-500 billion). Against this, the reported actual global public finance flows for adaptation in 2019/2020 were estimated at 46 billion (Naran et al. 2021). 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 institutions under climate finance in this chapter refer to the set of financial actors, instruments and markets that are recognised to play a key role in financing decisions on climate mitigation and adaptation. For a definition of climate financial stock and flows see further Section 15.3 and the glossary. The issue of climate finance is closely 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 issue is also related to more general questions of how financial institutions, both public and private, can assess climate risks and opportunities from all investments, and what roles states, policy makers, regulators and markets can play in making them more sustainable. 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. The broader macroeconomic context is an important starting point. Four major events and macro trends mark the developments in climate finance in the previous five years and likely developments in the near-term.

- First, the 2015 Paris Agreement, with the engagement of the financial sector institutions 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 (*high confidence)* (see Section 15.2.1).

- Second, the last five years have been characterised by a series of interconnected "headwinds" (see Section 15.2.2), including rising private and public debt and policy uncertainty which work against the objective of filling the climate investment gap (*high confidence*).
- 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 (see Section 15.2.3). At the same time, while it is still too early to draw positive conclusions, this crisis highlights opportunities in terms of political and policy feasibility and behavioural change in respect of realigning climate finance (*medium confidence*).
- 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 (see Section 15.2.4) and a realignment of climate finance and policies that would be beneficial for a new social compact towards a more sustainable world that addresses energy equity and environmental justice (*high confidence*).

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 goals 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 Paris Agreement, 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. 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. (NGFS 2020)) 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 (see Section 15.5.2).

Financial investors have started to account for climate risk in some contexts but they do so only to a limited extent (Monasterolo and de Angelis 2020; Alessi et al. 2021; Bolton and Kacperczyk 2021) and the reasons for these remain unclear. Two aspects are relevant 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). Academics and practitioners in finance are aware that financial risk can in certain contexts be endogenous, i.e., the materialization of losses is affected by the action of financial players themselves. However, the standard treatment of risk both in financial valuation models and in asset pricing assumes that risk is exogenous. In contrast, endogeneity is a key feature of climate risk because today's perception of climate risk affects climate investment, which in turn affect directly the future risk. This endogeneity leads to the fact that multiple and rather different mitigation scenarios are possible (see Chapter 3). Moreover, the likelihood of occurrence of each alternative scenario is very hard to estimate. Further, the assessment of climate-related financial risk requires to combine information related to mitigation scenarios as well as climate impact scenarios, leaving open an important knowledge gap for the next years (see Section 15.6.1).

The second aspect is that the multiplicity of equilibria results in a coordination problem whereby the majority of investors wait to move and reallocate their investments until they can follow a clear signal. Despite the initial momentum of the Paris Agreement, for many investors, both public and private, the policy signal seems not strong enough to induce them to align their investment portfolios to climate goals.

Analyses of the dynamics of the low carbon transition suggest that it does not occur by itself and that it requires a policy signal credible enough in the perception of market players and investors (Battiston et al. 2021b). Credibility could require a policy commitment device (Brunner et al. 2012). The commitment would also need to be large enough (analogous to the "whatever it takes" statement by the European Central Bank during the 2011-12 European sovereign crisis (Kalinowski and Chenet 2020)). In principle, public investments in low carbon infrastructures (or private-public partnerships) as well as regulation could provide credible signals if their magnitude and time horizon are appropriate (past experiences with FiTs models across countries provide useful lessons).

15.2.2 Macroeconomic context

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

Near-term finance financial flows in aggregate often show strong empirically observed cycles over time, especially in terms of macroeconomic and financial cycles. By *near-term*, we mean here the likely cycle over the next five to ten years (2020–2025 and 2020–2030), as influenced by global macroeconomic real business cycles (output, investment and consumption), with periodic asymmetric downside impacts and crises (Gertler and Kiyotaki 2010; Borio 2014; Jordà et al. 2017; Borio et al. 2018). Financial cycles typically have strong co-movements (asset prices, credit growth, interest rates, leverage, risk factors, market fear, macro-prudential and central bank policies) (Coeurdacier and Rey 2013), They have large consequences for all 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). This is in contrast to *longer-term trend considerations* (2020–2050) that typically focus the attention on drivers of disaggregated flows of climate finance and policies. The upward trends of the cycles tend to favour speculative bubbles like real estates at the expenses of investment in production and infrastructures whereas the asymmetric downsides raise uncertainty and risks for longer-term investments on 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 (see Section 15.5) – making the challenge of longer-term low-carbon transition more difficult. In this respect, the impact of financial regulation is unclear. On the one hand, it could be argued that the tighter bank regulations under Basel III, combined with an economic environment with higher uncertainty and flatter yield curve, can push banks to retrench from climate finance projects (Blended Finance Taskforce, 2018a), since banks tend to limit loan maturity to 5 or 8 years, while infrastructure projects typically require the amortisation of debt over 15-20 years (Arezki et al. 2016). On the other hand, other studies report that stricter capital requirements are not a driving factor for moving away from sustainability projects (CISL and UNEP FI 2014)

Four key aspects of the 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 is often made that there is enough climate financing available if the right projects and enabling policy actions ('bankable projects') present themselves (Cuntz et al. 2017; Meltzer 2018). The attention to 'bankability' does not however address access and equity issues (Bayliss and Van Waeyenberge 2018). Some significant gains in climate financing at the sectoral and microeconomic level were nevertheless happening in specific segments, such as solar energy financing and labelled green bonds (although how much of such labelled financing is incremental to unlabelled financing that might have happened anyway remains uncertain) (Tolliver et al. 2019). Issues of 'labelling' (Cornell 2020) apply even more to ESG (environmental, social and governance) investments which started to grow rapidly after 2016 (see Section 15.6.6. for more details). Overall, these increments for climate finance remained, however, small in aggregate relative to the size of the shifts in climate financing required in the coming decade. Annual energy investments in developing regions (other than China) which account for two-thirds of the world population, with least costs of mitigation per ton of emissions (one-half that in developed regions), and for the bulk of future expected global GHG emissions, saw a 20 percent decline in investments since 2016, and only a one-fifth share of global clean energy investment, reflecting persistent financing problems and costs of mobilizing finance towards clean energy transition, even prior to the pandemic (IEA 2021a). 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 in part global macroeconomic headwinds, which show a relative stagnation since 2016 and limited cross-border flows in particular (Yeo 2019).

Slowing and more unstable GDP growth. 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, and worst for the most climate-vulnerable developing countries (*high confidence*). 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 may work in the opposite direction for private decisions by raising the financing costs now (Cherif and Hasanov 2018). With some climate tipping points, potentially in the near-term reach (see Chapter 4: Future global climate: scenario-based 1 projections and near-term information in WGI) the uncertainty with regard to the economic viability and growth prospects of selected macroeconomically critical sectors increases significantly (see Chapter 8 and Chapter 17 in WGII). Taking account of other behavioural failures, this was creating a barrier for pro-active and accelerated mitigation and adaptation action.

Public finances. 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 (Cevik and Jalles 2020; Klusak et al. 2021) at a time of growing stresses on public finances and debt (Benali et al. 2018; Kling et al. 2018; Kose et al. 2020) (*high confidence*). Every climate shock and slowing growth puts greater pressures on public finances to offset these impacts. Crucially, the negative consequences were typically greater at the lower end of income distributions everywhere (Acevedo et al. 2018; Aggarwal 2019). As a result, the standard prescription of raising distributionally adverse carbon taxes and reducing fossil fuel subsidies to raise resources faced political pushback in several countries (Copland 2020; Green 2021), and low rates elsewhere. Reduced taxes on capital, by contrast, was viewed as a way to improve growth (Bhattarai et al. 2018; Font et al. 2018), and working against broader fiscal action. Progress with carbon pricing remained modest across 44 OECD and G20 countries, with 55-70% of all carbon emissions from energy use entirely unpriced as of 2018 (OECD 2021a). Climate vulnerable countries meanwhile 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.

Credit risks. 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. 2018; Rudebusch 2019; Battiston et al. 2021a) *(high confidence)*. Central banks are beginning to take notice (Carney 2019; NGFS 2019). 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 large global financial institutions rose significantly since 2016, because of perceived lower private risks and higher private returns in these investments and other factors than in alternative but perceived more risky low carbon investments.

Global growth. The fourth headwind entering 2020 was the sharply slowing global macroeconomic growth, and prospects for near-term recession (which occurred in the pandemic). During global real and financial cycle downturns (Jordà et al. 2019), the perception of general financial risk rises, causing financial institutions and savers to reallocate their financing to risk-free global assets *(high confidence)*. This 'flight to safety' was evident even before the recent pandemic, marked by an extraordinary tripling of financial assets to about 16.5 trillion USD in negative-interest earning 'safer' assets in 2019 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 have worsened dramatically with the onset of COVID-19. Almost two years after the pandemic started, it is still too uncertain and early to conclude impacts of the pandemic until 2025-2030, especially as they affect climate finance. Multiple waves of the pandemic, new virus mutations, accumulating human toll, and growing vaccine coverage but vastly differing access across developed versus developing regions are evident. They are causing divergent impacts across sectors and countries, which combined with the divergent ability of countries and regions to mount sufficient fiscal and monetary policy actions imply continued high uncertainty on the economic recovery paths from the crisis. The situation remains more precarious in middle and low-income developing countries (IMF 2021a). While recovery is happening, the job losses have been large, poverty rates have climbed, public health systems are suffering long-term consequences, education gains have been set back, public debt levels are higher (5-10% of GDP higher), financial institutions have come under longer-term stress, a larger number of developing countries are facing debt distress, and many key high-contact sectors such as tourism and trade will take time to recover (Eichengreen et al. 2021). The implication is negative headwinds for climate finance with public attention focused on pandemic relief and recovery and limited (and divergent) fiscal headroom for a low carbon transition, with considerable uncertainties ahead (Hepburn et al. 2020b; Maffettone and Oldani 2020; Steffen et al. 2020).

The larger and 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. The outcomes will depend on the robustness of recovery from the pandemic, and the still evolving public policy responses to the climate agenda in the recovery process. Private equity and asset markets have recovered surprisingly rapidly during the pandemic (in response to the massive fiscal and central bank actions generating large excess savings with very low or negative yields boosting stock markets). On public spending, some early studies suggest that the immediate economic recovery packages were falling well short of being sufficiently climate sustainable (Gosens and Jotzo 2020; Kuzemko et al. 2020; O'Callaghan 2021) but several governments have also announced intentions to spend more on a green recovery, a 'build back better' and Just Transition efforts (see Section 15.2.4), although outcomes remain highly uncertain (Lehmann et al. 2021; Markandya et al. 2021).

An important immediate finding from the COVID-19 crisis was that the slowdown in economic activity is illustrating some of these choices: immediately after the onset, more costly and carbon-intensive coal use for energy use 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 led to a -30-35% decline in individual country GDP, and was 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 ±1σ) 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). Along with the carbon emissions drop was 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 however 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. Studies generally suggest that the gains from long-term impacts of the pandemic on future global warming will be limited and depend more on the nature of public policy actions and long-term commitments by countries to raise their ambitions, not just on climate but on sustainable development broadly (Barbier 2020; Barbier and Burgess 2020; Forster et al. 2020; Gillingham et al. 2020; Reilly et al. 2021). 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 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 (Hepburn et al. 2020b).

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 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 the recovery 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 (UKERC 2014; Vona et al. 2018; Jaeger et al. 2020). 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 five possible elements:

(a) Reaffirmation of a strong financial agenda in future Conference of Parties' meetings, and a new collective finance target, which will need to be undertaken by 2025. Given that the shortfalls in financing are likely to be acute for developing regions and especially the more debt-stressed and vulnerable (Dibley et al. 2021; Elkhishin and Mohieldin 2021; Laskaridis 2021; Umar et al. 2021), developed countries may wish to step up their collective support (Resano and Gallego 2021). One possibility is to expedite the new SDR issuance allocation rules for the 650 billion USD recently (2021) approved, most of which will go to increase the reserves of G-7 and other High-Income countries unless voluntarily reallocated towards the needs of the most vulnerable low-income countries, raising resources potentially 'larger than the Marshall Plan in today's money' (IMF 2021b; Jensen 2021; Obstfeld and Truman 2021), with decisions to be taken (Ameli et al. 2021a) note the climate investment trap of current high cost of finance that effectively lowers green electricity production possibilities in Africa for a cost optimal pathway. Other initiatives could also include G-7 and G-20 governments (especially with the lead taken by the developed members for cross-border support to avoid over-burdening public resources in developing countries) running coordinated fiscal deficits to accelerate the financing of low carbon investments ('green fiscal stimulus').

(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, primarily from developed countries but jointly with developing countries to create a level-playing field (Dafermos et al. 2021) 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) (Hourcade et al. 2018; 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 (IEA 2021a), and where the role of multilateral, regional and global institutions such as the IMF (including the expansion in availability of climate SDRs referred earlier) could be important.

(d) global central banks acting in coordination to include climate finance as intrinsic part of their monetary policy and stimulus (Carney 2019; Jordà et al. 2019; Hilmi et al. 2021; Schoenmaker 2021; Svartzman et al. 2021)

(e) an acceleration of Just Transition initiatives, outlined further below (Section 15.2.4).

15.2.4 Climate Finance and Just Transition

Climate finance in support of a Just Transition is likely to be a key to a successful low-carbon transition globally *(high confidence)*. Ambitious global climate agreements are likely to work far better by maximising cooperative arrangements (IPCC 2018; Gazzotti et al. 2021) with greater financing support from developed to developing regions in recognition of 'common but differentiated responsibilities and respective capabilities' and a greater ethical sense of climate justice (Khan et al. 2020; Sardo 2020; Warner 2020; Pearson et al. 2021). While Just Transition issues apply within developed countries as well (see later discussion), these are of relatively second-order significance to addressing climate justice issues between richer and poorer countries – given the scale of financing and existing social safety nets in the former and their absence in the latter. For example, over the past three decades drought in Africa has caused more climate-related mortality than all climate-related events combined from the rest of the world (Warner 2020). These issues can however serve both as a bridge and a barrier to greater cooperation on climate change. The key is to build greater mutual trust with clearer commitments and well-structured key decisions and instruments (Sardo 2020; Pearson et al. 2021).

The Just Transition discussion has picked up steam. It 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.' Originally proposed by global trade unions in the 1980s, the recent discourse has become broader. It has coalesced into a more inclusive process to reduce inequality across all three areas of energy, environment and climate (McCauley and Heffron 2018; Bainton et al. 2021). It seeks accelerated public policy support to ensure environmental sustainability, decent work, social inclusion and poverty eradiation (Burrow 2017), widely shared benefits, and protection of indigenous rights, and livelihoods of communities and workers who stand to lose (including workers in fossil fuel sectors such as coal and oil and gas) (UNFCCC 2018b; EBRD 2020; Jenkins et al. 2020). Because the process involves 'climate justice' and equity within and across generations, it involves difficult political trade-offs (Newell and Mulvaney 2013). The implications for a Just Transition in climate finance are clear: expanding equitable and greater access to climate finance for vulnerable countries, communities and sectors, not just for the most profitable private investment opportunities, and a larger role for public finance in fulfilling existing finance commitments (Bracking and Leffel 2021; Kuhl 2021; Long 2021; Roberts et al. 2021) .

Large shocks, such as pandemics and slow-growing one such as climate are typically known to worsen inequality (IMF and World Bank 2020). Evidence from 133 countries between 2001–2018 suggests that such shocks can cause social unrest, and migration pressures, especially when starting inequality is high and social transfers are low (Saadi Sedik and Xu 2020). Additionally, climate policies are more politically difficult to implement, when the setting is one of high inequality but much less politically costly where incomes are more evenly distributed with stronger social safety nets (Furceri et al. 2021). A redrawn social compact incorporating climate (Beck et al. 2021) that would adopt redistributive taxes and lower carbon consumption, and strengthen state capacity to deliver safety nets, health, education with accelerated climate and environmental sustainability within and across countries is increasingly recognised as important. Countries, regions and coordination bodies of the larger countries (G-7, G-20) have already begun such as shift to financing of a Just Transition, but primarily focused on the developed countries, although gaps remain (Krawchenko and Gordon 2021).

Such a redrawing of a social compact has happened significantly in the past, for example, after the 1860s 'gilded age of capital' with the enlargement of the franchise in democratization waves in Europe and the Americas (Dasgupta and Ziblatt 2015, 2016). Not only was social conflict avoided but growth outcomes became more equitable and faster. Similarly, comprehensive modern social safety nets and progressive taxation, which started in the Great Depression and was extended in the post-war period, had both a positive pro-growth and lower inequality effects (Brida et al. 2020) .

There are three levels of at which policy attention on climate financing now may need to be focused. The first is the need for to addressing the global equity issues in climate finance in a more carefully constructed globally cooperative public policy approach. The second is to address issues appropriately with enhanced support, at the national level. The third 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).

Climate finance will likely face greater challenges in the post-pandemic context (Hanna et al. 2020; Henry et al. 2020). Evidence from COVID-19 pandemic suggests that those in greatest vulnerability often had the least access to human, physical, and financial resources (Ruger and Horton 2020). It has also left in in its wake divergent prospects for economic recovery, with rising constraints on credit ratings and costly debt burden in many developing countries contrasted with the exceptionally low interest rate settings in developed economies driving the limited fiscal space in the former groups (Benmelech and Tzur-Ilan 2020). Similarly, monetary policies are likely to be much tighter in developing countries in part structurally because of the absence of 'exceptional privilege' of global reserve currencies in developed economies.

The result is a divergence in recovery prospects in the aftermath of the pandemic, with output losses (compared to potential) set to worsen in developing economies (excluding China) as compared to developed countries (IMF 2020b). In these circumstances, a coordinated and cooperative approach, instead of unilateralism, might work better (McKibbin and Vines 2020). In the case of climate, simulations clearly suggest the need and advantages of better coordinated climate action with stepped-up Paris Agreement envisaged transfers (IMF 2020b). Several options in international climate finance arrangements to support a Just Transition are both available and urgent.

As a first priority, measures might need to accelerate a mix of equitable financial grants, low-interest loans, guarantees and workable business models access across countries and borders, from developed countries to in low-income countries. A big push on low-carbon energy access globally, especially in large low-income regions such as Africa, with accelerated financial transfers makes sense (Boamah 2020). For about one billion people globally at the base of the pyramid without access to modern low-carbon energy access, such an action, with enormous immediate leap-frogging potential, would be a key pathway to achieve the SDGs, ensure that high-carbon energy use is avoided, such as the burning of biomass and forests for charcoal, and improve air quality and public health, especially women's health (van der Zwaan et al. 2018; Nathwani and Kammen 2019; Dalla Longa and van der Zwaan 2021; Michaelowa et al. 2021; Osabuohien et al. 2021).

A second priority is to accelerate the implementation of the 100 billion USD a year (and likely more given growing financing gaps) in climate finance commitments expressed in the Copenhagen Agreement Accord (and reiterated since) from developed to developing countries, and to build greater confidence 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 measurement with greater accuracy about the effective transfer of resources. The journey to get to a clear and precise definition of net Official Overseas Development Assistance (ODA) took time. The original proposal was first initiated in the 1960s (Pincus 1963) but it was not till MDB's and others laid out the compelling reasons why (Chang et al. 1998) that this was accomplished: especially to resolve 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' (Bulow and Rogoff 2005; Hynes and Scott 2013; Scott 2015, 2017).

A third related and increasingly crucial priority is to expedite the operational definition of blended finance and promote the use of public guarantee instruments. Private flows to accelerate the low-carbon transition in developing countries would benefit enormously, by gaining clearer access to public international funds and support defined on a grant equivalent basis, provided development and climate finance operational definitions and procedures were improved on an urgent basis (Blended Finance Taskforce 2018a; OECD-DAC 2021). When blended and supported by public finance and policy, the grant equivalency measure can easily and more accurately measure the value and benefit of blended public and private finance by comparing the effective interest cost (and volume) gain with such financing, against the benchmark costs without such blending. Here again, a pressing challenge is to improve the operational definitions of what counts as ODA within blended finance. Blended finance remains very poorly defined and accounted (Pereira 2017; Andersen et al. 2019; Attridge and Engen 2019; Basile and Dutra 2019). Guarantees are expressly not included in the definition of ODA (Garbacz et al. 2021), As a result, bilateral and multilateral agencies have no incentive or limited authority and basis to use such instruments, while multilateral development banks continue to approach guarantees with great caution because of the limits of their original charters (World Bank 2009) and require counter-indemnities by recipient countries, internal and historic agency inertia, perceived loss of control over the use of funds (compared to their preferred direct project-based lending) and employ restrictive accounting rules for capital provisioning of guarantees at 100% of their face value to maintain AAA ratings with credit rating agencies (Humphrey 2017; Pereira dos Santos and Kearney 2018a; Bandura and Ramanujam 2019; Hourcade et al. 2021a). Largely because of such official uncertainty the actual flows of blended finance and guarantees continue to remain a very small share (typically, less than 5%) of official and multilateral finance flows to lower project risks and costs, and hence the potential for large-scale accelerated low-carbon private investments in developing countries. Public guarantees can offer a fifteen times multiplier effect on the scale of low-carbon investments generated with such support, compared to a 1:1 ratio in direct financing (Hourcade et al. 2021a).

It makes sense to expedite these operational procedures (Khan et al. 2020) which cannot be otherwise explained except in terms of avoiding responsibilities, even where the benefits would be high (Klöck et al. 2018). It also causes (unnecessary) fragmentation and complexity and often 'strategic' ambiguity by many actors (Pickering et al. 2017), which worsens the possibilities for international cooperation, a critical requirement to achieve the Paris goals (IPCC 2018). The world would gain collectively if these issues were to be decided soon. The absence of such a collective decision continues to be exceptionally costly for the implementation of the Paris Agreement because of the fractious and seemingly insoluble negotiating climate and a breakdown of trust that this has created (Roberts and Weikmans 2017).

A fourth priority is on expanding jobs and dealing with job losses in the global low carbon transition (Carley and Konisky 2020; Crowe and Li 2020; Pai et al. 2020; Cunningham and Schmillen 2021; Hanto et al. 2021), especially in coal and other sectors, as well as land and other effects for indigenous communities (Zografos and Robbins 2020). Many countries, especially low-income countries, remain dependent on fossil fuels for their energy and exports and jobs, and support for their transition to a low-carbon future will be essential. Global recovery from the pandemic will take longer than initially envisaged (IMF 2021c; OECD 2021b) and an accelerated climate action for a Build Back Better global infrastructure plan with better and more resilient jobs might play a key role as part of the Just Transitions. Already, there is substantial evidence (Sulich et al. 2020; Dell'Anna 2021; Dordmond et al. 2021) that a more sustainable climate path would generate many more net productive jobs (with much higher employment multipliers and mutual gains from given spending) than would any other large-scale alternative. But this would nevertheless require a carefully managed transition globally, including access to much larger volumes of 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), but have been hampered by the of constraints on their mandates and instruments (as noted earlier). Political leadership and direction will be again crucial to enhance their roles. The recent expansion of SDR quotas at the IMF similarly might help, but the current distributions of quota benefits flow primarily to the developed countries and does little to expand investment flows on a longer-term basis for a global expansion in growth and job opportunities in the low-carbon transition.

As a fifth priority, transformative climate financing options based on equity and global sustainability objectives may also need to consider a greater mix of public pricing and taxation options on the consumption side (Arrow et al. 2004; Folke et al. 2021). Two-thirds of global GHG emissions directly or indirectly are linked to household consumption, with average per capita carbon footprint of North America and Europe of 13.4 and 7.5 tCo_2-eq/capita, respectively, compared to 1.7 in Africa and Middle East (Gough 2020) and as high as 200tCO_2-eq/capita among the top 1% in some high-income geographies versus 0.1tCO_2-eq at the other end of the income distribution in some least-developed countries (Chancel and Piketty 2015). Globally, the highest-expenditure households account for eleven times the per capita emissions of lowest-expenditure households, with rising carbon income elasticities that suggest 'redistribution of carbon shares from global elites to global poor' as welfare efficient (Chancel and Piketty 2015; Hubacek et al. 2017). Within countries and regions, and within sectors, similar patterns hold. The top 10% of the population with the highest per capita footprints account for 27% of the EU carbon footprint, and the top 1% have a carbon footprint of 55tCO_2-eq/cap, with air transport the most elastic, unequal and carbon-intensive consumption (Ivanova and Wood 2020). Similarly, within sectors, there are large differences in carbon-intensity in the building sector in North America (Goldstein et al. 2020) and across cities where consumption-based GHG emissions vary widely across the world (ranging from 1.8 to 25.9 tCO_2-eq/capita).

Numerous options exist (Broeks et al. 2020; Nyfors et al. 2020) for such carbon consumption reduction measures, while potentially improving societal well-being, for example: (a) inner-city zoning restrictions on private cars and promoting walking/bicycle use and improved shared low-carbon transport infrastructure; (b) advertising regulation and carbon taxes and fees on high-carbon luxury status goods and services; (c) subsidies and exemptions for low-carbon options, higher value-added taxes on specific high-carbon products and services, subsidies for public low-carbon options such as commuter transport, and other behavioural nudges (Reisch et al. 2021); and (d) framing options (emphasizing total cost of car over life-times), mandatory smart metering, collective goods and services (leasing, renting, sharing options) and others. Finally, reducing subsidies on fossil fuels, raising the progressivity of taxes and raising overall wealth taxes on the richest households, which has been sharply falling (Scheuer and Slemrod 2021) even as global income and wealth has risen with regressive and falling overall taxes (Alvaredo et al. 2020; Saez and Zucman 2020) could effectively generate significant revenues (over 1% of GDP yr^{-1}, about the same size as the proposed global 50 USD per ton carbon price proposed and estimated by the IMF/OECD 2021 report to G20 (IMF and OECD 2021) to cover expected net interest costs on overall decarbonization initiatives and financing of green new deals (Schroeder 2021).

These five options identified above on near-term actions and priorities will however, require greater collective political leadership. A review of past crisis episodes 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). They but do not appear to work as well for more complex global collective action problems which concern a number of economic actors, sectors, without inexpensive and mature technological options, and where political and institutional governance is fragmented. Greater political coordination is needed because the impacts are often not near-term or imminent, but diffuse, slow-moving and long-term, and where preventive disaster avoidance is costly even when these costs are low compared to the longer-term damages—till tipping points are reached of the need for reduced 'stressors' and increasing 'facilitators' (Jagers et al. 2020). But by then, it may be too late.

Private institutional investors equally might equally wish to pay greater attention to the Just Transition finance issues. It would be useful for investors to identify ways to support to such initiatives, and more clearly identifying the benefits of such transition measures envisaged by both countries and investment financing proposals, including incorporating Just Transition consideration in their support to broader ESG (environmental, social and governance) and green financing initiatives.

The second level of attention needed on Just Transitions has to do with inequities within a large country setting, developed or developing. The Just Transition issue exists within developed countries as well. As the ongoing pandemic illustrates, the first climate burden hit is often felt most acutely at the level of states and cities, with many smaller ones without enough fiscal capacity or ability to mount an adequate discretionary counter policy. Only national governments have ability to borrow more in their fiscal accounts 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 Just Transition initiatives in their NDCs for financing (as South Africa has recently done), and attention by external financing agencies and MDBs to large-scale adverse impacts in their climate policies and investments. For example, the EU Green Deal plans (Nae and Panie 2021) includes 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-carbonization measures in the fossil fuel sectors, transportation, as well as those who are harmed by polluting sectors: indigenous men and women, minorities and generally the poor. It is evident that very few resources are available to countries, investors, civil society, and smaller development institutions seeking to achieve a just transition (Robins and Rydge 2020).

Finally, greater support is warranted for smaller towns and cities, local networks, SMEs, communities, local authorities and universities for projects, research ideas and proposals (Lubell and Morrison 2021; Moftakhari et al. 2021; Stehle 2021; Vedeld et al. 2021).

15.3 Assessment of current financial flows

15.3.1 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 15.3.2.3 and 15.3.2.4 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 (IMF 2009; UN and ECB 2015). On the flows side, GDP, a System of National Accounts (SNA) statistical standard that measures the monetary value of final goods and services produced in a country in a given period of time. In 2020, global GDP represented above 70 trillion USD_{2015} (down from almost 80 trillion USD in 2019), out of which developed countries represented approx. 60% (Figure 15.1); a slowly decreasing share over the last years. The GDP metric is useful here as an indicator of the level of activity of an economy but gives no indication relating to human wellbeing or SDG achievements (Giannetti et al. 2015) counts positively activities that negatively impact the environment, without making deductions for the depletion and degradation of natural resources.

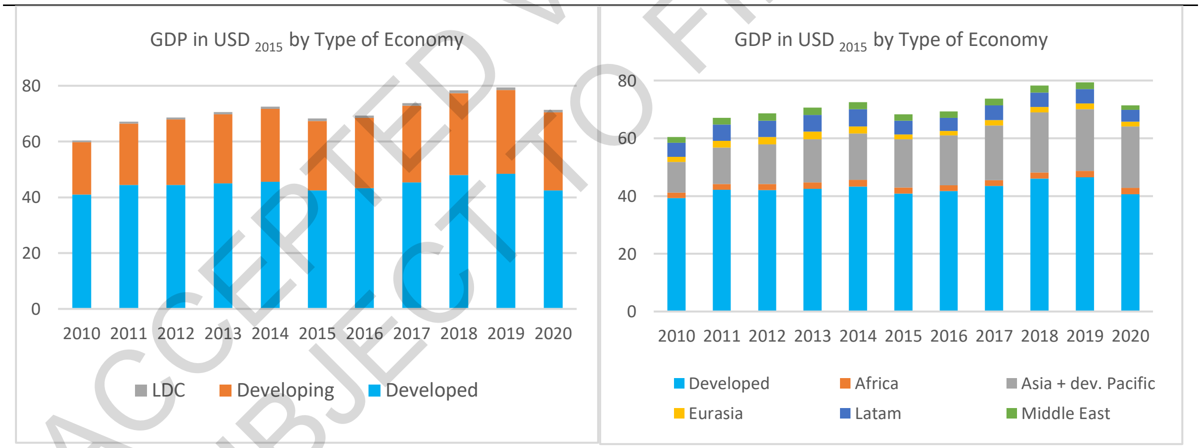


Figure 15.1 Financial flows – GDP (USD_{2015} tr.) by Type of Economy (left) and Region (right)

Note: Regional breakdown based on official UN country classification. GDP in USD_{2015} trillion. Source: World Bank Data (2020a). Numbers represent aggregated country data. Last updated data on 15 September 2021. CC BY-4.0

Gross-fixed capital formation (GFCF), another SNA standard that covers tangible assets (notably infrastructure and equipment) and intangible assets, is a good proxy for investment flows in the real economy. In 2019, global GFCF reached 23 trillion USD compared to 16.2 trillion USD in 2010, a 42% increase (Figure 15.2). 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 goals.

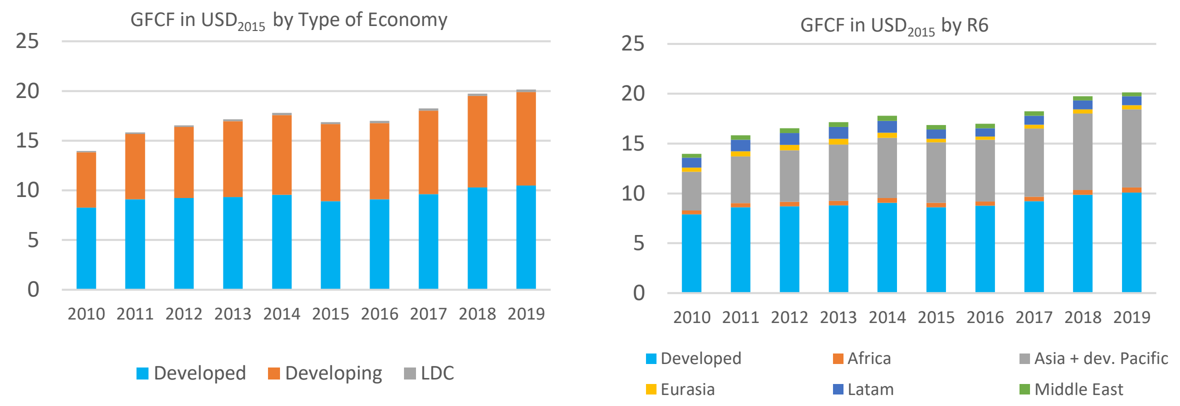


Figure 15.2 Financial flows – GFCF (USD$_{2015}$ tr.) by Type of Economy (left) and Region (right)

Note: Regional breakdown based on official UN country classification. GDP in constant 2015 USD trillion USD$_{2015}$. 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. Source: World Bank Data (2020b). Data for 2020 not available. Last updated Data 15 September 2021. CC BY-4.0

One the stock side, an increasingly significant portion of the growing value of financial capital (stocks in particular) may be disconnected from the value of underlying productive capital in real economy (Igan et al. 2020). This trend, however, remains uneven between developed countries, most of which have relatively deep capital markets, and developing countries at different stages of development (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 later in the Chapter, since AR5, an increasing number and volume of bonds have been earmarked for climate action but these still only represent less than 1% of the total bond market. As of end 2020, climate aligned bonds outstanding were estimated at 0.9 trillion (Giorgi and Michetti 2021), though 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 the relatively small size of current climate finance flows and relatively larger size of remaining fossil fuel-related finance flows (discussed in the following two sub-sections), as well as, more generally, the significant overall scale of financial flows and stocks that have to be made consistent with climate goals. These orders of magnitude further make it possible to put in perspective climate-related investment needs (Section 15.4) and gaps (Section 15.5).

15.3.2 Estimates of climate finance flows

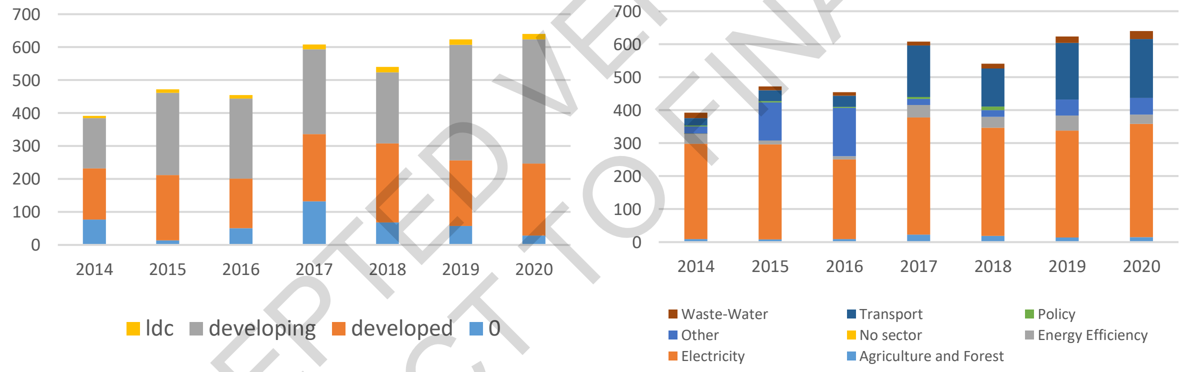
The measurement of climate finance flows continues to face similar definitional, coverage and reliability issues than at the time of AR5 and special report on the impacts of global warming of 1.5°C, despite progress made (more sources, greater frequency, and some definitional improvements) by a range of data providers and collators. Based on available estimates (Table 1 and Figure 3), flows of annual global climate finance are on an upward trend since AR5, reaching a high-bound estimate of 681 billion USD in 2016 (UNFCCC 2018a). Latest available estimates, indicate a drop in 2018 (Buchner et al. 2019) and a rebound in 2019 and 2020 (Naran et al. 2021) (*medium confidence*). Although not directly comparable in terms of scope, current climate finance flows remain small (approx. 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 15.3.2.3) (*medium confidence*).

Table 15.1 Total climate finance flows between 2013 and 2020

Source (type)	2013	2014	2015	2016	2017	2018	2019	2020
UNFCCC SCF (total high)	687	584	680	681	Published after lit. cut-off		n/a	n/a
UNFCCC SCF (total low / CPI)	339	392	472	456	/608	/540	/623	/640

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. Source: (UNFCCC 2018a; Buchner et al. 2019; Naran et al. 2021).



Type of Economy **Sector**

Figure 15.3 Available estimates of global climate finance between 2014 and 2020

Note: Numbers in billion USD. Type of Economy figure (left): Regional breakdown based on official UN country classification. "0" no regional mapping information available. Sectorial figure (right): *Policy*, incl. "Disaster Risk Management"; "Policy and national budget support & capacity building". *Transport*, incl. "Sustainable/Low Carbon Transport". Energy Efficiency, incl. "Industry, Extractive Industries, Manufacturing & Trade", "Low-carbon technologies", "Information and Communications Technology", "Buildings & Infrastructure". *Electricity*, incl. "Renewable energy generation", "Infrastructure, energy and other built environment", "Transmission and distribution systems", and "Energy Systems". *No sector*: no sector information available, or neglegting flows. *Other*, incl. Non-energy GHG reductions, Coastal protection. Source: Own calculations, based on (Naran et al. 2021).

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 (Buchner et al. 2019). This 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 a few large economies (*high confidence*), with Brazil, India, China and South Africa accounting for 25% to 43% depending on the year, a share similar to that represented by developed countries. Least-developed countries (LDCs), on the other hand, continue to represent less than 5% year-on-year (BNEF 2019; Buchner et al. 2019) (*medium confidence*). 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.

At a global level, the majority of tracked climate finance is assessed as coming from private actors (Buchner et al. 2019), although, as discussed in Box 15.2, the boundaries between private and public finance include significant grey zones, which implies that different definitions could lead to different conclusions (for instance see (Yeo 2019; Weikmans and Roberts 2019)). However, 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 as well as balance sheet financing (which can rely on both own resources and further debt) and project financing (combining a large debt portion and smaller equity portion) represent the lion's share. In this context, the rapid rise of climate-related bond issuances since AR5 (Giorgi and Michetti 2021) represents an opportunity for scaling up climate finance but also poses underlying issues of integrity (Nicol et al. 2018a; Shishlov et al. 2018) and additionality (Schneeweiss 2019), as further discussed in Section 15.6.6, as well as needs to be considered in the context of overall indebtedness and debt sustainability (Sections 15.6.1, 15.6.3).

Mitigation continues to represent the lion's share of global climate finance (between 90% and 95% between 2017 and 2020), and in particular renewable energy, followed by energy efficiency and transport (UNFCCC 2018a; Buchner et al. 2019) (*high confidence*). 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 could 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 (Agrawala et al. 2011; Averchenkova et al. 2016) (Brown et al. 2015). Despite these limitations, evidence shows that finance for adaptation remains fragmented and significantly below rapidly rising needs (Section 15.4 and WG2, TSU please confirm). Further, there is increasing awareness about the need to better understand and address the interlinkages 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 (Climate Funds Update 2014; Nakhooda et al. 2014a,b; Watson et al. 2015). For the private sector, insurance and reinsurance remain the dominant way to transfer risk, as discussed in Section 15.6.4).

More generally, significant gaps remain to track climate finance comprehensively at a global level:

- Available estimates are based on a good coverage of investments in renewable energy and, where available, energy efficiency and transport, while other sectors remain more difficult to track, such as industry, agriculture and land use (UNFCCC 2018a; Buchner et al. 2019). (*high confidence*)
- In contrast to international public climate finance, domestic public finance data remain 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). (*high confidence*)

Data on private and commercial finance remains very patchy, particularly for corporate financing (including debt financing provided by commercial banks), for which it is difficult to establish a link with activities and projects on the ground. (*high confidence*). Further, as individual source of aggregate reporting (UNFCCC 2018a; Buchner et al. 2019; FS-UNEP Centre and BNEF 2020) 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, while accounting scope and methodologies continue to be debated (see Box 15.4), progress has been achieved on these matters in the context of the UNFCCC (UNFCCC 2019b). 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 (Carty et al. 2020). The relatively low share of adaptation in international climate finance to date 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 or regional (Abadie et al. 2013).

'START BOX 15.4 HERE'

Box 15.4 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 goal is further embedded as a target under SDG 13 Climate Action Such finance may come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance." (UNFCCC 2009). While the parameters for what and how to count were not defined when the goal was set, progress in this area has been achieved under the UNFCCC (UNFCCC 2019b) and via a UN-driven independent expert review (Bhattacharya et al. 2020).

There remains well documented interpretations and debates on how to account for progress (Clapp et al. 2012; Stadelmann et al. 2013; Jachnik et al. 2015; Weikmans and Roberts 2019). 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 2018a). 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 2015a, 2019a, 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 translate gross flows of bilateral and multilateral public climate finance in grant equivalent terms, while also, for some activities, applying discounts to the proportion considered as climate finance (Carty et al. 2016; Carty and Le Comte 2018 and Carty et al 2020). The resulting annual averages for 2015– 2016 and 2017–2018range 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).

A point of method that attracts much attention relates to how to account for private finance mobilised. The OECD, through its Development Assistance Committee, established an international standard to measure private finance mobilised by official development finance, which consists in methods tailored to different financial mechanisms. These methods taking into account the role of, risk taken, and/or amount provided by all official actors involved in a given project, including recipient country institutions, thereby also avoiding risks of double counting. (OECD 2019b). MDBs apply a different method (World Bank 2018a) in their joint climate finance reporting (AfDB et al. 2020)., which 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).

'END BOX 15.4 HERE'

15.3.3 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 goal of the Paris Agreement of holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels requires making all finance consistent with this goal. Data on investments and financing to high GHG activities 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 1.5°C warming, however, make it clear that the share of fossil fuels in energy supply has to decrease. For instance, the International Energy Agency (IEA) Net Zero by 2050 scenario relies on halting sales of new internal combustion engine passenger cars by 2035, rapid and steady decrease of the production of coal (minus 90%), oil (minus 75%) and natural gas (minus 55%) by 2050, and phasing out all unabated coal and oil power plants by 2040 (IEA 2021b). To avoid locking GHG emissions incompatible with remaining carbon budgets, this implies a rapid scaling down of new fossil fuel-related investments, combined with a scaling up of financing to allow energy and infrastructure systems to transition (*high confidence*).

The IEA provides comprehensive analyses of global energy investments, estimated at about 1.8 trillion USD a year over 2017–2019 (IEA 2019a, 2020a), and expected to reach that level again in 2021 after a drop to about 1.6 trillion in 2020 (IEA 2021c). Energy investments represent about 8% of global GFCF (Section 15.3.2.1). In the power sector, fossil fuel-related investments reached an estimated 120 billion USD yr^{-1} on average over 2019–2020, which remains well above the level that underpin the IEA's own Paris-compatible Sustainable Development Scenario (SDS) and Net Zero scenarios. The IEA observes a similar inconsistency with for supply side new investments: in 2019-2020 on average yr^{-1}, an estimated 650 billion USD were invested in oil supply and close to 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 2020b). As discussed in the remainder of this Chapter, shifting investments towards low-GHG solutions requires a combination of conducive public policies, attractive investment opportunities, as well as the availability of financing to finance such a transition.

In terms of financing provided to fossil fuel investments, available 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 DeAngelis and Tucker 2020).

Finance for new fossil fuel-related assets lock in future GHG emissions that may be inconsistent with remaining carbon budgets and, as discussed above, with emission pathways to reach the Paris Agreement goals. This inconsistency exposes investors and asset owners to the risk of stranded assets, which results from potential sharp strengthening climate public policies, i.e. 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), with also a wide variety of metrics, methodologies, and approaches developed by commercial providers that contribute to disparate outcomes (Kotsantonis and Serafeim 2019; Boffo and Patalano 2020). Further, as developed in Sections 15.6.1, there is currently not enough evidence in order to conclude whether climate-related risk assessments result in increased climate action and alignment with the goals of the Paris Agreement(e.g. 2° Investing Initiative (The 2°Investing Initiative and Wuest Partner 2020)).

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 2018). Such lack of coherence includes low pricing of carbon and of environmental externalities more generally, as well as misaligned policies in non-climate policy areas such as fiscal, trade, industrial and investment policy, and financial regulation (OECD 2015b), as further specified in the 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 (Bast et al. 2015; Coady et al. 2017; Climate Transparency 2020). 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), which, in turn, reduces the efficiency of public instruments and incentives aimed at redirecting investments and financing towards low-GHG 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 (Schwanitz et al. 2014; Röttgers and Anderson 2018), as further discussed in Section 15.5.2. and Chapter 13.

15.4 Financing needs

15.4.1 Definitions of financing needs

Financing needs are discussed in various contexts, only one being international climate politics and finance. Also, financing needs are used as an indicator for required system changes (when compared to current flows and 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 focusing on initial investments required to realise new infrastructure. It compares relatively well with private sector flows dominated by return-generating investments but lacks comparability and explanatory power regarding the needs in the context of international climate cooperation where considerations on economic costs play a more substantial role. Chapter 12 elaborates on global economic cost estimates for various technologies. This indicator includes both costs and benefits of options, of which investment-related costs make up only one component. . Both analyses offer complementary insights. 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 facilitating to achieve social and economic goals underpinning knowledge, skills, notional and international cooperation might not be significant, but an enabling environment for future investments would not be established without satisfying it. Moreover, comprehending financial needs for addressing economic losses due to climate change 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 international public interventions can be needed to ensure enough supply of finance across sectors, regions and stakeholders. The location of financing needs and vicinity to capital matter given home bias (Fuchs et al. 2017; OECD 2017a; Ito and McCauley 2019) (prioritizing own country or regions), transaction costs and risk considerations (see also 15.2). 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, governments' enabling financial market frameworks, guidelines and supportive infrastructure 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 region for capital markets depend on several factors. Some essential elements are the duration of loan and profile as long term loans and heavily heterogeneous returns represent challenges in financing mitigation technologies and policies. After the financial crisis and restricted access to long-term debt, capital intensity of technologies and resulting long payback periods of investment opportunities for mitigation technologies have been a crucial challenge (Bertoldi et al. 2021). Also, implicit discount rates applied during the investment decision process vary depending on the payback profile, with research mainly 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 climate projects 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 (optimizing return and risk of a portfolio through diversification) (Marinoni et al. 2011). Transaction cost is a significant barrier to the diffusion and commercialization of low-carbon technologies and business models and adaptation action. High transaction costs, attributed to various factors, such as complexity and limited standardisation of investments, limited pipelines, complex institutional and administrative procedures, create significant opportunity costs of green investments comparing with other standard investments (IRENA 2016; Nelson et al. 2016; Feldman et al. 2018). For example, transaction costs are commonly observed in small-scale, dispersed independent renewable energy systems, especially in rural areas, and energy efficiency projects (Hunecke et al. 2019). A more robust standardisation and alignment of Power Purchase Agreement (PPA) terms with best practices globally has led to a substantially increased interest in capital markets in developing countries (WBCSD 2016; Schmidt et al. 2019; World Bank 2021). Notably, Power Purchase Agreement (PPA) significantly increases the probability of more balanced investment and development outcomes and ultimately more sustainable independent power projects in developing 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 investors' critical size. 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.

Economic viability of investments – ideally not relying on the pricing of positive externalities – has been a critical driver of momentum in the past. The falling technology costs and the competitiveness of renewable technologies, especially solar PV and wind, have accelerated the deployment of renewable technologies over the past years. renewable energy technologies now often competitive, even become the cheapest, in many countries, even without financial support, (FS-UNEP Centre and BNEF 2015, 2016, 2017, 2018, 2019; IEA 2020c; IRENA 2020a) 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 is often volatile 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 FiT in 2018 led to a significant drop in renewable investment and new capacity addition in China (FS-UNEP Centre and BNEF 2019; Hove 2020). However, the significant bouncing back of newly installed capacity (72 GW wind power and 47 GW solar power in 2020) shows the strong development of zero carbon power generation driven by lower cost and policies to support them by energy revolution strategies in China. 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 allowed industrialised countries to implement emission-reduction projects in developing countries to meet their emission targets (Michaelowa et al. 2019). However, the collapse of carbon markets and prices, especially of the EU ETS, led to the continuous decline of Certified Emission Reductions (CER) issuances from CDM in the past years (World Bank Group 2020). 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 2017b). For instance, energy-system developments require effective and credible commitments and action by policy-maker to ensure an efficient capital allocation aligned with climate targets (Bertram et al. 2021).

There are a lot of discussion about the regulated ownership of the private sector (European Commission 2017) and the restructuring of electricity market contributed to low level of investment in baseline electricity capacity and in investment research and innovation. This changes 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 (Finon 2006; Joskow 2007; Grubb and Newbery 2018). This is also the case in developing countries (Foster and Rana 2020).

The positive development in the energy sector has benefitted from the evident stand-alone character of renewable energy generation projects. First movers realised these projects with investors and developers acting from conviction (Steffen et al. 2018). Such action is not possible to this extent in 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 the benefits that improvement of energy efficiency has in contributing to curbing energy consumption, mitigating greenhouse gas emissions, and providing multiple co-benefits (IEA 2014a), investment in energy efficiency is at a low priority for firms, and the financial environment is not favourable due to lacking awareness of 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 models are 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. Each sector has different characteristics along the arguments listed above making the supply of finance by commercial investors an enabling factor or barrier. In the transport sector, transformation towards green mobility would provide significant co-benefits for human health by reducing transport-related air pollution, so the transport sector cannot achieve such transformation in isolation with other sectors. However, a considerable involvement of the public sector in many transportation infrastructure projects 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). Financial constraints, including access to adequate finance, pose a significant challenge in the agriculture sector, especially for SMEs and smallholder farmers. The distortion created by government failure and a lack of effective policies create barriers to financing for agriculture. 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 it difficult for financial institutions to reach agricultural SMEs and farmers and increases transaction costs (World Bank 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 the industrial manufacturing and residential sector, gaining energy efficiency remains one of the critical challenges. Investment in achieving energy efficiency encounters some challenges 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 robust financial market, awareness of financial institutions, and regulatory frameworks (e.g., stringent building codes, incentives for ESCOs) (IEA 2014a; Barnsley et al. 2015).

15.4.2 Quantitative assessment of financing needs

Multiple stakeholders prepare and present quantitative financing needs assessments with methodologies applied to vary significantly representing a major challenge for aggregation of needs (i.e. (Osama et al. 2021) for African countries), most of them with a focus on scenarios likely to limit warming to 2°C or lower. The differences relate to the scope of the assessments regarding sectors, regions and periods, top-down versus bottom-up approaches, and methodological issues around boundaries of climate-related investment needs, particularly full vs incremental costs and the exclusion or inclusion of consumer-level investments. Information on investment needs and financing options in NDCs mirror this challenge and is heavily heterogeneous (Zhang and Pan 2016).

In particular, for global approaches, modelling assumptions are often heavily standardised, focusing on technology costs. Only limited global analysis is available on incremental costs and investments, reflecting the reality of developing countries, also considering the interplay with significant infrastructure finance gaps, and can hardly serve as a robust basis for negotiations about international public climate finance. The focus on investment irrespective of uncertainty as well as other qualitative aspects of needs does not allow for a straightforward analysis of the need for public finance to leverage private sector financing and of the country heterogeneity in terms of investment risks and access to capital (Clark et al. 2018).

One source of uncertainty about the investment estimates for the power sector is the evolution of the levelized cost of technical options in the future for example the continuation of the observed declining trend of renewable energy (IRENA 2020b) which has been underestimated in many modelling exercises. The learning by doing processes and economies of scale might be at least partially outweighted, in all countries and more specifically in SIDS and other developing countries because of different risk factors, scales of installations, accessibility, and others (Lucas et al. 2015; van der Zwaan et al. 2018). These parameters, together with transaction costs/soft costs (see Section 15.5), financing costs and the level of technical competences need to be better represented in the future to represent the “climate investment trap” in many developing countries (IDB 2019). This “climate investment trap”, as flagged by (Ameli et al. 2021b) is created by existing and expected physical effects of climate change, higher financing costs and resulting lower investment levels in developing countries. Applying significantly standardised assumptions can consequently not provide robust insights for specific country groups. This will require progress in the spatiotemporal granularity of the models (Collins et al. 2016).

Another source of uncertainty about the financing needs is the interplays between a) the baseline economic growth rates, b) the link between economic growth and energy demand, including rebound effects of energy efficiency gains c) the evolution of microeconomic parameters such as fossil fuel prices, interest rates, currency exchange rates d) the level of integration between climate policies and sectoral policies and their efficacy and e) the impact of climate policies on growth and the capacity of fiscal and financial policies to offset their adverse effect (see (IPCC 2018) and AR5 (IPCC 2014, 2018)). Integrated assessment models (IAMs) try to capture some to these interplays even though they typically do not capture the financial constraints and the structural causes of the infrastructure investment gap. Many of them rely on growth models with full exploitation of the means of production (labour and capital). They nevertheless provide useful indications of the orders of magnitude at play over the long run, and the determinants of their uncertainty. Global yearly average low-carbon investment needs until 2030 for electricity, transportation, AFOLU and energy efficiency measures incl. industry and buildings are estimated between 3% and 6% of the world’s GDP according to the analysis in section 15.5. The incremental costs of low carbon options are less than that and their funding could be achieved without reducing global consumption by reallocating 1.4% to 3.9% of global savings, 2.4% on average (see Box 4.8 of (IPCC 2018)) currently flow towards real estate, land and liquid financial vehicles. For the short term decisions, the major information they give is the uncertainty range because this is an indicator of the risks decision-makers need.

While the IAMs database provides good transparency with regard to technology costs for electricity generation, assumptions driving in particular investments in energy efficiency are rarely made available in both, IAM based assessments but also other studies. Taking into account the much broader range of tested and untested technologies the confidence levels, in particular for 2050 estimates, remains low but can provide an initial indication. Also, the ranges allow for a rough indication on possible "green" investment volumes and respective asset allocation for financial sector stakeholders.

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 sub-sectors for scenarios likely to limit warming to 2°C or lower. These pathways explore the energy, land-use, and climate system interactions and thus help identify required energy sector transformations 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 (Bertram et al. 2021)(Ekholm et al. 2013; McCollum et al. 2018); and Box 4.8 in (IPCC 2018)). 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 system (see "Annex III: Scenarios and modelling methods" for details). Tables 15.2 and 15.3 focus on the near-term (2023–2032) investment requirements in the energy sector and how this differs depending on temperature category (Figure 3.36 and 3.37 in Chapter 3) presents the data for the medium-term (2023-2052)). The results highlight both requirements for increased investments and a shift from fossil towards renewable technologies and efficiency for more ambitious temperature categories. The substantial ranges within each category reflect multiple pathways, differentiated by socio-economic assumptions, technology etc. It is necessary to open up these extra dimensions and contrast them with national and sub-regional analysis to understand how investment requirements depend on particular circumstances and assumptions within a country for a specific technology. Limiting peak temperature to levels of 1.5°C–2°C requires rapid decarbonization of the global energy systems, with the fastest relative emission reductions occurring in the power generation sector (Hirth and Steckel 2016; Luderer et al. 2018).

Table 15.2 Global average yearly investments from 2023–2032 for Electricity supply in billion USD$_{2015}$.

Category	Fossil	Nuclear	Storage	T&D	Non-Biomass Renewables	Thereof Solar	Thereof Wind
C1	53 [50]	127 [52]	221 [39]	549 [50]	1190 [52]	498 [52]	390 [52]
(Range)	(34;115)	(85;165)	(88;295)	(422;787)	(688;1430)	(292;603)	(273;578)
C2	78 [100]	116 [92]	57 [66]	489 [81]	736 [96]	312 [96]	237 [96]
(Range)	(50;129)	(61;150)	(37;139)	(401;620)	(482;848)	(181;385)	(174;328)
C3	75 [221]	96 [190]	28 [129]	389 [157]	639 [207]	220 [207]	266 [207]
(Range)	(52;129)	(50;122)	(8;155)	(326;760)	(432;820)	(167;345)	(137;353)

Note: Global average yearly investments from 2023-2032 in USD$_{2015}$). Electricity subcomponents are not exhaustive, hydro, geothermal, biomass and others are not shown, as these are shown to be of smaller magnitude (Chapter 3). Difference between non-biomass renewables and solar/wind represents hydro and in some scenarios geothermal, tidal, and ocean. Scenarios are grouped into common AR6 categories (vertical axis, C1-C3). 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. C6, C7, and C8 not shown in Table 15.2. Reference C5 category for T&D is 364bn (294bn to 445bn) [111] used for calculation of incremental needs in Figure 4.

This requires fast shifts of investment as infrastructures in the power sector generally have long lifetimes of few decades. In the scenarios limiting warming to below 1.5°C, investments into non-biomass renewables (especially solar and wind, but also including hydro, geothermal, and others not shown in Table 15.2) increase to over 1 trillion USD yr^{-1} in 2030, increasing 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. While decreasing technology costs have substantially reduced the challenge of high capital intensity, still remaining relative disadvantages in terms of capital intensity of low-carbon power technologies can especially create obstacles for fast decarbonization in countries with high interest rates, which decrease the competitiveness of those technologies (Iyer et al. 2015; Hirth and Steckel 2016; Steckel and Jakob 2018; Schmidt et al. 2019). CCS as well as nuclear will not drive investment needs until 2030, given considerably longer lead-times for these technologies, and the lack of a significant project pipeline currently.

Table 15.3 Regional average yearly investments from 2023–2032 for Electricity supply in billion USD2015.

	Africa	East Asia	Europe	South Asia	Latin America	Middle East	North America	Asia-Pacific Developed	East. Eur. W.C. Asia	South East Aisa
Non-Biomass Renewables										
C1	41 [39]	302 [41]	130 [41]	120 [41]	69 [41]	67 [41]	177 [41]	37 [41]	48 [41]	85 [41]
(Range)	(36;66)	(188;356)	(101;150)	(83;164)	(55;97)	(31;90)	(149;222)	(28;39)	(35;65)	(59;141)
C2	32 [77]	179 [87]	95 [87]	69 [87]	55 [87]	28 [87]	106 [87]	19 [87]	17 [87]	63 [87]
(Range)	(27;42)	(124;255)	(64;104)	(35;84)	(27;73)	(19;43)	(73;134)	(12;29)	(10;37)	(35;78)
C3	17 [170]	166 [185]	91 [185]	53 [182]	53 [185]	22 [182]	119 [185]	22 [179]	15 [185]	38 [182]
(Range)	(12;47)	(108;200)	(42;118)	(35;80)	(25;81)	(11;32)	(71;167)	(12;30)	(11;30)	(22;67)
Thereof Solar										
C1	16 [39]	134 [41]	43 [41]	53 [41]	22 [41]	33 [41]	81 [41]	11 [41]	20 [41]	33 [41]
(Range)	(8;24)	(89;147)	(38;55)	(37;82)	(14;34)	(16;40)	(75;95)	(10;16)	(10;25)	(17;56)
C2	10 [77]	83 [87]	34 [87]	37 [87]	16 [87]	15 [82]	44 [87]	7 [80]	5 [81]	20 [87]
(Range)	(6;14)	(54;125)	(19;47)	(17;41)	(8;21)	(10;23)	(18;69)	(4;10)	(1;12)	(9;33)
C3	7 [170]	53 [185]	28 [184]	23 [182]	12 [184]	12 [164]	32 [185]	9 [157]	8 [164]	14 [182]
(Range)	(3;14)	(42;83)	(17;36)	(17;39)	(5;25)	(9;20)	(21;74)	(4;11)	(3;12)	(7;27)
Thereof Wind										
C1	10 [39]	133 [41]	59 [41]	45 [41]	19 [41]	22 [41]	58 [41]	20 [41]	17 [41]	28 [41]
(Range)	(4;30)	(86;164)	(29;86)	(23;71)	(15;26)	(13;39)	(44;122)	(12;25)	(10;23)	(17;52)
C2	5 [77]	63 [87]	41 [83]	23 [87]	15 [87]	8 [81]	31 [87]	8 [87]	4 [81]	19 [87]
(Range)	(4;14)	(44;102)	(9;59)	(14;30)	(7;18)	(3;16)	(19;75)	(5;12)	(2;12)	(6;23)
C3	3 [170]	64 [185]	59 [169]	21 [182]	12 [184]	10 [160]	52 [184]	10 [179]	4 [164]	10 [182]
(Range)	(2;15)	(40;93)	(12;65)	(12;37)	(7;22)	(5;13)	(19;86)	(6;13)	(2;10)	(5;32)
Storage										
C1	3 [27]	68 [32]	46 [32]	27 [32]	7 [29]	13 [30]	56 [30]	4 [32]	3 [24]	15 [30]
(Range)	(0;8)	(30;80)	(9;54)	(24;45)	(2;11)	(3;19)	(30;62)	(2;6)	(0;4)	(1;30)
C2	2 [36]	19 [60]	18 [52]	10 [57]	3 [42]	3 [31]	13 [44]	1 [43]	0 [20]	3 [41]
(Range)	(0;4)	(6;36)	(7;35)	(4;17)	(1;8)	(0;4)	(11;34)	(1;2)	(0;0)	(2;13)
C3	4 [78]	20 [106]	22 [92]	9 [107]	9 [85]	4 [78]	29 [81]	1 [90]	0 [78]	9 [83]
(Range)	(Range)	(Range)	(Range)	(Range)	(Range)	(Range)	(Range)	(Range)	(Range)	(Range)
Transmission and Distribution										
C1	24 [39]	147 [39]	67 [39]	51 [39]	40 [39]	27 [39]	87 [39]	16 [39]	24 [39]	64 [39]
(Range)	(13;39)	(96;250)	(61;105)	(46;97)	(29;62)	(22;40)	(70;120)	(13;19)	(18;35)	(26;94)
C2	24 [77]	132 [77]	60 [77]	49 [77]	36 [77]	33 [77]	70 [77]	14 [77]	26 [77]	36 [77]
(Range)	(14;30)	(84;175)	(48;79)	(43;56)	(28;45)	(27;37)	(53;92)	(8;19)	(17;34)	(28;61)

C3	14 [150]	93 [153]	61 [153]	46 [150]	26 [153]	25 [150]	70 [153]	14 [147]	23 [153]	26 [150]
(Range)	(10;37)	(74;190)	(52;86)	(38;86)	(21;62)	(17;40)	(52;90)	(11;16)	(17;27)	(17;87)
C5	13 [109]	81 [110]	55 [110]	41 [109]	25 [110]	23 [109]	58 [110]	14 [109]	23 [110]	25 [109]
(Range)	(9;13)	(67;160)	(46;59)	(22;46)	(19;28)	(15;28)	(51;67)	(12;16)	(16;26)	(17;29)

Note: Average yearly investments from 2023-2032 for Electricity generation capacity, by aggregate regions (in billion USD$_{2015}$). Further notes see Table 15.2. Reference C5 category for T&D shown in Table 2 as it is used for calculation of incremental needs for Figure 4. Vertical axis vertical axis, C4-C8 except T&D not shown. Reference C5 category for T&D shown because it is used for calculation of incremental needs for Figure 4.

What is apparent is that the bulk of investment requirements corresponds to medium- and low-income countries such as Asia, Latin America and the Middle East and Africa, as these still have growing energy demand and it is still considerably lower than the global average. This illustrates a vital opportunity to ensure the build-up of sustainable energy infrastructures in these regions and constitutes a risk of additional carbon lock-in if investments into fossil infrastructures, especially coal-fired power plants and uncontrolled urban expansion, continue.

Investment needs in electrification derived from IAMs do not include systematically investments in end-use equipment and distribution (See Box 4.8 in IPCC 1.5°C (IPCC 2018)). Model-based estimates of investment needs don't have the regional granularity to single out LDCs, as model regions typically are defined based on geographic proximity and therefore aggregate LDCs and other countries. With the average electricity consumption per capita in Africa increasing to 0.68-0.87 (1.43-2.92) MWh in 2030 (2050) yr-1 and remaining at the very low end of the global range [0.46 in Africa compared to the upper end of 12.02 in North America, MWh per capita and year in 2020], the targeted full electrification until 2030 appears unrealistic across all scenarios. SEforAll and IEA estimate assume investment needs to decentralised end-user electrification to come in around 40 billion USD on average until 2030 (SEforALL and CPI 2020; IEA 2021d).

Quantitative analysis of investment needs in energy generation based on IRENA and IEA data and comparison to AR6 scenario database output.

According to IRENA, the government plans in place today call for investing at least 95 trillion USD in energy systems over the coming three decades (2016–2050) (IRENA 2020c). Redirecting and increasing investments to ensure a climate-safe future (Transforming Energy Scenario) would require reaching on average around 1 USD trillion yr^{-1} (average until 2030) for electricity generation as well as grids and storage, increasing to above 2 USD trillion yr^{-1} (average until 2030) in the 1.5 scenario (IRENA 2021). IEA's respective SDS and NZE scenarios come in at average annual investments between 1.1 USD trillion yr^{-1} and 1.6 USD trillion yr^{-1} (average until 2030) (IEA 2021b). These additional data points for the C1 and C3 category underpin the range presented in the IAM database for needs until 2032 despite the slightly varying periods.

In contrast to the IAMs, IRENA and IEA assessments do not allow for an analysis of mitigation-driven investment needs in transmission and distribution which likely results in an overestimation of the mitigation driven investment needs in their analysis.

It is worth highlighting that driven by technology cost assumptions IRENA forecasts falling average annual investments needs for energy, but also energy efficiency, for the period 2030-2050 compared to 2020-2030. In the 1.5-S scenario the total annual investment needs excluding fossils and nuclear decrease from 5.0 trillion USD until 2030 yr^{-1} to 3.8 trillion USD yr^{-1} for 2030-2050 (IRENA 2021).In IAM scenarios of Category C1, Electricity supply investments (incl. generation, T&D, and storge) remain flat at 2.2 trillion USD yr^{-1} through the coming three decades in absolute terms. Given rising GDP, the complementary methods and sources thus consistently point to a peak in electricity supply investments as a percentage of GDP in mitigation scenarios in the coming decade. This reflects the fact that the coming decade requires low-carbon power generation investments to both cover the demand increase and (partly premature) replacement of fossil generation capacities, both concentrated in emerging and developing countries. Relative investment numbers for electricity measured against GDP then decrease towards 2050, as they only need to cover natural replacement and increasing demands (which due to electrification will also pick up in developed countries), and due to further declining technology costs. Investments for low-carbon fuel supply like hydrogen and synthetic fuels, and for direct electrification equipment (heat pumps, electric vehicles, etc.) scale up from much lower levels and will likely continue to grow as a share of GDP until mid-century, though uncertainties and accounting is still much more uncertain. (Bertram et al. 2021).

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.

Energy efficiency Estimates on energy investment needs vary significantly with a low level of transparency with regard to underlying technology cost assumptions burdening the confidence levels.

IRENA only selectively reports financing needs for EE in buildings and industry as separate categories. For the 1.5-S average yr^{-1} needs until 2050 come in at 963 billion USD for buildings, 102 billion USD for heat pumps, and 354 billion USD for industry. Applying the relative share of these categories on higher total needs until 2030, around 1.8 trillion USD yr^{-1} in buildings and 1.7 trillion USD yr^{-1} in industry are needed in the 1.5-S and TES scenario. For the TES total EE investment needs until 2030 are stated at 29 trillion USD translating into an yearly average of around 1.8 trillion USD yr^{-1}. IEA estimates come in at a much lower level at 0.6 and 0.8 billion USD yr^{-1} on average between 2026-2030 for their SDS and NZE scenarios.

Transportation 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 between 2015 and 2035. The assessment comprises road, rail and airports/ports infrastructure with only rail infrastructure being considered in our analysis amounting to 0.4 trillion USD on average until 2030.

On a regional level, (Oxford Economics 2017) shows, that annual infrastructure investments between 2016 and 2040 vary widely. For all available countries (n=50) estimates counts close to 0.4 trillion USD, including 0.2 trillion USD for China. Based on available data for 9 African countries, investments in rail infrastructure range from 0.1 billion USD in Senegal to 1.6 billion USD in Nigeria. (Osama et al. 2021) highlights a 4.7 billion USD financing gap for African countries in the transport sector. In Latin America the report identifies Brazil as frontrunner of required rail investments with 8.3 billion USD, followed by Peru with 2.3 billion USD. Totally, developed countries mounting up to 117 billion USD yr^{-1} (n=14, mean=8.35bn USD) for rail infrastructure funding needs, succeeded by developing countries (excl. LDCs) with 26 billion USD yr^{-1} (n=28, mean=0.93bn USD, excluding China).

Fisch-Romito and Guivarch (2019) show, by endogenizing the impact of urban infrastructure policies on mobility needs and modal choices that transportation investment needs globally might be lower in low-carbon pathways compared with baselines, with lower investments in road and air infrastructure. This does mean that higher investments are not needed over the following two decades; this means, this is confirmed by (Rozenberg and Fay 2019) that strong policy integration between urban, transportation and energy policies reduce the total investment gap..

IRENA as well as IEA have presented estimates for energy efficiency investments in the transport sector. For the 1.5-S scenario, IRENA indicates average investment needs of 0.2 trillion USD yr^{-1} for electric vehicle infrastructure, 0.2 trillion USD yr^{-1} for transport energy efficiency and 0.3 trillion USD yr^{-1} for EV batteries (IRENA 2020d) (average until 2030). IEA indicates a total of around 0.6 and 0.8 trillion USD yr^{-1} for transport energy efficiency in the SDS and IEA scenario for the 2026-2030 period (IEA 2021c). Many investment categories relating to mitigation options in particular with regard to behavioural change and transport mode changes (see Chapter 10, Figure SPM.8) are neglected in these analyses despite their significant mitigation potential.

AFOLU 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 300-350 billion USD. Considering the change in global diets as well as the land-based nature-based solutions only, annual investment needs would come in between 110–135 billion USD. Chapter 7 stresses the importance of opportunity costs for AFOLU mitigation options, in particular for afforestation projects [cross-reference], and derives average yearly investment needs of around 278 billion USD yr^{-1} until 2030 and 431 USD billion yr^{-1} in the next several decades, including opportunity costs. The estimate is based on an assumption of emission reductions consistent with pathways C1-C4, leading to average abatement of 9.1 $GtCO_2$ yr^{-1} (median range 6.7 – 12.3 $GtCO_2$ yr^{-1}) from 2020-2050 and marginal costs of 100 USD per ton CO_2, excluding investments in BECCS and changes in food consumption and food waste (see Section 7.4). The largest investments are projected to occur in Latin America, Southeast Asia, and Africa, constituting 61% of total expenditure. The implied change of land use might trigger negative effects on other SDGs which need to be addressed to offer robust safeguards and labelling for investors.

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 (Shakhovskoy et al. 2019). These numbers can only provide “an indication of the magnitude of the climate investments required in small-scale agriculture” (CPI 2020). The following table summarises the studies used as well as adjustments made to determine needs for the gap discussion in Section 15.5.2.

Table 15.4 Sector studies to determine average financing needs.

Sector	Studies	Global ranges tr USD yr^{-1} - *Confidence Level*		Regional breakdown		Comment
Energy	IAM database, SEforAll (SEforALL and CPI 2020), IRENA 1.5-S and TES scenarios (IRENA 2021), IEA SDS and NZE scenarios (IEA 2021b)	0.7-1.6	*High confidence*	Detailed breakdown for R10 possible for IAM database and applied to the derived range	*Medium confidence*	Wide ranges primarily driven by varying assumptions with regard to grid investments relating to the increased RE penetration.
Energy Efficiency	IRENA 1.5-S and TES scenarios, IEA SDS and NZE scenarios	0.6-1.8	*Medium confidence*	Adjustments required to regional categorization by IEA and IRENA	*Low-medium confidence*	Medium confidence levels due to missing transparency with regard to underlying assumptions on technology costs. Low-to-medium confidence level

						on regional allocations due to required adjustments.
Transport	OECD/IEA (OECD 2017b) and Oxford Economics (Oxford Economics 2017) on rail investment data, IRENA 1.5-S and TES scenarios, IEA SDS and NZE scenarios for transport (energy efficiency) and electrification	1.0-1.2	*Medium confidence*	Adjustments required to regional categorization by IEA and IRENA	*Low-medium confidence*	Needs including battery costs, not total costs, of EVs, likely underestimation of needs due to missing data points on rail infrastructure.
AFOLU	Chapter 7 analysis, Section 7.4; The Food and Land use Coalition (Shakhovskoy et al. 2019)	0.1-0.3	*High confidence*	Breakdown for R10 possible for chapter 7 analysis	*Medium confidence*	Upper end of range incl. opportunity costs as these likely increase costs of investment of land.

Note: Total range 2,4 trillion to 4.8 trillion USD yr^{-1}.

Adaptation financing needs.

Financing needs for adaptation are even more difficult to define than those of mitigation because mobilizing specific adaptation investments is only part of the challenge since ultimately improving societies' adaptive capacities depends on the SDGs' fulfilment (Hallegatte et al. 2016). Bridging the investment gap on irrigation, water supply, healthcare, energy access, and quality buildings is an essential enabling condition for adapting to climate change. The scenario analysis conducted by (Rozenberg and Fay 2019) show that fulfilling the SDGs to improve the adaptive capacity of low and middle income countries would require investments in water supply, sanitation, irrigation and flood protection that would account for about 0.5% of developing countries GDP in a baseline scenario to 1,85% and 1% with a strong and anticipatory policy integration (USD 664 billion and 351 billion on average by 2030).

Most studies choose to assess public sector projects ignoring household level investments as well as private sector adaptation (UNEP 2018; Buchner et al. 2019). UNEP 2016 Adaptation Gap Report estimates adaptation financing needs amounting to 140–300 billion USD yr^{-1} by 2030 and 280–500 billion USD yr^{-1} by 2050 (UNEP 2016, 2018, 2021). Over 100 countries included adaptation components in their intended NDCs (INDCs) and approximately 25% of these referenced national adaptation plans (NAPs) (GIZ 2017a) but estimates of the financing required for NAP processes is not available (NAP Global Network 2017). These NAPs, as formally agreed under the UNFCCC in 2010 are iterative, continuous processes that have multiple stages with a developmental phase that requires country specific financing of primarily packages domestic sources, grants, bond issuance or debt conversion (NDC Partnership 2020). At the same time, multilateral climate funds such as the Green Climate Fund and the GEF/LDCF offer ‘readiness and preparatory support’ and implementation for the NAPs and adaptation planning process (GCF 2020a; GEF 2021a,b). There has been no significant updating of adaptation cost estimates since (UNEP 2016, 2018). The Global Commission on Adaptation makes the case that investing USD 1.8 trillion in early warning system, climate resilient infrastructure, global mangrove and resilient water resources would generate about USD1.7 trillion in benefits due to avoided cost and non-monetary and social resources (Verkooijen 2019; UNEP 2021).

There is increasing recognition of rising adaptation challenges and associated costs within and across Developed countries. Undoubtedly many developed countries 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 (USGCRP 2018). Developed countries climate change adaptation spending covers areas such as federal insurance programmes, federal, state and local property and infrastructure, supply chains, water systems.

15.5 Considerations on financing gaps and drivers

15.5.1 Definitions

The analysis of financing gaps in climate action, which is used to measure implementation action and mitigation impact (FS-UNEP Centre and BNEF 2019) cannot be carried out as a pure demand-side challenge, in isolation from the analysis of barriers to deploy funds (e.g. (Ramlee and Berma 2013)) and to take investment initiatives. These barriers are friction that prevents socially optimal investments from being commercially attractive' (Druce et al. 2016). They are at the root of the "microeconomic paradox" of a deficit of infrastructure investments despite a real return between 4% and 8% (Bhattacharya et al., 2016), of the low share of carbon saving potentials tapped by dedicated policies such as energy renovation programmes (Ürge-Vorsatz et al. 2018), and, more generally of a demand for climate finance lower than the volume of economically viable projects(de Gouvello and Zelenko 2010; Timilsina et al. 2010)..

A few exercises tried and assess the consequences of the perpetuation of these drivers on the magnitude of the financing gap. They suggest, comparing the evolution of the infrastructure investment trends (beyond energy) by comparison with what they should be in an optimal scenario, a cumulative deficit between 15.9% in 2035 (Oxford Economics 2017) and 32% (Arezki et al. 2016). The volume of this gap is of the same order of magnitude than the incremental infrastructure investments (energy and beyond) for meeting a 1.5°C target, 2.4 % of the world GDP on average, (Box 4.8, IPCC 1.5°C 2018 (IPCC 2018)) calculated by exercises assuming no pre-existing investment gap. This figure is consistent with the 1.5% to 1.8% assessed by (European Commission 2020) for Europe and the 2% of the (IMF 2021d) for the G20 which do not encompass many developing countries of which economic take-off is today fossil fuels dependent. For low and middle income economies, (Rozenberg and Fay 2019) results suggest to increase the infrastructure investments by 2.5 to 6 percentage points of the GDP to cover both the reduction of the structural investment gap and the specific additional costs for bridging it with low carbon and climate resilient options. These assessments indicate the challenge at stake but do not exist at very disaggregated sectoral and regional levels for sectors other than energy.

The below quantitative analysis does not differentiate between financing gaps driven by barriers within or outside the financial sector given that the IAM models as well as most other studies used do not incorporate actual risk ranges depending on policy strength and coherence and institutional capacity, low-carbon-policy-risks, lack of long-term capital, cross-border currency fluctuation, and pre-investment costs and barriers within the financial sector that are discourage private sector funding. They comprise short-termism (e.g. (UNEP Inquiry 2016b)), 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 the quantitative analysis thus needs to be performed, taking into account the qualitative needs assessment in Section 15.4.1 and the evolution of parameters that determine the risk-weighted relative attractiveness low carbon and climate resilient investments compared to other investment opportunities. With some institutions having announced climate finance commitments and/or targets (see also Box 15.4 Measuring progress towards the 100 billion USD yr^{-1} by 2020 goal: issues of method), the actual asset allocation of commercial financial sector players 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 Identified financing gaps for sector and regions

The following section compares current climate finance flows as reported by CPI and IEA to needs derived in section 15.4 ignoring the slight mismatch in time horizons. The analysis ignores interlinked gaps in particular infrastructure investment gaps and other SDG-related investment gaps, which need to be addressed in parallel to reach the LTGG but also at least partially to facilitate green investments.

Total investments in mitigation need to increase by around 3 and 6 times with significant gaps existing across sectors and regions *(high confidence)*. The findings on still significant gaps and limited progress over the past few years to some extent seem to contradict the massive increase in commitments by financial institutions. As discussed in section 15.6 the investment gap is not due to global scarcity of funds.

However, these investment gaps 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 standardization, 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.

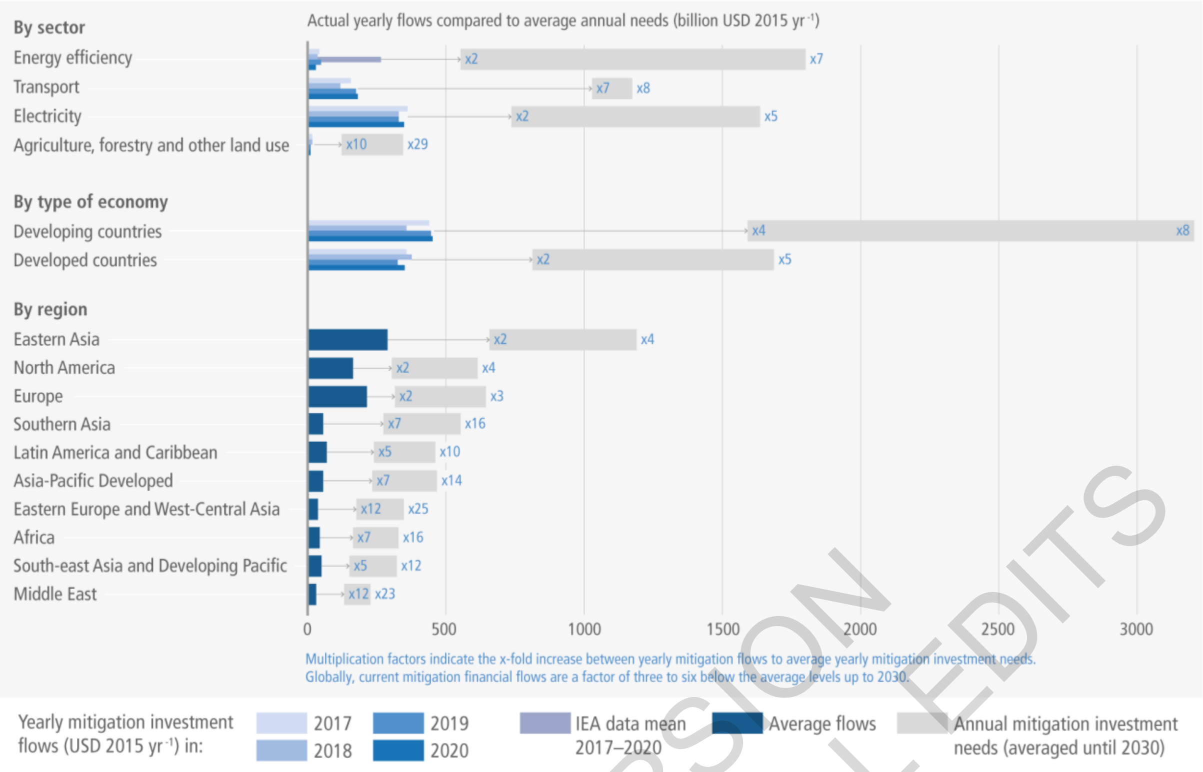


Figure 15.4 Breakdown of average investment flows and needs until 2030
Flows: Yearly CPI data for the *Agriculture and Forest*, *Electricity*, *Energy Efficiency*, and *Transport*. Adaptation pegged transactions are excluded. Technical assistance (i.e. Policy and national budget support or capacity building) and other non-technology deployment financing excluded from analysis. Small differences between sector and regional breakdowns due to non-regional/sectoral allocatable flows. In addition, 2017-2020 yearly average for IEA *End-use Energy Efficiency* are considered (WEI 2021). Minor adjustments to match IEA and IPCC regions applied based on CPI pro-rata allocation. Total Needs: See Table 15.4. Regional breakdown of needs: For *Electricity* based on IAM output for Non-Biomass renewable (mean C1:C3) plus incremental investment needs for T&D and Storage (mean C1:C3 less mean C5:C7) (see Table 15.2, 15.3., except C6 and C7). For *Energy Efficiency* based on IRENA Transforming Energy Scenario (TES) and adjusted to IPCC regional categories based on GDP. *Agriculture and Forestry* based on chapter 7.4 analysis and additional needs based on GDP. *Transport* investments for rail investment based on GIO rail investment needs per country and IRENA regional breakdown for total energy efficiency for needs for EV charging infrastructure, transport energy efficiency, and costs of batteries of EVs with adjustments to IPCC regional categories based on Energy Efficiency pro rata.

Sectoral considerations. The renewable energy sector attracted 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 2019; 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 (Pauw et al. 2016; Schletz et al. 2017). Still, the investment gap tends to remain stable with flows over the past years not showing an upward trend.

Comparing annual average total investments in global fuel supply and the power sector of approximately 1.61 trillion USD yr^{-1} in 2019 (IEA 2020a) 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 from fossil to renewables even more than the need to increase sector allocations (Granoff et al. 2016; McCollum et al. 2018).

Ensuring access to the heavily regulated electricity markets is a key driver for an accelerated private sector engagement (IFC 2016; FS-UNEP Centre and BNEF 2018; REN21 2019) 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, 2020). 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 (FS-UNEP Centre and BNEF 2019; IRENA 2020a). DFI climate portfolios tend to be driven by concessional loans for renewable energy generation assets with equity often being provided by (semi-) commercial investors (see Section 15.3) which will have to change to accelerate renewable energy investment activity.

Given the wide range of estimates on current investment flows into energy efficiency, substantial uncertainty exists with regard to the magnitude of the investment gaps. While CPI publishes investment levels of 44 billion in 2019 and 26 billion in 2020) for energy efficiency, counting majorly international flows, IEA results come in at a much higher level of more than annually 250bn USD between 2017 and 2020 (IEA 2021c) and (IRENA 2020c) estimates energy efficiency investments in buildings between 2017-2019 at an average of 139 bn USD yr^{-1}.

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. Provision of funding by capital markets for public transport infrastructure among others heavily depend on suitable financing vehicles and increased funding for development of projects with a low level of standardization (OECD, 2015a).

Both IRENA and IEA include only incremental costs of EVs in their estimates on needs while CPI, when measuring actual flows, includes those at full costs. Total private flows for EVs included in CPI numbers amount to 41bn USD in 2018 (Buchner et al. 2019), representing more than 80% of private sector finance into the transport sector around one third of total, public and private, funding to the transport sector in 2018. This likely results in an underestimation of the financing gap – in addition to the fact that estimates for investment needs for rail infrastructure are only available for selected countries.

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 (Buchner et al. 2019). A stronger focus on deforestation-free value chain, including a stronger reflection in taxonomies and financial sector investment decision processes are necessary to *ensure* an alignment of financial flows with the LTGG. Taking into account the specifics of land-based mitigation (in particular long investment horizons, strong dependency on the monetization of mitigation effects, strong public sector involvement) a significant scale-up of commercial funding to the sector can hardly be expected in absence of strong climate policies (Clark et al. 2018). Agriculture is likely to develop more potential to mobilise private finance than the 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. fertilizer subsidy) (Searchinger et al. 2020). 600 billion USD of annual governmental support for agriculture in the OECD database contributes only modestly to the related objectives of boosting crop yields and just transition (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).

Analysis by region and type of economy. The analysis of gaps by type of economy illustrates the challenge for developing countries. Estimated mitigation financing needs as percentage of current GDP (USD_{2015}) comes in at around 2-4% for developed countries, and around 5-10% for developing countries (see Figure 15.4) (*high confidence*). Climate finance flows have to increase by factor 4-8 in developing countries and 2-5 in developed countries. This disparity is further exacerbated when considering adaptation, infrastructure and SDG related investment needs (Hourcade et al. 2021a) (*high confidence*). However, differences across developing countries are significant. Flows to Eastern Asia, with its average flows of 269 billion USD being dominated by China (more than 95% of total mitigation flows to Eastern Asia), would have to increase by a factor of 2-4, a comparable level to developed countries. Section 15.6.2 elaborates on outlooks with regard to fiscal space and ability to tap capital markets, in particular for developing countries. In particular, 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 fuelwood for cooking and charcoal with impacts on deforestation) amid fast-rising urbanization 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. Notably, climate finance flows to African countries might have even decreased by about one fifth for mitigation technology deployment (stagnated for adaptation between 2017 and 2020), widening the finance gap in African countries in the recent years *(high confidence).*

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 (Osama et al. 2021). 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) and a strong need for robust institutional capacity to manage the transformation in a sustainable and human rights based way (Duyck et al. 2018). One example to consider unaddressed social concerns, is the ongoing call for feedback by the European Commission and its platform on sustainable finance. It argues for a social taxonomy, that can support the identification of financing opportunities of economic activities contributing to social objectives (European Commission 2021b). SEforAll has highlighted the issue of investments not going to the countries with the greatest need, also partly driven by institutional capacity levels (SEforALL and CPI 2020). 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 (UNFCCC 2017; DANIDA 2018). 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).

Early stage/Venture capital funding/Pilot project funding Early-stage companies in impact investment sectors with business solutions can contribute positively to climate impact. Figure SPM.8 highlights the need for new business models facilitating parts of the behavioural change. Also, SE4All has underpinned the need for an expansion of available business models to achieve universal access (SEforALL and CPI 2020). Further research and development needs range from resource efficiency of proven technologies and next generation technologies but also new technologies (see Chapter 16). Access to early stage funding remains critical with performance in in recent years being weak (Gaddy et al. 2016). This historically weak performance of clean tech start-ups burdens the interest of investors in the sector on the one hand and discourage experienced executive talent (Wang and Yee 2020). Besides that, the concentration of VC markets in the US, Europe and India represents a major challenge (FS-UNEP Centre and BNEF 2019; Statistica 2021). With regard to commercial-scale demonstration projects, IEA estimates a need of 90 USD billion of public sector funding before 2030 having around 25 billion USD already planned by governments to 2030 (IEA 2021c).

Need parallel rather than sequential investment decisions. The needs and gaps assessment does not include upstream investment needs required to facilitate the technology deployment as foreseen in the scenarios presented above. For example, for their transforming energy scenario IRENA estimates the number of EVs to increase from around 8m units in 2019 to 269m units in 2030 (IRENA 2020c). This would require investments in battery factories amounting to approximately 207 USD billion with further investment requirements in the value chain (IRENA 2020d). This illustrates the extent of parallel investments based on goals rather than concrete regulatory interventions and/or demand and poses a problem of up-front investment risks for each industry in the chain in the absence of certainty of the presence of parallel decisions in the upstream and downstream links in the chain. This is a typical element of the 'valley of the death' of innovation (Scherer et al. 2000; Åhman et al. 2017). It discourages risk-taking and slows-down the learning-by-doing processes, economies of scale and increasing returns to adoption needed for lowering the costs of systemic technical change (Kahouli-Brahmi 2009; Weiss et al. 2010). Implications on risk perception, financing costs as well as investment decision making processes and ultimately on feasibility are rarely considered.

Finance for adaptation and resilience. As explained early the reduction of the infrastructure gap to increase the societies' resilience and the implementation of the NAPs of will require more and higher levels of sustained financing. Activities mobilized for adaptation and resilience are often non marketable and their funding will continue coming from the public sector noted by (Murphy and Parry 2020) and, at the international level from grants based technical assistance or through budgetary support or basket funding for large projects/program or sector wide approaches or multilateral funding under (Non-)UNFCCC[2] 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. According to the UNFCCC, 'in 2015–2016, 3 per cent of international public adaptation finance flows was supplied by multilateral climate funds, while 84 per cent came from development finance institutions and 13 per cent from other government sources' (UNFCCC 2019c). Comprehensive reporting on adaptation finance by (Murphy and Parry 2020) and (Buchner et al. 2019) argues that flows of finance for adaptation action in developing countries in 2017 and 2018 were estimated to be approximately USD 30 billion; this plus an additional estimated flow of USD 12 billion for dual adaptation and mitigation actions totalled USD 42 billion accounting for 7.25% of the total estimated international public and private flows of climate finance (Buchner et al. 2019). They are far below the financing needs given in 15.4. To date, the private sector has limited involvement in NAPs

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FOOTNOTE[2] 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.

and adaptation projects and planning but can be involved through public-private partnership (discussed in section 15.6.2.1) and other incentives provided by governments (Schmidt-Traub and Sachs 2015; Koh et al. 2016; Druce et al. 2016; UNEP 2016; NAP Global Network 2017; Murphy and Parry 2020) and innovative private financing mechanisms such as green and blue bonds. However, adaptation financing is only about 2% of the share of green bond financing raised up to June 2019 (UNFCCC 2019c)[3] , whereas it is about 10% of sovereign green bonds raised (UNFCCC 2019d). (Tuhkanen 2020a), in a detailed review of green bond issuance in the Environmental Finance Data base 2019, found that between March 2010 to April 2019, '5% of all green bonds issued were categorized as adaptation and that 'the private sector accounts for a significant proportion of adaptation-related green bond issuances' (p.11). However, citing (GIZ 2017b; Nicol et al. 2017, 2018a) (Tuhkanen 2020b) highlights that there is scepticism about this stream of funding for adaptation due to the factors that has thus far limited the private sector's involvement in adaptation: lack of resilience-related revenue streams, the small-scale of some adaptation projects and the overall "intangibility" of funding adaptation projects,' (p.9). (Larsen et al. 2019)

Financing for resilience is limited 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 (ISDR 2009, 2011; Kellett and Peters 2014; 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).. 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 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 losses and damages from extreme events requires rapid pay-outs; 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 (Paul 2019; Serdeczny 2019).

15.6 Approaches to accelerate alignment of financial flows with long-term global goals

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

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[3] FOOTNOTE[3] According to climate bonds initiative, total green bond finance raised in 2018 was 168.5 billion USD across 44 countries (UNFCCC 2019c).

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 *(high confidence)*. 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.

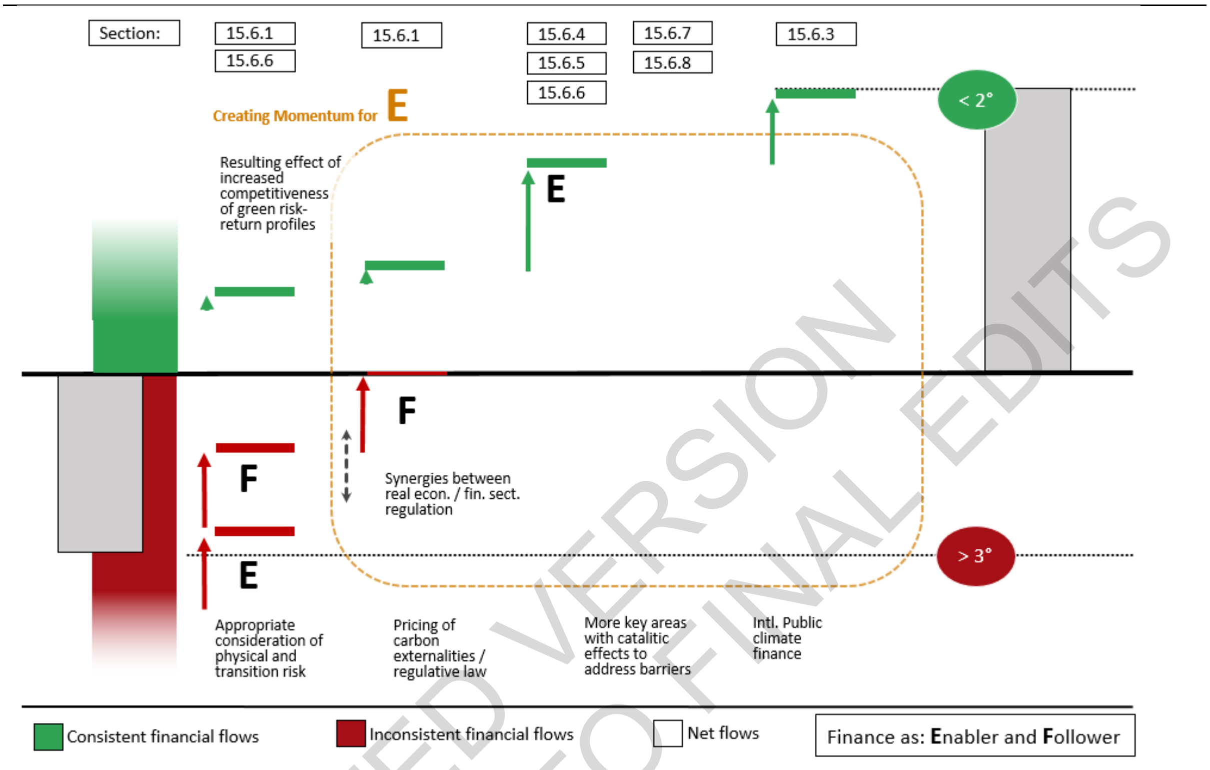

Figure 15.5 Visual abstract to address financing gaps in Section 15.6

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 financing (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 can explain that the current allocation of capital among financial institutions is often inconsistent with the mitigation objectives (Rempel et al. 2020). Moreover, even a correct assessment of risk, which could provide incentives for divesting from carbon-intensive activities, does not necessarily lead to investing in the technical options needed for deep decarbonisation. Therefore, understanding the dynamics of the low carbon transition require to fill in at the same time gaps about risk and gaps about investments in enabling activities in a broader sense.

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 *(high confidence)*. 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 *(high confidence)*. 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 refer 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? Should climate risk be explicitly accounted for in regulatory frameworks for financial institutions, such as Basel III for banks and national frameworks for insurance? 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.[4] 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

Assessment of physical risk. There is a literature on estimates of economic losses on physical assets (see respective chapter in WGII). Here we discuss some figures and mechanisms that are relevant for the financial system. Significant cost increases have been observed related to increases in frequency and magnitude of extreme events (see Section 15.4.2) *(high confidence)*. 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 (Mandel 2020), accounting in particular for the propagation of losses through financial networks, estimate global yearly GDP losses at 7.1% (1.13%) in 2080, without adaptation (with adaptation), the former corresponding to a 10-fold increase with respect to the current yearly losses (0.76% of global GDP). Finally, climate physical risk can

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[4] FOOTNOTE 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.

impact on the value of sovereign **bonds** (one of the top asset classes by size), in particular for vulnerable countries (Volz et al. 2020).

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. The indirect costs of climate-related flooding event can be up to 50% of the total costs, the majority of which is not covered by insurance (Alnes et al. 2018) (see chapter 15.6.4). The gap between total damage losses and insurance payouts has increased over the past 10 years (Swiss Re Institute 2019). Indeed, the probability of 'extreme but plausible' scenarios will be progressively revised upwards in the 'value at risk' (VaR). As a result it becomes more difficult to find financial actors willing to provide insurance as it was observed for real estate in relation to flood and wildfires in California (Ouazad and Kahn 2019). This progressive adjustment would keep the financial system safe (Climate-Related Market Risk Subcommittee 2020; Keenan and Bradt 2020), but transfer to taxpayers the onus of damage compensation and the funding of adaptation investments (OECD 2021c) as well as build up latent liabilities.

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 (Meinshausen et al. 2009; McGlade and Ekins 2015; Millar et al. 2017) *(high confidence)*. 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). In this context, a delayed deployment of climate funding and consequently limited alignment of investment activity with the Paris Agreement tend to strengthen carbon and thus to increase the magnitude of stranded assets.

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 2020)). 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; ECB 2019; EBA 2020; ESMA 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 *(high confidence)*.

Several financial super visors have conducted assessments of transition risk for the financial system at the regional level. 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).

Given the magnitude of the assets that are potentially exposed, reported in the previously cited studies, a delayed or uncoordinated transition risk can have implications for financial stability not only at the level of individual financial institutions, but also at the macro-level. The possible systemic nature of climate financial risk has been highlighted on the basis of general equilibrium economic analysis (Stern and Stiglitz 2021).

Some financial authorities recognize that Climate change represents a major source of systemic risk, particularly for banks with portfolios concentrated in certain economic sectors or geographical areas (de Guindos 2021). Specifically, the concern that central banks 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 in the financial supervisor community (Bolton et al. 2020). The systemic nature of climate risk is reinforced by the possible presence of moral hazard. Indeed, if many enough financial actors have an incentive to downplay climate-related financial risk, then systemic risk builds up in the financial system eventually materialising for tax payers (Climate-Related Market Risk Subcommittee 2020). While such type or risk may go undetected to standard market indicators for a while, it can materialise with a time delay, similarly to the developments observed in the run up of the 2008 financial crisis.

These considerations are part of an ongoing discussion on whether the current financial frameworks, including Basel III, should incorporate explicitly climate risk as a systemic risk. In particular, the challenges in quantifying the extent of climate risk, reviewed in this section, especially if risk is systemic, raise the question whether a combination of quantitative and qualitative restrictions on banks' portfolios could be put in place to limit the build-up of climate risks (Baranović et al. 2021).

Endogeneity of risk and multiplicity of scenarios. One fundamental challenge is that climate-related financial risk is endogenous *(high confidence)*. 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 scenario simplifies first of all those multiple scenarios are possible, and that which scenario is ultimately realised can depend on policy action. The coordination problem associated also with low-carbon investments opportunities increases the uncertainty. Further, not all low-carbon activities are directly functional to the transition (e.g. investments in pharmaceutical, IT companies, or financial intermediaries), thus not all reallocations of capital lead to the same path.

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) *(high confidence)*. 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 (Battiston et al. 2017; Monasterolo and Battiston 2020; Roncoroni et al. 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 *(high confidence)*. 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 2018a; Battiston et al. 2020b). In particular, IAMs solve for least cost pathways to an emissions target in 2100 (AR4 WGIII SPM Box 3), 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. 2018a); see also (Clarke et al. 2014)) *(high confidence)*. 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. 2021). An example is the transport sector, which uses around 50% of oil extracted (IEA 2018; Thomä 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 far before mid-century (Mercure et al. 2018b; Mercure et al. 2021). 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).

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 *(medium confidence)*. 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. 2018a).

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) *(high confidence)*. 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 2015, 2018; TCFD 2019). 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 (UNEP FI 2018; CDSB and SASB 2019). 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.

Illustrative mitigation pathways and financial risk for end-users of climate scenarios

Decision makers in financial risk management make increasingly use of climate policy scenarios, in line with the TCFD guidelines and the recommendations of the NGFS. In order to reduce the number of scenarios to consider, Illustrative Mitigation Pathways (IMPs, Chapter 3), have been elaborated to illustrate key features that characterise the possible climate (policy) futures. The following considerations can be useful for scenario end-users who carry out risk analyses on the basis of the scenarios described in Chapter 3. It is possible to associate climate policy scenarios with levels of physical and/or transition risk, but these are not provided with the scenario data themselves.

On the one hand, each scenario is associated with a warming path, which in turn, on the basis of the results from WGII, implies certain levels of physical risk (see WGII Chapter 16). However, climate impacts are not accounted for in the scenarios. Moreover, levels of risk may vary with the Reason for Concern (RFC, ibidem) and with the speed in the implementation of adaptation. On the other hand, while mitigation can come with transition risk, in the case of lack of coordination among the actors, as discussed earlier in this section, this is not modelled explicitly in the trajectories, since the financial sector is not represented in underlying models. The scientific state of the art in climate-related financial risk offers an analysis that is not yet comprehensive of both the physical and transition risk dimensions in the same quantitative framework. However, decision makers can follow a mixed approach where they can combine quantitative risk assessment for transition risk with more qualitative risk analysis related to physical risk.

Figure 15.6 represents sequences of events following along a scenario both in terms of physical risk (left) and transition risk (right). Four groups of IMPs (more are considered based on the warming level they lead to in 2100. Current Policies (CurPol) considers climate policies implemented in 2020 with only a gradual strengthening afterwards, leading to above 4°C warming (with respect to pre-industrial levels). Moderate Action (ModAct) explores the impact of implementing the NDCs (pledged mitigation targets) as formulated in 2020 and some further strengthening afterwards, leading to below 4°C, but above 3°C warming. In these two scenarios, there is no stabilization of temperature, meaning that further warming occurs after 2100 (and higher risk) even if stabilization could be eventually achieved. They are referred to as pathways with higher emissions. The warming levels reached along these two scenarios imply physical risk levels that are "Moderate" until 2050 and very high in 2050-2100 (with low levels of adaptation). Noting, that "Moderate" physical can mean for some countries (i.e. SIDS) significant and even hardly absorbable consequences (i.e. reaching hard adaptation limits). Transition risk is not relevant for these scenarios, since a transition is not pursued.

Illustrative Mitigation Pathways (IMP) include two groups of scenarios consistent with warming levels of *1.5°C* and < *2°C*, respectively. The two groups are representative for the IMPs defined in Chapter 3. In these scenarios, warming is stabilized before 2100. The warming levels along these paths imply "Moderate" physical risk until 2050 and "High" risk in 2050-2100 (with low levels of adaptation). Transition risk can arise along these trajectories from changes in expectations of economic actors about which of the scenarios is about to materialise. These changes imply, in turn, possible large variations in the financial valuation of securities and contracts, with losses on the portfolio of institutional investors and households. High policy credibility is key to avoid transition risk, by making expectations consistent early on with the scenario. Low credibility can delay the adjustment of expectations by several years, leading either to a late and sudden adjustment. However, if the policy never becomes credible, this changes the scenario since the initial target is not met.

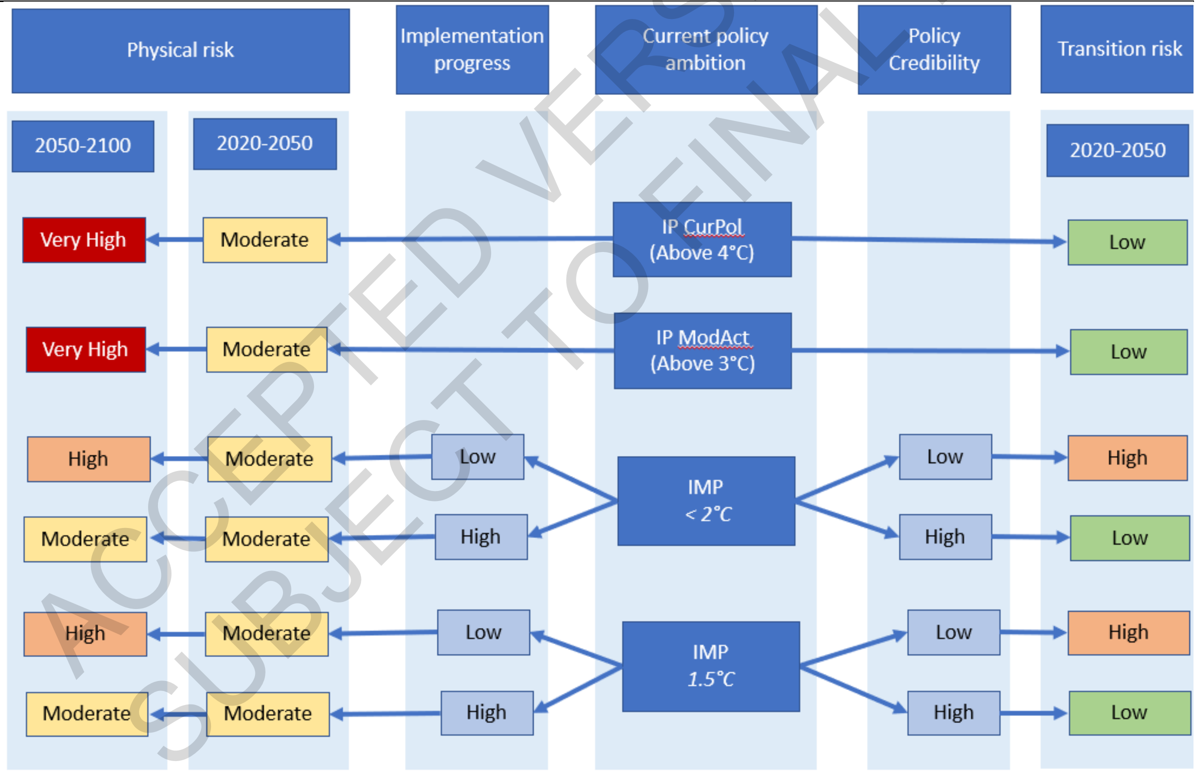


Figure 15.6 Schematic representation of climate scenarios in terms of both physical and transition risk. While the figure does not cover all possible events, it maps out how the combination of stated targets can lead to different paths in terms of risk, depending on implementation progress and policy credibility. IMP *1.5°C* and IMP < *2°C* are representative for IMP-GS (Sens. Neg; Ren), IMP-Neg, IMP-LD; IMP-Ren; IMP-SP. Note that the figure defines "High" progress as higher, but it is important that the physical risk varies by region and country. This means, that "Moderate" physical risk can be significant and even hardly absorbable for some countries.

15.6.2 Enabling environments

The Paris Agreement recognised for the first time the key role of aligning financial flows to climate goals. It further emphasises the importance of making financial flows to consistent with climate actions and SDGs (Zamarioli et al. 2021).This alignment has now to be operated in a specific environment where the scaling-up of climate policies is conditional upon their contribution to post-Covid recovery packages (see 15.2.2, 15.2.3 and Box 15.6). The enabling environments are to be established account for the structural parameters of the underinvestment on long-term assets. The persistent gap between the 'propensity to save' and 'propensity to invest' (Summers 2016) obstructs the scaling up of climate investments, and it results from a short-term bias of economic and financial decision making (Miles 1993; Bushee 2001; Black and Fraser 2002) that returns weighted on short-term risk dominate the investment horizon of financial actors. Overcoming this bias is the objective of an enabling environment apt to *launch of a self-reinforcing circle of trust* between project initiators, industry, institutional investors, the banking system, and governments.

The role of government is crucial for creating an enabling environment for climate (Clark 2018), and governments are critical in the launching and maintenance of this circle of trust by lowering the political, regulatory risks, macroeconomic and business risks (*high confidence*). The issue is not just to progressively enlarge the space of low-carbon investments but replacing one system (fossil fuels energy system) rapidly by another (low-carbon energy system). This is a wave of 'creative destruction' with the public support to developing new markets and new entrepreneurship and finance for green products and technologies in a context which requires strong complementarities between Schumpeterian (technological) and Keynesian (demand-related) policies (Dosi et al. 2017). However, it is challenging to overcome the constraint of public budget under the pressure of competing demands and of creditworthy constraints for countries that do not have an easy access to reserve currencies. It is needed to maximize, both at the national and international levels, the leverage ratio of public funds engaged in blended finance for climate change which is currently very low, especially in developing countries (Attridge and Engen 2019).

Transparency: 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) (*high confidence*). Organizations such as the Task Force on Climate-related Financial Disclosures (TCFD) can help increase capital markets' climate financing, including private sector, by providing financial markets with information to price climate-related risks and opportunities (TCFD 2020). However, risk disclosures alone would likely be insufficient (Christophers 2017) *(high confidence)*. Transparency can help but on its own as long as market failures that inhibit the emergence of low-carbon investment initiatives with positive risk-weighted returns (Ameli et al. 2020).

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 particularly in a post-COVID world *(high confidence)*. Instruments and institutional arrangements for better international monetary policy coordination will likely be necessary in the context of growing external debt stress and negative credit rating pressures facing both emerging and low-income countries. Central bankers have started examining the implications of disruptive risks of climate change, as part of their core mandate of managing the stability of the financial system (Chenet et al. 2021). Climate-related risk assessments and disclosure, including central banks' stress testing of climate change risks can be considered as a first step (Rudebusch 2019), although such risk assessments and disclosure may not be enough by themselves to spur increased institutional low-carbon climate finance (Ameli et al. 2020).

Green QE is now being examined as a tool for enabling climate investments (Dafermos et al. 2018) in which central banks could explicitly conduct a program of purchases of low-carbon assets (Aglietta et al. 2015). 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) *(medium confidence)*. Green QE would have positive effects for stimulating a low-carbon transition, such as accelerating the development of green bond markets (Hilmi et al. 2021), 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, 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).

Additional monetary policies and macroprudential financial regulation may facilitate the expected role of carbon pricing on boosting low-carbon investments (D'Orazio and Popoyan 2019) *(medium confidence)*. 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). This 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. 2021). Financial supervisors needs to implement stricter guidelines to overcome the greenwashing challenges (Caldecott 2020).

Efficient Financial Markets and Financial Regulation. An influential efficient financial markets hypothesis (Fama 1970, 1991, 1997) 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. Despite an increasing challenges to the theory (Sewell 2011), especially by repeated episodes of global financial crashes and crises, and other widely noted anomalies, a weaker form of the efficient markets hypothesis may still apply *(medium confidence)*. It is arguable that accumulating scientific evidence of climate impacts is being accompanied by rising levels of climate finance. Banks and institutional investors are also progressively rebalancing their investment portfolios away from fossil-fuels and towards 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 (Carney 2015; Dietz et al. 2016; Zenghelis and Stern 2016; Campiglio et al. 2018). However, disclosure requirements of risks and information in private settings remain mostly voluntary and difficult to implement (Battiston et al. 2017; Monasterolo et al. 2017).

Nevertheless, financial markets are innovating in search of solutions (see 15.6.6). 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.

Markets, finance and creative destruction. Branches of macro-innovation theory could be grouped into two principal classes (Mercure et al. 2016): '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. The latter suggests 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. The financial system is part of complex policy packages involving multiple instruments (cutting subsidies to fossil fuels, supporting clean energy innovation and diffusion, levelling the institutional playing field and making risks transparent) (Polzin 2017) and the needed big systemic push (Kern and Rogge 2016) requires it takes on the role of 'institutional innovation intermediaries' (Polzin et al. 2016).

As far as climate finance is concerned, public R&D support had large cross-border knowledge spill-overs 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 (Grafström and Lindman 2017) (see box 16.4 for further findings of public R&D on energy technologies). The FiTs program has been associated with rapid increase in early renewables capacity expansion across the world by reducing market risks in financing and stability in project revenues (Menanteau et al. 2003; Jacobsson et al. 2009). (see Chapter 9.9.5). Competitive auctions that the successful bidder with the lowest price or other criteria is selected for government's call for tender are increasing being utilised as an alternative to FITs due their strengths of flexibility, potential for real price discovery, ability to ensure greater certainty in price and quantity and capability to guarantee commitments and transparency (IRENA and CEM 2015).

Outside of RE, scattered but numerous examples are available on the role of innovative public policy to spur and create new markets and technologies (Arent et al. 2017): i) pro-active role of the state in energy transitions (the retirement of all coal-fired power plants in Ontario, Canada between 2007 and 2014 (Kern and Rogge 2016; Sovacool 2016), ii) Too early exit and design problems not considering the market acceptability and financing issues (e.g., energy-efficient retrofitting in housing in UK (Rosenow and Eyre 2016), low or negative returns in reality versus engineering estimates in weatherisation programs in US (Fowlie et al. 2018)), iii) Energy performance contracting for sharing the business risks and profits and improving energy efficiency (Energy service company (Bertoldi and Boza-Kiss 2017; Qin et al. 2017) and Utility Energy Service Contracts in the US (Clark 2018)).

Crowding out. Literature has discussed the risks of a low effectiveness of public interventions and of a crowding out effects of climate targeted public support to other innovation sectors (Buchner et al. 2013). However, much academic literature suggests no strong evidence of crowding out. (Deleidi et al. 2020). Examining the effect of public investment on private investment into renewables in 17 countries over 2004-2014, showed that the concept of crowding out or in does not apply well to sectoral studies and found that public investments positively support private investments in general.

Support of climate action via carbon pricing, taxes, and emission trading systems. Literature and evidence suggest that futures markets regarding climate are incomplete because they do not price in externalities (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) *(high confidence)*. 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 *(high confidence)*. The reallocation of revenues from carbon taxes can be used for low-carbon investments, supporting poorer sections of society and fostering technological change (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. 2021). (see Chapter 9.9.3 for carbon taxes). The effectiveness of carbon pricing has been supported by various evidences. EU ETS has been cut the emissions by 42.8% in the main sectors covered (European Commission 2021a), and China had achieved emissions reductions and energy conservations through its pilot ETS between 2013 and 2015 (Hu et al. 2020; Zhang et al. 2019). Institutional learning, administrative prudence, appropriate carbon revenue management and stakeholder engagement are key ingredients for successful ETS regimes (Narassimhan et al. 2018).

The presence of carbon prices 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). The expansion of carbon prices is dependent on country-specific fiscal and social policies to hedge against regressive impacts on welfare, competitiveness, and employment (Michaelowa et al. 2018). Such impacts need to be offset using the proceeds of carbon taxes or auctioned emission allowances to reduce distortive taxation (Bovenberg and de Mooij 1994; Goulder 1995; de Mooij 2000; Chiroleu-Assouline and Fodha 2014) and fund compensating measures for the population sections that are most adversely impacted (Combet et al. 2010; Jaccard 2012; Klenert et al. 2018). This is more difficult for developing countries with a large share of energy-intensive activities, fossil fuels exporting countries and countries which have lower potential to mitigate impacts due to lower wages or existing taxes (Lefèvre et al. 2018).

Non-carbon price instruments, such as market-oriented regulation, public programs involving low carbon infrastructure, may be preferential in developing countries where market and regulatory failure and political economy constraints are more prevalent (Finon 2019). . 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 financing sources. Efforts to address climate change can be scaled up through the mobilisation of domestic funds (Fonta et al. 2018). Publicly organised and supported low-carbon infrastructures through resurrected national development banks may be justified (Mazzucato and Penna 2016). It is important to efficiently allocate the public financing, and SIBs can take up key roles (i) to provide capital to assist with overcoming financial barriers, (ii) to signal and direct investments towards green projects, and (iii) to attract the private investors by taking up a de-risking role. Also, they can become a first mover by investing in new and innovative technologies or business models (Geddes et al. 2018). State owned enterprises (SOEs) can also have an overall positive effect on renewables investments, outweighing any effect of crowding out private competitors (Prag et al. 2018). Green investment banks (GIB) can assist in the green transition by developing valuable expertise in implementing effective public interventions to overcome investment barriers and mobilise private investment in infrastructure (OECD 2015c). De-risking measures may reduce investment risks, but lacking research and data availability hinders designing such measures (Dietz et al. 2016). Local governments efforts to de-risk by securitization might have negative effects by narrowing the scope for a green developmental state and encouraging privatisation of public services (Gabor 2019).

The potential role of coordinated multilateral initiatives. There is a growing awareness of the low leverage ratio of public to private capital in climate blended finance (Blended Finance Taskforce 2018b) and of a glass ceiling', caused by a mix of agencies' inertia and perceived loss of control over the use of funds, on the use of public guarantees by MDBs to increase it (Gropp et al. 2014; Schiff and Dithrich 2017; Lee et al. 2018) (*high confidence*). Many proposals have emerged for multilateral guarantee funds: Green Infrastructure Funds (de Gouvello and Zelenko 2010; Studart and Gallagher 2015), Multilateral Investment Guarantee Agency (Enhanced Green MIGA) (Déau and Touati 2018), guarantee funds to bridge the infrastructure investment gap (Arezki et al. 2016), and multi-sovereign guarantee mechanisms (Dasgupta et al. 2019). The obstacle of limited fiscal space for economic recovery and climate actions in low-income and some emerging economies can be overcome only in a multilateral setting. Several multilateral actions are being envisaged: G20's suspension of official bilateral debt payments, IMF's adoption of new SDRs allocation (IMF 2021b). However, any form of unconventional debt relief will generate development and climate benefits only if they credibly target bridging the countries' infrastructure gap with low-carbon climate-resilient options.

An interest of multilateral setting is a credibility-enhancing effect provided by reciprocal gains for both the donor and the host country. Guarantor countries can compensate the public cost of their commitments with the fiscal revenues of induced exports. As to the host countries, they would benefit from new capital inflows and the grant equivalents of reduced debt service which might potentially go far beyond 100 billion USD yr^{-1} (Hourcade et al. 2021a). A second interest would be to support a learning process about agreed-upon assessment and monitoring methods using clear metrics. Developing standardized and science-based assessment methods at low transaction costs is essential to strengthen the credibility of green investments and the emergence a pipeline of high-quality bankable projects which can be capitalized in the form of credible assets and supported with transparent and credible domestic spending. Multi-sovereign guarantees would provide a quality backing to developing countries and allow for expanding developing countries' access to capital markets at a lower cost and longer maturities, overcome the Basel III's liquidity impediment and the EU's Solvency II directive on liquidity (Blended Finance Taskforce 2018b), accelerate the recognition of climate assets by investors seeking safe investments havens (Hourcade et al. 2021b). It would also strengthen the efficacy of climate disclosure through high grades climate assets and minimize the risks of 'greening' of the portfolios by investing in 'carbon neutral' activities and not in low carbon infrastructures. Finally, it would free up grant capacities for SDGs and adaptation that mostly involve non-marketable activities by crowding in private investments for marketable mitigation activities.

***** START BOX 15.5 ******

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

A widely used indicator for the relative attractiveness of renewable energy but also development of price levels is the levelized 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 the indicator sole of 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 and 0.35 USD/kWh with a global weighted average of 0.085 USD/kWh. However, comparative analysis taking into account societal costs are hardly available driven by challenges in the context of the quantification of public support.

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

(Egli 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).

***** END BOX 15.5 ******

15.6.2.1 The public-private and mobilization narrative and current initiatives

Financing 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. Many development and climate projects in developing and emerging countries have traditionally been supported with concessional loans by DFIs/IFIs. 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. MDBs and IFIs were crucial for opening and growth in the early years of the green bonds, which represent a substantial share of issuances (CBI 2019a). Drivers of an efficient private sector involvement are stronger incentives to have projects delivered on time and in budget as well as market competition (Hodge et al. 2018). It remains key that the private sector mobilization goes hand in hand with institutional capacity building as well as strong sectoral development in the host country as a strong, knowledgeable public partner with the ability to manage the private sector is a dominating success factor for public-private cooperation (WEF 2013; Yescombe 2017; Hodge et al. 2018).

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

Public guarantees have been increasingly proposed to expand climate finance, especially from the private sector, with scarce public finance, by reducing the risk premium of the low-carbon investment opportunities (de Gouvello and Zelenko 2010; Emin et al. 2014; Studart and Gallagher 2015; Schiff and Dithrich 2017; Lee et al. 2018; Steckel and Jakob 2018). They have the advantage of a broad coverage including the 'macro' country risks and to tackle the up-front risks, during the preparation, bidding and development phases of the project life cycle that deter projects initiators especially for capital intensive and immature options. Insurances are also powerful de-risking instruments (Déau and Touati 2018) but they entitle the issuer to review claims concerning events and cannot cope with up-front costs. Contractual arrangements like power purchase agreements are powerful instruments to reduce market risks through a guaranteed price but they weigh on public budgets. Risk-sharing that bring together public agencies, firms, local authorities, private corporates, professional cooperatives, and institutional financiers can reduce costs (UNEP 2011), and support the deployment of innovative business models (Déau and Touati 2018). Combined with emission taxes they can contribute to reducing credit rationing of immature and risky low-carbon technologies (Haas and Kempa 2020).

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 *(high confidence)*. Using IMF data for stimulus packages, (Andrijevic et al. 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 (Andrijevic et al. 2020; Vivid Economics 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 *(high confidence)*. 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 (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 costs 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 *(high confidence)*. A similar plan has also been proposed by the US administration and the European Union through the Next Generation EU (European Council 2020).

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 *(high confidence)*. In more debt constrained developing 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).

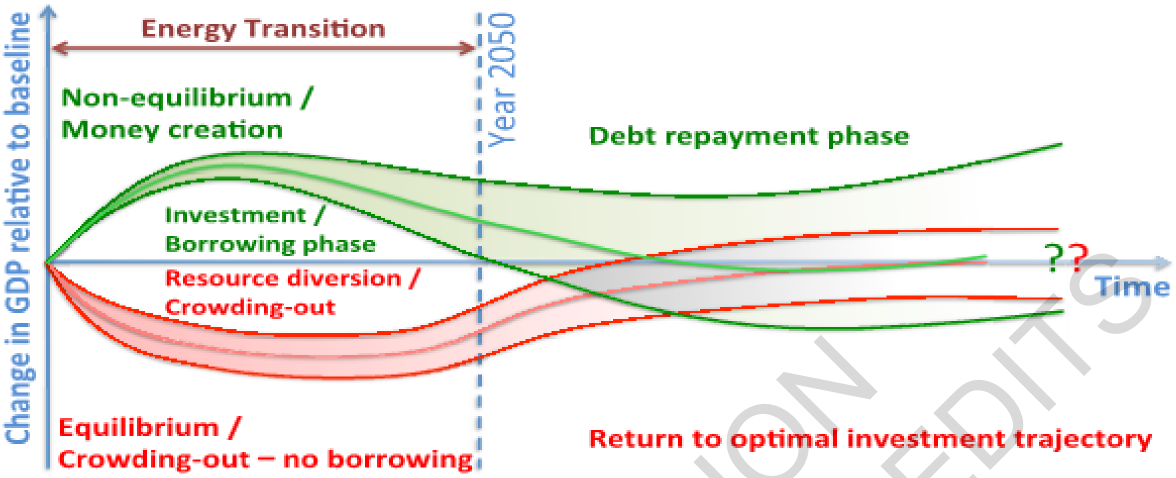
Second, a strong assumption is that voters will be politically supportive of extended and increased fiscal deficit spending on climate on top of COVID-19 related emergency spending and governments will overcome treasury biases towards fiscal conservatism (to preserve credit ratings). However, evidence 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) *(high confidence)*. 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 flows are not yet clear since current additional funding prioritises urgent 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.

***** START BOX 15.6 ******

Box 15.6 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 *(high confidence)*. 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 (Balint et al. 2016; Nordhaus 2018). 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 2018b). 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).

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. 2020b). The expected results are opposite to the standard supply-led equilibrium models as a response to investment stimulus (the green-shaded part of Box 15.6, Figure 1), as intended by 'green-stimulus' packages such as proposed by the EU (Balint et al. 2016; Mercure et al. 2019).



Box 15.6, Figure 1 Two Worlds – Energy transition outcomes under alternative model assumptions (Keynesian vs General Equilibrium) Source: Mercure et al. (2019)

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. The results of recent macroeconomic modelling work (Liu et al. 2021) represented by 10 major countries/regions suggests answers. It uses a non-standard macroeconomic framework, with Keynesian features such as financial and labour market rigidities and fiscal and monetary rules (McKibbin and Wilcoxen 2013). 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 15.6, 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.

Substantial effects of the COVID-19 pandemic, which is relatively unique on its public health impacts when combined with the consequences of deep economy-wide shocks (economic downturn, public finances, and debt), are expected to last for decades even in the absence of no significant future recurrence. A scenario where the pandemic recurs mildly every year for the foreseeable future further hinders GDP and investment recovery, where growth is unlikely to rebound to previous trajectories, even within OECD economies (McKibbin and Vines 2020) and with worse effects in developing regions. History is strongly supportive: studies on the longevity of pandemics' impacts indicate significant macroeconomic effects persisting for decades, with depressed real rates of return, increased precautionary savings (Jordà et al. 2020), unemployment (Rodríguez-Caballero and Vera-Valdés 2020) and social unrest (Barrett and Chen 2021). The direct effect on emissions is likely to be a small reduction from previous trajectories, but the longer-lasting impacts are more on the macroeconomic-finance side. Pandemic responses have increased sovereign debt across countries in all income bands (IMF 2021e). However, its sharp increase in most developing economies and regions has caused debt distress (Bulow et al. 2021), widening the gap in developing countries' access to capital (Hourcade et al. 2021b). While strong coordinated international recovery strategies with climate-compatible economic stimulus is justified (Pollitt et al. 2021; Barbier 2020; Barbier and Burgess 2020; Le Quéré et al. 2021; IMF 2020c), national recovery packages announced do not show substantial alignment with climate goals (Shan et al. 2021; Rochedo et al. 2021; D'Orazio 2021; Hourcade et al. 2021b). Contradictory post-COVID-19 investments in fossil fuel-based infrastructure may create new carbon lock-ins, which would either hinder climate targets or create stranded assets (Hepburn et al. 2020a; Le Quéré et al. 2021; Shan et al. 2021), whilst deepening global inequalities (Hourcade et al. 2021b).

***** END BOX 15.6 ******

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. 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 *(high confidence)*. The level of climate alignment of debt is hardly considered in debt related regulation and/or debt sustainability agreements like the Maastricht Treaty ceilings (3% of GDP government deficit and 60% of GDP (gross) government debt) 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. (BCG 2018; McKinsey 2020a) *(high confidence)*. With many studies underpinning the strong economic rationale for high investments in the short-term e.g.(McKinsey 2020a) [More studies to be added], 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 *(high confidence)*. 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 needed (Acevedo 2016) [Check for cross-referencing to WG1]. 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; Mallucci 2020). While climate change considerations have already impacted country ratings and debt sustainability assessments (and financing costs), it is unclear whether current GDP forecasts are realistic. 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 *(high confidence)*. 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 space further shrinks their ability to actively steer the required transformation (Buhr et al. 2018). Limited progress in increasing debt transparency remains another burden (see Section 15.6.7).

Considering the need for responses to both, short-term liquidity issues and long-term fiscal space, current G20/IMF/World Bank debt service suspension initiatives are focused the liquidity issue rather 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 bilateral and 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 swaps, 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 "hurricane" clause introduced by Grenada, or wider natural disaster clauses provide issuers with an option to defer payments of interest and principal in the event of a qualifying natural disaster and can reduce short-term debt stress (UN AAAA Art. 102) (UN 2015a). A mainstreaming of such clauses has been pushed by various international institutions. 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.

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 *(high confidence)*.

An increasing number of debt-for-climate/nature swaps have been seen in recent years applied primarily in international climate cooperation and in bilateral contexts, however, not (yet) to an extent addressing severe and acute debt crises (Essers et al. 2021; Volz et al. 2021) offering significant potential if used correctly (Warland and Michaelowa 2015). Significant lead times, needs-based structuring, transparency with regard to the additionality of financed climate action, uncertainty with regard to own resource constraints and ODA accountability remain as barrier for a massive scale-up needed to make transactions relevant (Mitchell 2015; Fuller et al. 2018; Essers et al. 2021). 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).

Ensuring efficient debt restructuring and debt relief in events of extreme shocks and imminent over-indebtedness and sovereign debt default are further crucial elements with a joint responsibility of debtors and creditors (UN 2015a) 2015). 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) and the UN AAAA raising concerns about non-cooperative creditors and disruption of timely completion of debt restructuring (UN 2015a) 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 (see also 15.6.7).

Stranded assets. The debate around stranded assets focuses strongly on the loss of value to financial assets for investors (see Section 15.6.1, para. on the assessment of transition risk and carbon stranded assets), 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 payers" (EEAC 2016) *(high confidence)*. 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 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 untransparent.

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 *(high confidence)*. 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**).** Despite a significant share of fossil resources which need to become stranded in developing countries to reach the LTGG, REDD+ remains a singular example for international financial cooperation in the context of compensation for stranded resources. [Potentially add sentence on ADB buyout facility]

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 4,210 billion USD, 2000-2018 (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 EUR. For the EEA member countries (EEA-33), the 'total reported economic losses caused by weather and climate-related extremes' over the same period amounted to approximately 453 billion EUR (EEA 2019), (EEA 2019). Asia Pacific and Oceania 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 (inclusive of loss by private insurers and government sponsored programs (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). Similarly, Latin America countries, such as Argentina, El Salvador and Guatemala, experienced severe losses in agriculture totalling about 6 billion USD due to drought in 2018 (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, insurance can help to cover immediate needs directly, provide rapid response and transfer financial risk in times of extreme crisis (GIZ 2015; Lucas 2015; Schoenmaker and Zachmann 2015; Hermann et al. 2016; Wolfrom and Yokoi-Arai 2016; Kreft and Schäfer 2017; UNESCAP 2017; Matias et al. 2018; UNECA 2018; Broberg and Hovani-Bue 2019; EEA 2019; Martinez-diaz et al. 2019) *(high confidence)*. 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 may be but a starting point given the likely need for upward adjustment due to climate change and potential consequential economic damage. Different risk perceptions between policyholders and insurers will create contrary assessments on premium levels and consequently underinsurance. (McKinsey 2020b) also stresses the systemic effect of climate change on insurers' business models and resulting availability of appropriate insurance products.

The conventional 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 decades, there have been a trend towards weather-index insurance and other parametric insurance products based on predefined pay-out risk pooling instrument. It has gained favour with governments in developing regions such as Africa, the Caribbean and the Pacific because it provides certainty and predictability about funding - financial preparedness - for emergency actions and initial reconstruction and reduces moral hazard. This 'financial resilience' is also increasingly appealing to the business sector, particularly MSMEs, in developing countries (MEFIN Network and GI RFPI Asia 2016; Woods 2016; Schaer and Kuruppu 2018).

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 the Foreign, Commonwealth & Development Office (FCDO, formerly 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 is relatively advantageous when compared to conventional insurance because of the effective subsidizing of 'affected regions' using revenues from unaffected regions which involve pooling among a large subset of countries (Lucas 2015) *(high confidence)*. 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 2015). The World Bank argues that the experience with Pacific Catastrophe Risk Insurance Pilot (PCRIP) and Africa Risk Capacity risk pooling (ARC) show saving of 50% in obtaining insurance cover for pooled risk compared with purchasing comparable coverage individually (Lucas 2015; World Bank 2015; ARC 2016). However, it requires, as noted by UNESCAP, 'extensive coordination across participating countries, and entities' (Lucas 2015).

At the same time, this approach has substantial basis risk, (actual losses do not equal financial compensation) (Hermann et al. 2016) *(high confidence)*. With parametric insurance, 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 *(high confidence)*. The best-known example is the Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC 2018), which involves cooperation among Caribbean states, Japan, Canada, UK and France and international organizations such as World Bank (UNESCAP 2017). But there are growing platforms of such an approach mainly under the umbrella of the G7's InsuResilience Initative (Deutsche Klimafinanzierung 2020), including, the Pacific Catastrophe Risk Assessment and Financing Initiative) for the Pacific Islands, the African Risk Capacity (ARC Agency and its financial affiliate), and the African Risk Capacity Limited (ARC Ltd/ the ARC Group) (ARC 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), (SEADRIF 2018; GIZ and World Bank 2019; Martinez-diaz et al. 2019; Vyas et al. 2019; World Bank 2019a). The group of 20 vulnerable countries (V-20) has also developed a Sustainable Insurance Facility (SIF), billed as technical assistance facility for climate-smart[5] insurance for MSMEs in 48 developing countries as well as potentially to de-risk renewable energy in these countries and regions (ACT Alliance 2020; V20 2020, 2021).

However, as noted above, climate risk pooling is not a panacea. There are very obvious and significant challenges. According to (Kreft and Schäfer 2017), limitations of insurance schemes, include coordination challenges, limited scope, de-stabilization due to exit of one or more members as premiums risk and inadequate attention to permanent (Schaeffer et al. 2014). There are also challenges with risk diversification, replication, and scalability *(high confidence)*. For example, CCRIF is extending both its membership and diversifying its geographic dimensions into Central America in seeking to lower covariate risk (similar shocks among cohorts such as droughts or floods). Under the SPC portfolio, CCRIF is able to segregate risk across the regions. 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. Only recently (July 2019) has CCRIF initiated coverage of fisheries with the development of its he Caribbean Oceans and Aquaculture Sustainability Facility (COAST) instrument (CCRIF SPC 2019; ACT Alliance 2020). Historically, risk pool mechanisms, like

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FOOTNOTE[5] According to the V20, 'the term "climate-smart" captures the need for two types of climate-related insurance products for MSMEs in vulnerable economies: (1) Climate risk insurance (2) Insurance products which enable low carbon investments, and thereby contribute to increased efficiencies through cost-savings from cheaper low-carbon technologies (2021).

CCRIF and ARC, only cover a small subset of perils, such as tropical cyclone, earthquake and excess rainfall but do not include other perils such as drought. Since 2016, ARC has increased its scope to cover drought and in 2019 launched ARC Replica which not only covers drought but offers premiums and coverage to NGOs and the World Food Programme through the START Network and a pastoral drought product for protecting small farmers and ensuring food security. 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 conventional 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' especially if it addresses the major gaps in climate risk insurance for poor and vulnerable communities by enhancing demand through 'smart support instrument' for premium support such as full or partial premium subsidies and investment in providing risk reduction (Schäfer et al. 2016; Le Quesne et al. 2017; MCII 2018; Vyas et al. 2019). This it is argued may help to smoothen out the limited uptake of regional institutions such as ARC, CCRIF SPC which are osnly in three regions of the world (with missing mechanism in South America). (Kreft and Schäfer 2017). Existing regional mechanisms, while they may perform very well, only cover a portion of climatic hazards and tend to have limited subscribers. For example, across the key four sovereign risk pools (ARC, CRIFSPC, PCRAFI and SEADRIF), though there are 68 countries only 1/3 or 32% have purchased coverage in 2019 and 46% 'did not deploy disaster risk financing instruments (ACT Alliance 2020).

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 incentivization of risk reduction *(high confidence)*. Here, they recognise the work of ARC's Africa Risk Capacity 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).

In the literature, there are two attempts at systematic evaluation or comprehensive assessment of regional climate risk pools. A comprehensive study by (Scherer 2017) and FCDO ten-year evaluation (2015-2024). Overall, none of these studies draw adverse conclusions about regional climate risk pooling initiatives/mechanisms. According to Scherer 'it appears that insurances work in principle and there is certainly successes' and 'initial experiences demonstrate regional climate risk insurances works'. The author cited the 28 pay-outs to 16 countries of 106 million USD arguing that it provides cash-starved countries with much needed cash (Scherer 2017, p. 4). The FCDO study examines the uptake of ARC 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, 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. Both (Scherer 2017), (Forest 2018) and (Panda and Surminski 2020), seems to indicate that 'there is enthusiasm to support and scale up regional climate risk insurance' (Scherer 2017, p. 4) 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 (WFP 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 failings areas: policy holder and hazard coverage, the cost of premium and risk transfer parameters and the use of pay-out, 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 exploring climate risk pool and its impacts, flag lack of transparency around pay-out, 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; Moro et al. 2018) *(high confidence)*. Scaling up subnational climate finance and investment is a necessary condition to achieve climate change mitigation and adaptation action (Ahmad et al. 2019).

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; Colenbrander et al. 2018b; Ahmad et al. 2019) *(high confidence)*. Yet the significant potential of subnational climate finance mechanisms remains unfulfilled. Policy frameworks, governance, and choices at higher levels underpin subnational climate investments (Colenbrander et al. 2018b; 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 mechanisms reaching or utilizing 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 and 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) *(high confidence)*.

The International Finance Corporation estimates a cumulative climate investment opportunity of 29.4 trillion USD across six urban sectors (waste, renewable energy, public transportation, water, electric vehicles, and green buildings) in emerging market cities, cities in the developing country with more than 500,000 population, to 2030 (IFC 2018). However, State of Cities Climate Finance report estimated that an average of USD 384 billion was invested in urban climate finance annually in 2017-2018 (Negreiros et al. 2021). 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).

Subnational climate public and private finance. Urban climate finance and investment are prominent among the subnational climate finance landscape (CCFLA 2015; Buchner et al. 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 decentralization (Granoff et al. 2016; Floater et al. 2017b; 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). Better standardization in processes is needed, including those bearing on contracts and regulatory arrangement, to reflect local specificities (Bayliss and Van Waeyenberge 2018) [Reference to Public private mobilization Section in 15.6.1.1].

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 *(high confidence)*. 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).

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 evidence related to asset performance and costs-benefits *(high confidence)*. 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 BankGroup 2019).

Debt financing via subnational bonds and borrowing, including municipal bonds, is another potential tool for raising upfront capital, especially for rich cities *(high confidence)*. The share of sub-national, 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. However, while green bonds have potential for growth at the subnational level and may result in a lower cost of capital in some cases, the market faces challenges related to scaling up and has been associated with limited measurable environmental impact to date (see Section 15.6.8 Innovative Financial Products for further discussion). Further, bonds with lower credit ratings drive higher issuance costs for climate risk cities, e.g., costs related to disclosure and reporting (Painter 2020).

Key challenges of subnational climate finance. Across all types of cities, five key challenges constrain the flow of subnational climate finance *(high confidence)*: (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 (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 (Canuto and Liu 2010) and; (v) insufficient positive value capture (Foxon et al. 2015).

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 *(high confidence)*. 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 decarbonization across carbon markets (Silver 2015), and (iii) the policy and jurisdictional ambiguity in urban public finance institutions (Padigala and Kraleti 2014; Cook and Chu 2018). In poorer cities, these differing features continue to be inhibited by contextual characteristics of subnational finance, including gaps in domestic and foreign capital (Meltzer 2016), the mismatch between investment needs and available finance (Gorelick 2018), weak financial autonomy, insufficient financial maturity, investment-grade credit ratings in local debt markets (Bahl and Linn 2014), scarce diversified funding sources and stakeholders (Gorelick 2018; Zhan et al. 2018; Zhan and de Jong 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 *(high confidence)*. Challenges facing cities in developing countries include insufficient appropriate institutional arrangements, the issues of minimum size, and high transaction costs associated with green bonds (Banga 2019). Green projects and project pipelines are generally smaller in scale feasible for a bond market transaction (Saha and D'Almeida 2017; DFID 2020). De-risking in the different phases of long-term project financing can be promoted to improve appetite of capital market [Reference to development of local capital markets Section in 15.6.7].

Climate investment and finance for communities. There is insufficient evidence that which financing schemes contribute to climate change mitigation and adaptations at community level *(high confidence)*. There is growing interest in the linkages between microfinance and adaptation on the agriculture sector (Agrawala and Carraro 2010; Fenton et al. 2015; Chirambo 2016; CIF 2018; Dowla 2018), the finance for community-based adaptation actions (Fenton et al. 2014; Sharma et al. 2014), and the relations between remittances and adaptation (Le De et al. 2013). However, there is less discussion on community finance 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 and 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).

Implications for the transformation pathway.
Cities often have capacity constraints on planning and preparing capital investment plans. An integrated urban capital investment planning is an option to develop cross-sectoral solutions that reduce investment needs, boost coordination capacity, and increase climate-smart impacts (Negreiros et al. 2021) *(high confidence)*. In countries with weak and poorly functioning intergovernmental systems, alliances and networks may influence their organizational ability to translate adaptive capacity for transformation into actions (Leck and Roberts 2015; Colenbrander et al. 2018a). Deepening understanding of country-specific enabling environment for mobilizing urban climate finance among and within cities and communities, design of policy, institutional practices and intergovernmental systems are needed to reduce negative implications of transformation (Steele et al. 2015).

15.6.6 Innovative financial products

Innovative financial products with increased transparency on climate risk have attracted investor demand, and can facilitate investor identification of low carbon investments *(high confidence)*. Innovative products may not necessarily increase financial flows for climate solutions in the near term, however they can help build capacity on climate risk and opportunities within institutions and companies to pave the way for increased flows over time.

Investor demand is driving developments in innovative financial products *(high confidence)***.** Since AR5, innovative financial products such as sustainability and green labelled financial products have proliferated (see financial stock estimates in Section 0). 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 *(high confidence)*. Demand for green financial products initially stemmed from public sector pension funds. Pension funds and insurance companies in OECD countries have traditionally favoured bonds as an asset class with lower risk (OECD and Bloomberg 2015).

Since AR5, labelled green bonds have grown significantly, exceeding 290 billion USD issued in 2020 with a total of 1.1 trillion USD in outstanding bonds (CBI 2021a) (see also local capital markets Section 15.6.7). Corporates, financial institutions and government-backed entities (e.g. in real estate, retail, manufacturing, energy utilities) issued the largest volumes, with use of proceeds focused primarily on GHG mitigation in energy, buildings and transport projects (CBI 2021a). Given their focus on GHG mitigation, green bonds are also sometimes referred to as climate bonds, but the common market terminology is 'green'. Municipal green bond issuance has also been growing (see further discussion on municipal green bonds in Section 15.6.7 on local actors). Beyond green bonds, additional products such as green loans, green commercial paper, green initial public offerings (IPOs), green commodities, and sustainability-linked bonds and loans have also been introduced in the market (CBI 2019a) (see discussion on building yield curves in local capital markets Section 15.6.7).

Investor demand for green bonds is evidenced by over-subscription of deals. Recent studies indicate an over-subscription for green labelled bonds by an average of between three and five times, as compared to non-labelled bonds (Gore and Berrospi 2019; Nauman 2020). Results of a survey of global treasurers showed a higher demand for green bonds than non-labelled bonds for 70% of the respondents (CBI 2020a).

The financial crisis associated with COVID-19 has put increased pressure on debt issuers, and the extent to which the increase in indebtedness for sovereigns and corporates has been financed via climate-related labelled debt products is not known. 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 Section 15.6.7) However, since the onset of the COVID-19 crisis, continued steady growth in issuance has been observed broadly across sustainable bonds (including green, social and sustainability bonds), with more significant growth in social bonds to support the COVID-19 recovery (Maltais and Nykvist 2020; CBI 2021a).

Index providers and exchanges can also play a supporting role in transparency for identification of benchmarks and 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). Indices can provide transparency on low-carbon opportunities making it simpler for funds and investors to identify green investment options. 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 2018). Green security listings can also be used to enhance local capital markets (see Section 15.6.7 for further discussion).

Significant potential exists for continued growth in innovative financial products, though some challenges remain *(high confidence)***.** Despite recent growth and diversification, green bonds face several challenges in scaling up. Issuance of green-labelled bonds constitutes approximately 1% of the global bond market issuance (ICMA 2020b; CBI 2021a) 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* concerns about greenwashing and limitations in application to developing countries (Shishlov et al. 2018; Banga 2019).

There is no globally accepted definition of green bonds, and varied definitions of eligible green activities are evolving across regional bond markets. Beyond the most commonly used green label, other related labels such as blue, sustainable, transition, sustainable development goal (SDG), social and environmental, social and governance (ESG) have some overlapping applications (Schumacher 2020). The degree to which these labels represent climate relevant investments depend on underlying criteria and how they are applied (see also discussion in local capital markets Section 15.6.4).

There are several initiatives aimed at protecting the integrity of the green label. Guidance on use and management of proceeds established by the International Capital Markets Association's Green Bond Principles (GBP) is followed on a voluntary basis, which notes eligible use of proceeds as primarily climate mitigation and adaptation projects. The GBP also recommend independent external reviews at the time of issuance, with 89% of green bond issuers in 2020 with external reviews at the time of issuance (CBI 2021a). In addition to best practice based on voluntary principles, 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; Deschryver and de Mariz 2020). A report on post-issuance green bond impact reporting notes that despite concerns (Shishlov et al. 2018), greenwashing incidence is rare, with 77% of green bond issuers reporting on allocation and 59% reporting on impact, but with significant variance in quality and consistency of impact reporting (CBI 2021b).

Financial disclosure regulatory developments can help further align and specify definitions of green in the financial sector but are not a substitute for climate policy *(high confidence)*. Developing a common basis for understanding a green label could further reduce uncertainty or concerns of greenwashing. Regulatory developments in some regions seek to further guard against greenwashing with more specific definitions. The EU sustainable finance package, including the EU Taxonomy and EU Green Bond Standard draft regulations, is the broadest reaching, but not the only, regional initiative focused on disclosure of climate risk (see also Section 15.6.3). Taxonomies across regions are not always aligned on what can constitute a green project, for example with respect to transition activities (International Capital Market Association 2021) (see also discussion on local capital markets in Section 15.6.7). While standardisation can help reduce uncertainty in markets with imperfect knowledge, the green bond market is currently developing and is expected to continue to reflect regional differences in economic governance approaches (Nedopil et al. 2021). Regulations may also have trade-offs in terms of transaction costs for green financial product issuers. Classification approaches can also face challenges, depending on how they are designed, in their ability to capture new technologies and social impacts (see Section 15.4).

Green bonds have been primarily targeting climate mitigation projects, with far fewer projects identified as adaptation. Green bonds mainly finance projects in the energy, buildings and transportation sectors, which constituted 85% of the use of proceeds of green bonds in 2020 (CBI 2020b, 2021a). Agriculture and forestry projects, including adaptation projects, have been less suited to be financed in a bond structure, which could be in part due to the more dispersed and smaller 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. However, adaptation projects may not be identified as such as resiliency becomes more mainstreamed into infrastructure planning (see Section 15.3.2)

While green bonds have the potential to further support financial flows to developing countries, local capital markets can be at varying stages of development (see discussion in Section 15.6.2 on enabling environments and in Section 15.6.7 on local capital markets for peer-learning examples and de-risking opportunities) (Banga 2019). While multilateral and bilateral development finance institutions have been active in the green bond market, global issuance in 2020 in the top 10 countries included only one developing country (CBI 2021a). Targeting international investors can be enhanced via de-risking activities (see further discussion in section 15.6.4).

Identifying green financial products can increase uptake and may result in a lower cost of capital in certain parts of the market *(high confidence)***.** Investors face a systematic under-pricing of climate risk in financial markets (Krogstrup and Oman 2019; Kumar et al. 2019). Transparent identification of financial products can make it easier for investors to include low carbon products in their portfolios. Investors with mandates that include or are focused on climate change are showing an interest in green-labelled financial products. Investors that identify themselves as green constitute approximately 53% of the investor base for green bonds in the first half of 2019 (CBI 2019b).

There is some evidence of a premium, or an acceptance of lower yields by the investor, for green bonds (*medium confidence*). A survey of recent literature finds some consensus of the existence of a green premium in 56% of the studies on the primary markets (with a wide variance of premium amount), and 70% of the studies on the secondary market (with an average premium of -1 to -9 basis points), particularly for government issued, investment grade and green bonds that follow defined governance and reporting practices (MacAskill et al. 2021). 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 arising (Baker et al. 2018; Karpf and Mandel 2018), or appearing 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 2019b), 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 (Gianfrate and Peri 2019; Nanayakkara and Colombage 2019; Zerbib 2019), with financial institution and corporate green bonds exhibiting a marginal premium compared with their non-green comparisons (Hachenberg and Schiereck 2018; Kempa et al. 2021).

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). One study linked enhanced credit quality induced by issuing green labelled bonds to a lower cost of capital for corporate 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 (Monasterolo and Raberto 2018).

Financial flows via these instruments have limited measurable environmental impact to date, however they can support capacity building on climate risk and opportunities within institutions to realise future impacts *(high confidence)***.** There is a lack of evidence to date that green and sustainable financial products have significant impacts in terms of climate change mitigation and adaptation (see also Box 15.7). 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).

It is challenging to link specific emission reductions with specific instruments that mainly target climate activities such as green bonds. Data challenges point to an inability to link emission reductions, including Scope 3 GHG emissions, at the organization or firm level with green bond use-of-proceeds issuance (Ehlers et al. 2020; Tuhkanen and Vulturius 2020). However one study found evidence of a signalling effect of issuing green bonds resulting in emission reductions at the corporate level following issuance (Flammer 2020), and another study characterised the lifecycle emissions of renewable energy financed by green bonds, indicating potentially substantive avoided emissions but with variance up to a factor of 12 across bonds depending on underlying assumptions (Gibon et al. 2020). There is also a lack of impact reporting requirements and consistency in the green bond market. Impact reporting is not typically required for green bond listings on specific exchanges, nor are there any requirements for independent reviews of impact reporting, 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. 2018b). However, 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.

Climate risk disclosure initiatives, some of which are voluntary in nature, may have a limited direct climate impact. Transparency on climate risk may not change investor decisions nor result in divestment, 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. 2021c). On the other hand, there is evidence of reduced fossil fuel investments following mandatory climate risk disclosure requirements, indicating a broader signalling effect of transparency (Mésonnier and Nguyen 2021).

***** START BOX 15.7. HERE *****

Box 15.7 Impact of ESG and sustainable finance products and strategies

While scaling up climate finance remains a challenge (see Section 15.3.2), there is consensus that investments that are managed taking into account broader sustainability criteria have increased consistently and ESG integration into sustainable investment is increasingly being mainstreamed by the financial sector over the last years (Maiti 2021). The United Nations Principles for Responsible Investment (PRI) grew to over 3000 signatories in 2020, representing over USD 100 trillion in assets under management (UN PRI 2020). And according to the 2018 biennial assessment by Global Sustainable Investment Alliance[6], sustainable investments in five major developed economies grew by 34% in the two year period following the 2016 assessment. The primary ESG approaches leveraged were exclusion criteria 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 around 6 percent of these investments (GSIA 2019). Shareholder activism or corporate engagement is the other key approach, which has been well established and continued to grow to nearly USD 10 trillion (GSIA 2019).

However, research indicates that ESG strategies by themselves, do not yield meaningful social or environmental outcomes (Kölbel et al. 2020). When it comes to the tangible impact of the financial sector on addressing climate change and sustainable development, there remains ambiguity. There is a growing need for more robust assessment of ESG scores, including establishing higher standardization

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FOOTNOTE[6] GSIA is an international collaboration of membership-based sustainable investment organizations.

of scoring processes and a common understanding of the different ESG criteria and their tangible impact on addressing climate change. The issue was highlighted in an assessment of six of the leading ESG rating agencies' company ratings under the MIT Aggregate Confusion Project, which found the correlation among them to be 0.61, leading them to conclude that available ESG data was "noisy and unreliable" (Berg et al. 2020). This need is reaffirmed by (Drempetic et al. 2020), who claim that a thorough investigation of ESG scores remains a relatively neglected topic, with extraneous factors, such as firm size, influencing the score (Drempetic et al. 2020).

There continues to be a research gap in assessing the direct impact of ESG and sustainable investments on climate change indicators, with most existing studies assessing the co-relation between either the factors driving the sustainable finance trends and the impact on sustainable investments, or sustainable investments and the impact on corporate financial performance. Nevertheless, since the post SDG adoption period, there has been a notable uptake on research linking sustainable business practices and financial performance (Muhmad and Muhamad 2020a). This research shows that there is a growing business case for ESG investing, with evidence increasingly indicating a non-negative co-relation between ESG, SDG adoption and corporate financial performance (Friede et al. 2015; Muhmad and Muhamad 2020b), and ESG performance having a positive relation with stock returns (Consolandi et al. 2020). Research, focused on developed economies, also indicates towards a positive relation between ESG criteria and disclosure, and economic sustainability of a firm (Giese et al. 2019; Alsayegh et al. 2020) and allays investor fears by showing that sustainable finance initiatives, such as divestment, doesn't adversely impact investment portfolio performance (Henriques and Sadorsky 2018; Trinks et al. 2018). It should be reiterated, that this research assesses the co-relation between ESG criteria and corporate financial performance, with the researchers in some cases, such as (Friede et al. 2015), including disclaimers of the results being inconclusive and highlighting the need for a deeper assessment for linking ESG criteria with impact on financial performance.

On the other hand, there is growing evidence for a sustainable investment lens having a broader positive impact on creating an enabling environment and strengthening the case for such investments. For instance, CSR activities and investments on the environment dimension, specifically in the areas of emission and resource reduction, were found to be profitable and a predictor of future abnormal returns in the longer term, from additional cash flow and additional demand (Dorfleitner et al. 2018). These factors could be contributing to the increasing trend of sustainable and green investments, and can said to be further reiterated by the spate of investor led collaborative initiatives and recent announcements by leading finance institutes in the developed economies, which is well recorded in a range of recent grey literature, including new climate-aligned investment strategies and ambition towards net zero targets.

Yet there is also a risk of companies announcing projected sustainability or net zero targets and claiming the associated positive reputational impact, while having no clear action plan in place to achieve these. The lack of mandatory reporting frameworks, which results in an over-reliance on self-reported carbon data by companies for ESG assessments, can be a primary contributor (In and Schumacher 2021).

While there is a lack of research on the impact of sustainable finance products, divestment impact has been assessed in more detail. Although the research here also 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 divestment movement for building awareness and mobilizing broader public support for effective climate policies, have been better researched and could be considered to be the more relevant outcomes (Braungardt et al. 2019). Arguments against divestment point to its largely symbolic nature, but (Braungardt et al. 2019) elaborate on the broader positive impacts of divestment, which includes its ability to spur climate action as a moral imperative and stigmatise and reduce the power of the fossil fuel lobby, 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.

Challenges remain with regards to overlapping definitions of sustainable and ESG investment opportunities, which also vary depending on social norms and pathways. There is also a general need for more extensive ESG disclosure on a corporate level, against the background of emerging mandatory impact reporting for asset managers in some regions. A movement is building towards sustainable investment strategies and increased sustainable development awareness in the financial sector (Maiti 2021; Muhmad and Muhamad 2020b), which points to the ability of civil society movements, such as divestment campaigns, to have some influence on investor behaviour, although there are other influences such as climate risk disclosure initiatives and regulations.

***** END BOX 15.7. HERE *****

15.6.7 Development of local capital markets

International Situational Context. Developing countries make up two thirds of the world population, carry carbon intensive economies where 70% of investments need to be conducted to limit warming to 2°C. The focus for climate investments has been on China, USA, Europe, India and the G-20 (UNEP 2019) but studies highlight Paris and SDG attention should be devoted to Africa, LDCs and SIDS (Africa Union Commission 2015; GCA-AAI 2020; Feindouno et al. 2020; Warner 2020; AOSIS 2021). The “special needs, circumstances and vulnerability” of Africa, LDC and SIDS nations are recognised under UNFCCC and UN agreements (UN 2009, 2015a,b,c; UNFCCC 2010, 2015; Pauw et al. 2019). These nations currently contribute very little to global emissions. Developing countries with their growing economies, including the vast Africa continent roughly the size of China, Europe, USA, India combined (IEA 2014b, p. 20) with a 1 billion population expected to double by 2050, growing reliance on fossil fuels and ‘cheap’ biomass (charcoal use and deforestation) amid rising urbanization and industrialisation ambitions – collectively these nations hold large leap-frog potential for the energy transition as well as risks of infrastructure lock-in. Accelerated international cooperation is a critical enabler (IPCC 2018) in recognising this potential. This could mobilise global savings, scale up development of local capital markets for accelerated low carbon investment and adaptation in low and lower middle income countries as well as tackle illicit finance including tax avoidance leakages that deprive developing countries of valuable resources (US DoJ 2009; Hearson 2014; Hanlon 2017a; US DoJ 2019; UN IATFD 2021). Diversifying funding sources is important at a time hard-currency Eurobond issuances reach records (Panizza and Taddei 2020; Moody’s Investors Service 2021). Otherwise, the structure of voluntary, nationally oriented, and financially fragmented arrangements under the Paris Agreement (see Chapter 17) could lead to ‘regional rivalry’ (SSP 3) pathways (IPCC 2018; Gazzotti et al. 2021). The benefits are many times greater than apparent costs in terms of expected decline in global GHG emissions and attaining SDGs. These could even generate large ‘win-win’ opportunities back in capital source countries which will benefit from a flow back in import demand (Hourcade et al. 2021a).

Lessons from literature on policy options in mobilising capital for Paris and SDGs in developing countries can be summarised as: a) development of national just transition strategies i) meet the 100 billion USD commitment on a grant-equivalent basis to support NDCs that integrate policies on COVID-19 recovery, climate action, sustainable development and equity b) increase the leverage of public funds on diverse sources of private capital through de-risking investments and public private partnerships involving location-based entities with AAA rated players and institutional investors c) co-ordination of project preparation and development of project pipelines by infrastructure co-ordinator agencies, one-stop structuring and financing shops, project risk facilities provided by cities development banks, green banks, world climate bank, global guarantee mechanism, and global infrastructure investment platform d) development of local currency bond markets backed-by cross-border guarantees, technical assistance, remediation assets especially by regional and national players whose mandates include nurturing local capital markets to support bond yield curve development and exchange listing options e) adopting advances in science-based assessment methods to foster accountability i) for project assessment, MRV and certification ii) for disclosures in climate, fossil fuels, SDG, debt transparency and debt sustainability iii) for progress on UN systems of national accounts particularly for public sector finance statistics.

Whole of society approach to mobilising diverse capital. There's no shortage of money globally: it is simply that it has yet to travel to where it's most needed. One challenge is unlocking unencumbered endowments to contribute to Paris and SDGs. *(high confidence).* The aggregate global wealth figures exceed 200 trillion USD (Davies et al. 2016; UBS 2017; Credit Suisse 2020; Heredia et al. 2020). Some developing countries have run pilots for investing in government bonds capitalising on fintech growth discussed in section 15.6.6 (The Economist 2017; Akwagyiram and Ohuocha 2021). Others are developing green products to encourage uptake by middle class retail investors (Eurosif 2018; HM Treasury and UK DMO 2021). Millennial-aged inheritors expected to receive intergenerational transfers mobilized by global citizen activism (see Chapter 2) invest in green retail and tech products (UBS 2017; Capgemini 2021; Morgan Stanley 2017). Historic inequity and diaspora-related private and public resources pledged and debated during the COVID-19 pandemic might have potential to contribute towards Paris and SDGs (Olusoga 2015; Glueck and Friedman 2020; Hall 2020; Piketty 2020; Timsit 2020; Goldman Sachs 2021; Guthrie 2021; Mieu 2021; Wagner 2021). Philanthropic institutions use grants, debt, equity, guarantees and issue investment grade bonds in using unencumbered endowments (Manilla 2018; Covington 2020; Moody's 2020) but only about 2% of their resources are dedicated to climate action (Williams 2015b; Kramer 2017; Morena 2018; Delanoë et al. 2021). The pandemic exemplified the unprecedented collaboration and mobilisation of multilateral and scientific communities supported by the COVAX risk sharing mechanism for COVID-19 vaccines with pooling of financial and scientific resources (OECD 2021d). This momentum in international cooperation can be harnessed to galvanise resources including for teaching of sciences in developing countries important in tackling society challenges, alleviating poverty (TWAS 2021) and inequity legacies compounded by climate impacts debated by many (Henochsberg 2016; Obregon 2018; The Economist 2021; Fernandez et al. 2021). Suggestions towards equitable models include "global adaptation funding approaches" (Chancel and Piketty 2015), a "world climate bank" to finance climate investments through long term bonds (Foley 2009; Broome 2012; Broome and Foley 2016), "cities development bank" (Alexander et al. 2019) , "public debt financing models" (Rendall 2021) to share the burden between generations which has precedence in history (Draper 2007; Fowler 2015).

Local financial institutions with local markets knowledge could benefit from technical assistance and partnership to scale up their potential. Institutional investors could be better mobilised *(high confidence).* The Global South has some 260 public development banks/PDBs representing 5 trillion USD in assets with a worldwide PDB capacity to provide more than 400 billion USD yr^{-1} of climate finance (IDFC and GCF 2020). Case studies discuss the potential for diaspora bond issuance being deployed for climate investments including securitisation of remittances as collateral for infrastructure bonds (Ketkar and Ratha 2010; Akkoyunlu and Stern 2012; Gelb et al. 2021). Such instruments could help harness diaspora remittances whose flows rose from under 100 to 530 billion USD during 1990-2018 (World Bank 2019b). PDBs could benefit from technical partnership with multilaterals and other local banks (Torres and Zeidan 2016). Their knowledge of local markets, can help build project pipelines (see Figure 15.7) to channel local, domestic and international capital (Griffith-Jones et al. 2020). Institutional domestic and international investors have growing assets estimated to exceed 100 trillion USD (*high confidence*) (Think Ahead Institute 2020; UN PRI 2020; Halland et al. 2021; Heredia et al. 2021; Inderst 2021) and could be better mobilized. Some 36 percent of total assets under management (AUM) by the 100 largest asset owners come from pensions and SWFs in the Asia Pacific region with the remainder split almost evenly across Europe, the Middle East, Africa and North

America. The largest pension fund in South Africa held about 130 billion USD AUM in 2019 and Africa institutional investors held USD 1.8 trillion in 2020 (GEPF 2019; PWC 2015; Bagus et al. 2020; Irving 2020). UK NGO (War on Want 2016) analysis of 101 fossil fuel and mineral resources companies listed on the London Stock Exchange (LSE) estimates these as holding a trillion USD assets inside Africa. The LAC region, holds just about USD 1 trillion AUM (Serebrisky et al. 2015; Cavallo and Powell 2019).

Investors with accumulated private capital are reported as looking for climate investments to ensure Just Transition, alignment with Paris and SDGs. However, progress remains pilot, slow and piecemeal (*high confidence*). Global investors have published statements on their possible contribution with recommendations to governments on de-risking to accelerate private sector investment to support Paris aligned NDCs in developing countries (IIGCC 2015, 2017, 2018, 2020; Global Investor Statement 2018; 2019). In March 2020, the UN Principles for Responsible Investment (PRI), had 3,038 members representing 103 trillion USD (UN PRI 2020); another coalition of investors published COVID-19 recovery plans (Investor Agenda 2020) and the Net Zero Asset Managers initiative was launched in December 2020 (NZAM 2020). However, it is still unclear how these pronouncements will be transformed to adequate financial flows and volumes of investment pipelines ((IEA 2021e), Chapter 3). (Rempel and Gupta 2020) posit that a proportion of institutional holding is in fossil fuels. Clean energy transition minerals raise ESG questions around inclusive development for indigenous populations and requires changes to supply chains exploiting child labour (Herrington 2021; IEA 2021a,f).

Options to mobilise institutional investors currently remain small pilots, relative to Paris and SDG ambitions *(high confidence*)**.** In terms of sample examples: in the *women of colour-led arena*, a Chicago pension fund invested in a developing country using a *private equity fund*; (Langhorne 2021). Institutional Blackrock's blended finance vehicle with OECD MDB partners focuses on developing countries (Blackrock 2021). In regional AAA MDB partnerships, AfDB collaborates with Africa nations through a *regional infrastructure fund* (Africa50 2020); ADB collaborates with a Philippines state-owned pension fund and Dutch pension fund in using a *private equity fund* to catalyse private sector (ADB 2012). A UN entity with several pooled public-private investment platforms include a SDG blended finance vehicle (UN CDF 2020a,b, 2021a). Multilateral IFC blended finance fund, supported by a sovereign guarantee from Sweden's SIDA and separately a 1 billion USD green bond fund by IFC and Europe's Amundi asset manager buys green securities issued by developing country banks financing local currency climate investments (IFC 2018; IFC 2021 2021; Amundi and IFC 2019)**.** The key parameter is the *investment multiplier,* the *ratio of private investment mobilised by a given amount of public fund*s which varies by product type. IFC's portfolio of blended finance investments point to a self-reported range of 3 to 15 times for project debt and even higher levels (10 to 30) for debt finance provided on concessional terms (IFC 2021a 2021). Although AAA-rated IFC blended finance fund was established in 2013, it took on seven of its eight institutional investors in 2017 with insurers AXA and Swiss Re investing 500 million USD each to bring the fund to 7 billion USD raised from eight global investors (Attridge and Gouett 2021). Critics of blended finance mechanisms point to lack of data transparency hampering independent assessment on i) value for public money and costs of blending versus other financial mechanisms ii) risks and benefits of de-risking private capital to collateralising climate vulnerable Global South populations iii) lack of partnership with local players iv) complex structures (Akyüz 2017; Mawdsley 2018; Convergence 2020; Daniela Gabor 2021; Attridge and Gouett 2021). Whilst blended finance transactions (BFTF 2018) are quite common in mature regulated markets with mandatory reporting requirements (Morse 2015; ICAEW 2021), the additional finance mobilised and their developmental impact remain unknown due to poor reporting that hammpers evidence-based policy making (Attridge and Gouett 2021). Projects that are aligned with blended finance principles in the UN Addis Agenda (UN 2015a) and take account of local contexts by involving local actors are much more likely to have sustainable impacts.

De-risking tools to lower capital costs and mobilise diverse investors. Paris aligned NDCs that integrate policies on COVID-19 pandemic recovery, climate action, sustainable development, just transition and equity can harness co-benefits including contribution to "*Invisible UN SDG 7 energy poverty sectors*" *(high confidence).* Developing countries require access to affordable finance for projects ranging from clean cooking solutions (Accenture 2018; World Bank et al. 2021); decentralised energy systems, intra-country power stations and regionally shared power pools with their associated energy distribution networks (IEA 2020d; IRENA 2020c). Close to 3 billion people in Africa and developing Asia have no access to clean cooking. For sub-Sahara Africa, the acute lack of electricity access lags behind all regions on SDG 7 indicators impacting mostly women and children (see Chapter 6, box 6.1; (IEA et al. 2021; IEA 2021e; Stritzke et al. 2021; Zhang 2021)). These dire statistics remind of compounding tensions: Historical inequities and the associated "first comer' exploiting Africa resources for development elsewhere, the local climate change, "latecomer" capacity development and technology transfer challenges, illicit mining finance and stranded assets (UNU-INRA 2019; Bos and Gupta 2019; War on Want 2016; Arezki 2021). The COVID-19 pandemic exacerbates this tension with more people pushed below the poverty line (Sumner et al. 2020) (see Box 15.6). Recent analysis points to the 60 largest banks providing 3.8 trillion USD to fossil fuel companies since 2016, including inside Africa (Rainforest Action Network et al. 2021). IMF estimated fossil fuel subsidies totalling 5.2 trillion USD or 6.5% of global GDP in 2017 (Coady et al. 2019) to be compared with the 2.4 trillion USD yr^{-1} energy investments over the next decade to limit global warming to 1.5°C (IPCC 2018). Analysts point to models in improvements to resources husbandry that include i) minerals strong governance SWFs for domestic development (Wills et al. 2016) and ii) compensation for Africa (Walsh et al. 2021) leaving fossil fuels underground (McGlade and Ekins 2015) in the *Just Transition* (section 15.2.4) and *Right to Develop* debates as assets continue to be mined (IEA 2019c). In many developing regions, some of the world's best renewable energy sources remain out of reach due to high costs which can be up to seven times that in developed countries (IEA 2021a). Shifting some risks through financial de-risking approaches could be instrumental (Schmidt 2014; Sweerts et al. 2019; Drumheller et al. 2020; Matthäus and Mehling 2020) .

Combining approaches: i) developed countries meeting UNFCCC 100 billion USD commitment on a grant-equivalent basis ii) stepped up technical assistance iii) infrastructure co-ordination iv) knowledge sharing by project preparation entities iv) harnessing project risk facilities such as guarantees could be instrumental for scaling climate finance for Paris-SDGs *(high confidence).* Figure 15.7 illustrates the interplay between infrastructure project financing phases, bond refinancing and opportunities for developing bond yield curve benchmarks in nurturing local capital markets and mobilising diverse investors. These project financing phases have varying risk-return profiles and different benchmarks to track performance are needed by investors for different types of securities that might be created (Ketterer 2014; Ketterer and Powell 2018).

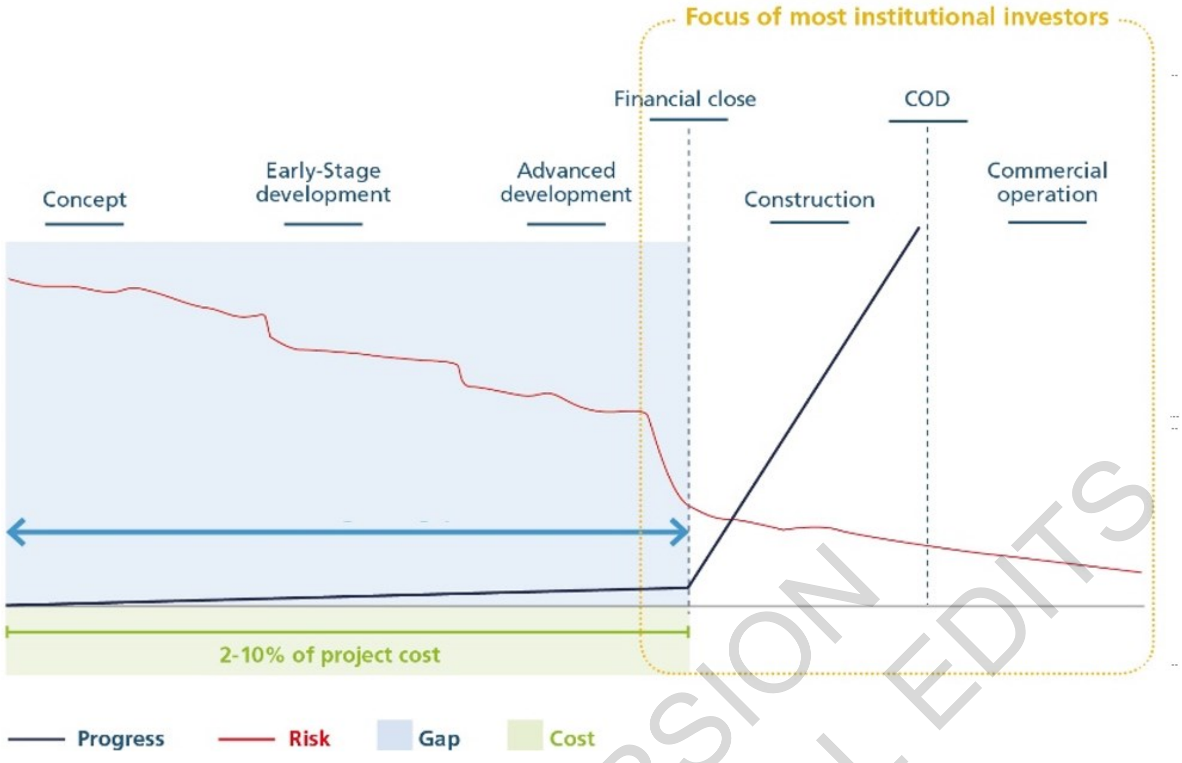

Figure 15.7 Bond refinancing mobilises institutional investors in mature project phase. De-risk early stage infrastructure projects. Source: Building on PIDG 2019

A (ODI 2018) survey of private and public project preparation facilities internationally, showed high failure rates in *early project preparation phases* with recommendations on "*one-stop-shops*" and knowledge sharing on effective approaches. During the very high-risk *concept phase* (Figure 15.7) – grants and technical assistance de-risk with design concepts, project proposals and feasibility studies completed to "kick-start" the right projects. The early stage developmental phase is characterised by short-term debt in the 2-5 year phase to complete construction enabled by concession finance. Bank loans are paid back by issuing bonds once the construction phase is completed. Such bond refinancing over say 15-25 years, in the *low risk mature project phase* can provide a lower cost of capital. Market-making to develop a pipeline of investment opportunities uses a complimentary mix of high-risk capital options in the form of grants, guarantees, equity, mezzanine financing that can help (Attridge and Gouett 2021) i) reduce up-front risks in the early phases ii) allow banks to recycle loans to new projects iii) galvanise multilateral technical assistance for building bond yield curve benchmarks and de-risking local currency bond issuance of long tenors such as green bonds/resilience bonds (Berensmann et al. 2015; CBI 2015; Mercer 2018; Dasgupta et al. 2019; PIDG 2019; Braga et al. 2021; CBI et al. 2021; Hourcade et al. 2021a,b) . Convergence 2019 points to investment from commercial banks with commercial debt of 11-15years maturity being covered by guarantees. To achieve scale, some have issued SPV green infrastructure project bonds combining tenors up to 15 years with credit ratings assigned to mobilise investors with community trusts for local participation (Mathews and Kidney 2012; Kaminker and Stewart 2012; Mbeng Mezui and Hundal 2013; Essers et al. 2016; Moody's Investors Service 2016; Ng and Tao 2016; Harber 2017). Bond refinancing could be facilitated through standardised national infrastructure style bonds, national infrastructure funds (Amonya 2009; Ketterer and Powell 2018) and country SPV infrastructure funds issuing bonds (Cavallo and Powell 2019) embedding MDBs.

Existing project risk facilities including guarantees could benefit from co-ordination, scaling and better reporting frameworks (high confidence**).** Individual and clubs of developed and developing countries currently provide public guarantees (ADB 2015; IIGCC 2015; Pereira Dos Santos 2018; GGGI 2019; PIDG 2019; AGF 2020; Garbacz et al. 2021). However MDB business model imposes limitations on use of guarantees and collaboration with other MDBs (Gropp et al. 2014; Schiff and Dithrich 2017; Lee et al. 2018; Pereira dos Santos and Kearney 2018b). Loans continue to dominate as the financial instrument of choice by MDBs and DFIs, with guarantees mobilising the most private finance for OECD reported data even if their use remains limited (IATFD 2020; OECD 2020c; Attridge and Gouett 2021). Ramping up the use of guarantees to mobilise private investment raises questions around understanding efficacy in the design as there is no one size that fits all and more research is required to better understand this aspect (Convergence 2019). Sample guarantee forms in literature: i) single country Sweden and USA DFI forms (SIDA 2016, DCA 2018) ii) multilateral institution offerings (Pereira Dos Santos 2018; IRENA 2020e) iii) multi-sovereign guarantees one-stop platforms such as those on the PIDG/Guarantco (PIDG 2019) and Africa Guarantee Fund owned by DFIs, including AfDB, AFD, NDF, and KfW (AGF 2020) iv) MIGA, established to provide political risk guarantees (enhanced green MIGA) (Déau and Touati 2018) v) multilateral partnerships with developing nations via infrastructure funds (see 15.6.7.2) and green infrastructure options (de Gouvello and Zelenko 2010; Studart and Gallagher 2015) vi) guarantees embedded in project risk facilities such as currency fund TCX established by 22 DFIs (TCX 2020) and vii) ASEAN and African multi-sovereign regional local currency bond guarantee funds and a co-guarantee platform (GGGI 2019; Garbacz et al. 2021). Fossil fuels currently benefit from de-risking tools from export credit agencies (Lawrence and Archer 2021) with questions around sustainable development (Wright 2011)); (Gupta et al. 2020) argue that these could be deployed for renewable energy. C40 Cities Facility; Blue Natural Capital Facility (IUCN 2021); Clean Cooking Fund (ESMAP 2021) and opportunities for guarantees in LDCs (Garbacz et al. 2021). World Bank's Renewables Risk Mitigation (GCF 2021), World Bank's Global Infrastructure Facility. UNEP Seed Capital are sample project facilities across diverse project types (GGGI 2019). Multilaterals offer credit enhancement to manage both actual and perceived risks: in the India corporate sector, renewable energy SPV project bonds have been guaranteed jointly by ADB and an infrastructure company raising the credit rating from sub-investment grade to investment grade to lower borrowing costs (ADB 2018; Agarwal and Singh 2018; Carrasco 2018).

Investment vehicles into green infrastructure come in various forms *(high confidence)* and can include indirect corporate investment such as bonds; semi-direct investment funds via pooled vehicles such infrastructure funds and private equity funds and project investment (direct) in green projects through equity and debt including loan, project bonds and green bonds. Pension funds in Australia and Canada direct investment in infrastructure is about 5% of total AUM (Inderst and Della Croce 2013) whilst less than 1% for OECD pension funds go to green infrastructure (Kaminker et al. 2013). Some regional developing country institutional investors use a variety of investment vehicles that span SPVs, private equity, domestic and regional local currency bond markets with statutory level mandates to address historic inequities (GEPF 2019). Cross-border collaboration in regional power markets such as Europe's Nordpool; for developing countries could be led by technical partnership from infrastructure funds and multilaterals (Oseni and Pollitt 2016; Juvonen et al. 2019; Chen et al. 2020; Nordpool 2021)**.** Barriers to investments include non-standardised investment vehicles of scale and lack of national infrastructure road maps to give investor confidence in government commitment. Some have set up infrastructure co-ordinating entities embedding local science and engineering R&D (IPA 2021; National Infrastructure Commission (NIC) 2021). (Arezki et al. 2016) argue that co-ordination within existing platforms could create a global infrastructure investment platform for de-risking through guarantees and securitization; (Matthäus and Mehling 2020) point to a global guarantee mechanism. Such multilateral approaches create credibility enhancing effects in developing capital markets. (Hourcade et al. 2021a) suggest that the overall economic efficiency could be higher with guarantees calibrated per ton on an agreed *"social, economic, and environmental value of mitigation actions [and] their co-benefits*" (Article 108, Paris

Agreement) which would operate as a notional carbon price (High-Level Commission on Carbon Prices 2017). The grant equivalent of guarantees and induced equity inflows could be far beyond the US 100 billion promise. Such cooperative solutions in adopting development of local capital markets would end the drawbacks of the current plethora of low-scale fragmented project-by-project and 'special-purpose' pilots and programs.

Harnessing existing bond markets and securities exchanges in nascent markets. The G20 has an action plan to support strengthening local currency bond markets and development of local capital markets is also part of the option for financing UN SDGs in developing countries (UN 2015a) 2015; UN 2019, 2020; IATFD 2016; UN IATFD 2021). Primers are available on bond market development to support policy choices (World Bank and IMF 2001; Silva et al. 2020; World Bank 2020; Adrian et al 2021; IMF and World Bank 2021). Developing government bond yield curves with different maturities can be an important policy objective *(high confidence)***.** This can support pricing discovery, liquidity (Wooldridge 2001) and can be achieved through step by step tranches from shorter to longer maturities to boost confidence and encourage municipals and other quasi-sovereigns. Money market instruments (such as, green commercial paper) anchor the short end of the yield curve with bonds of varying maturity issued by sovereign/quasi-sovereign entities (national treasuries, SOEs, municipalities) to mobilise investors (Goodfriend 2011; LSEG 2018; Tolliver et al. 2019). A variety of bonds are being used for developing countries including green (Ketterer et al. 2019), blue-water(Roth et al. 2019), transition, SDG/social, biodiversity bonds (Aglionby 2019), green/resilience bonds (AAC 2021); gender bonds (Andrade and Prado 2020)(; diaspora (LSEG 2017) and infrastructure project bonds (CBK 2021). Local policy-makers would gain from technical and financial assistance in building green yield curves, for example with support from multilaterals (EIB 2012; IATFD 2016; Shi 2017; EIB 2018). Green bonds are one of the most readily accessible to help fund Paris goals (Tolliver et al. 2019; Tuhkanen and Vulturius 2020). Section 15.3.2 refers to the growth in labelled bond markets (CBI 2021b), low borrowing costs and yield curve building in Europe (Bahceli 2020; Serenelli 2021; Stubbington 2021; HM Treasury and UK DMO 2021). For developing countries, labelled bonds have mostly been in hard currency (e.g. (Smith 2021)) despite local currency markets making up more than 80 percent total debt stock (IMF and World Bank 2016; Silva et al. 2020; Adrian et al 2021; Inderst 2021). The labelled bonds issuance by multilaterals do not currently mobilise the trillion levels needed. Research studies show that participating in green bond markets in part depends on a country having credible NDCs (Tolliver et al. 2020a,b) and highlights diverse approaches working together to support local bond market development (Amacker and Donovan 2021; ICMA 2021; IMF and World Bank 2021)

Technical assistance options would benefit from co-ordination. Labelled bond costs remain high. Developing countries are using fiscal incentives, grants, and guarantees to support nascent bond markets with most taxonomies under development *(high confidence*). Technical assistance requirements to improve the investment climate and bond market development will vary across national capacities. These would benefit from the 100 billion USD UNFCCC grant equivalent basis to develop i) regulatory and policy frameworks ii) UN national statistical systems (Singh et al. 2016; MacFeely and Barnat 2017; Paris21 2018; Bleeker and Abdulkadri 2020);iii) credible NDC and SDG investment plans iv) project assessment certification and taxonomies v) bond market guidelines vi) public finance management (US DoJ 2019, 2009). Other technical assistance channels include diaspora entities, universities and learned societies (ICEAW 2012; Mahmud and Huq 2018; UNFCCC 2021). LDCs are least likely to have active capital markets. Clubs of LDCs are partnering with AAA MDBs in aggregation approaches (AfDB 2020; GCF 2020b). Some UN entities provide technical assistance on municipal aggregation of projects (UN CDF 2020) with Africa, LDC, SIDS nations and cities accessing green technical facilities and listings for labelled bonds (C40 Cities Climate Leadership Group 2016; Gorelick 2018; Jackson 2019; FSD Africa and CBI 2020; Gorelick and Walmsley 2020; MoE Fiji 2020 2020; IFC 2021). Elevated climate risks imperil developing country ability to repay debts (Schmidt 2014; Buhr et al. 2018; Volz et al. 2020; Dibley et al. 2021). To lower overall costs and achieve more - entities have accessed technical assistance, listed local currency labelled bonds, used credit enhancing bond guarantees, regulatory treatments and philanthropy schemes (Europe 2020 Project Bond Initiative 2012; SBN 2018; Agliardi and Agliardi 2019; Banga 2019). In the regions, China issued guidelines for stock exchanges and regulatory support for green bonds (Cao and Ma 2021), India issued regulations for local issuance of green bonds (CBI 2019a) while in the LAC region; both plain vanilla and labelled bonds use the same authority (Ketterer et al. 2019). Africa, LDC and SIDS nations are reviewing ways to harness local exchanges (SSE 2018; GCF 2019; ASEA et al 2021; UN CDF 2021b). For taxonomies, the differences reflect the multitude of local Just Transition pathways, some with purely environmental focus and others incorporating livelihood improvements (ICMA 2021). The sustainable bond market has been expanding as transition bonds become listed in anticipation of future developments (Roos 2021).

Progress towards transparency using scientific-based methods to build trust and accountability. After 60years of development finance, critics underline limits coming from i) lack of aid and debt transparency (Moyo 2009; Mkandawire 2010; PWYF 2020) ii) mining-fossil fuels sector and illicit finance (Plank 1993; Sachs and Warner 2001; Hanlon 2017b)) iii) lack of developed country commitment to pledges (Nhamo and Nhamo 2016) iv) unregulated players as financial intermediaries in blended finance (Pereira 2017; Donaldson and Hawkes 2018; Tan 2019) v) weak accountability reflected in soft SDG data measurement and vi) burden of responsibility in mobilising resources for Paris and SDG to countries with historically soft institutional capacity (Hickel 2015; Donald and Way 2016; Scheyvens et al. 2016; Liverman 2018). Literature around trust in blended finance pinpoints four progress areas in accountability. First, debt transparency through public debt registries, centralised UN legacy debt restructuring and science-centred UN national statistical systems (Donaldson and Hawkes 2018; Jubilee Debt Campaign 2019; Stiglitz and Rashid 2020). Second, international reporting bell-weathers could be called upon to produce harmonized mandatory reporting frameworks that capitalize on TCFD to capture climate, debt sustainability (see 15.6.7.3), SDG and fossil fuel (GISD 2020); third, standardization of assessment by third parties of the quantity and values of carbon saved by green projects (Hourcade et al. 2012) and of their contribution to quantified performance biodiversity targets (FfB 2021) to facilitate their bundling, securitization and repackaging in standardized liquid products and bonds (Arezki et al. 2016; Blended Finance Taskforce 2018a).

15.6.8 Facilitating the development of new business models and financing approaches

New and innovative business models and financing approaches have emerged to help overcome barriers related to transactions costs by aggregating and/or transferring financing needs and establishing supply of finance for stakeholder groups lacking financial inclusion *(high confidence)*.

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

Energy-as-a-service (EaaS) is a business model whereby customers pay for an energy service without having to make any upfront capital investment (PWC 2014; Hamwi and Lizarralde 2017; Cleary and Palmer 2019). EaaS 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 and deployment of decentralised renewable energy (KPMG 2015; Moles-Grueso et al. 2021). Innovation in EaaS has started at the household level, where smart meters using real-time data are used to predict peak demand levels and optimise electricity dispatch (Chasin et al. 2020)(Government of UK 2016) (Smart Energy International 2018).

Aggregators. An aggregator is a grouping of agents in a power system to act as a single entity when engaging in power system markets (MIT 2016). Aggregators can use operation optimisation platforms to provide real-time operating reserve capacity and a range of balancing services to integrate higher shares of variable renewable energy (VRE) (Zancanella et al. 2016)(Ma et al. 2017; Enbala 2018; Research and Markets 2017; IRENA 2019b). This makes a business case for deferred investments in grid infrastructure *(medium confidence)*. Aggregating and managing demand-response of heat systems (micro CHP and heat pumps) has shown reduction in peak demand (TNO 2016).

Peer-to-peer (P2P) electricity trading. Producers and consumers can directly trade electricity with other consumers in an online marketplace to avoid the relatively high tariffs and the relatively low buy-back rates of traditional utilities (IRENA 2020f; Liu et al. 2019). P2P models trading with distributed energy resources reduce transmission losses and congestion (Mengelkamp et al. 2018; SEDA 2020; Lumenaza 2020; Sonnen 2020; UNFCCC 2020).

Community-ownership models. Community-ownership models refer to the collective ownership and management of energy-related assets with lower levels of investment, usually distributed renewable energy resources but also recently in heating systems and energy services (e.g. storage and charging) (Gall 2018; IRENA 2018; Kelly and Hanna 2019; Singh et al. 2019; Bisello et al. 2021; Maclurcan and Hinton 2021). Community-ownership projects may need significant upfront investments, and the ability of communities to raise the required financing might prove insufficient, which can be supported by microcredits in the initial stages of the projects (Aitken 2013; Federici 2014; REN21 2016; Rescoop 2020).

Payment method: Pay-as-you-go (PayGo). PayGo business models emerged to address the energy access challenge and provide chiefly solar energy at affordable prices, using mobile telecommunication to facilitate payment through instalments (IRENA 2019c) (Yadav et al. 2019). However, PayGo has the technology and product risk, requires a financially viable and large customer base, and the system supplier must provide a significant portion of the finance and requires substantial equity and working capital (C40 Cities Climate Leadership Group 2018).

Transport sector business models. Analog to EaaS, Mobility-as-a-Service (MaaS) offers a business model whereby customers pay for a mobility service without making any upfront capital investment (e.g., buying a car). MaaS tends to deliver significant urban benefits (e.g., cleaner air) and brings in efficiency gains in the use of resources *(high confidence)*. However, the switch to MaaS hardly improves the carbon footprint and further tempted on-demand mobility is likely to nurture carbon emissions (Suatmadi et al. 2019). Therefore, to support climate change mitigation, MaaS must be integrated with the deployment of smart charging of electric (autonomous) vehicles coupled to renewable energy sources (IRENA 2019d)(Jones and Leibowicz 2019).

Financial technology applications to climate change. Financial technology abbreviated as 'fintech' applies to data-driven technological solutions that aims to improve financial services (Schueffel 2018; Dorfleitner et al. 2017; Lee and Shin 2018). Fintech can enhance climate investment in innovative financial products and build trust through data, but also presents some challenges including related to potentially significant emissions from increased energy use with distributed transactions (Lei et al. 2021). 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 (OECD 2019c; World Energy Council 2019). Fintech applications with climate change mitigation potential have been growing recently, including tracking payment or asset history for credit scoring in AFOLU activities (Nassiry 2018; Davidovic et al. 2019), blockchain supported grid transactions (Livingston et al. 2018), carbon accounting throughout value chains (World Bank 2018b), or transparency and verification mechanisms for green financial instrument investors (Kyriakou et al. 2017; Stockholm Green Digital Finance 2017). Generally, blockchain and digital currency applications are not well covered by governance systems (Tapscott and Kirkland 2016; Nassiry 2018), which could lead to problems with security (Davidovic et al. 2019), and some licensing and prudential supervision frameworks are in flux.

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 studies on the investment and finance for the nature-based solutions is still limited. However, framework and schemes to incentivise the implementation of nature-based solutions, such as reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+), which contributes to the climate change mitigation has 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 2019d; Griscom et al. 2020; Dasgupta 2021) *(high confidence)*.

The nature-based solutions have large potential to address climate change and other sustainable development issues *(high confidence)*. Nature-based solutions are undercapitalised and the limited investment and finance, especially limited private capital is widely recognised as one of the main barriers to the implementation and monitoring of the nature-based solutions (Seddon et al. 2020; Toxopeus and Polzin 2021; UNEP et al. 2021) Finance and investment models that generates its own revenues or consistently saves costs are necessary to reduce dependency on grants (Schäfer et al. 2019; Wamsler et al. 2020).

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 (Milbank et al. 2018; Morita and Matsumoto 2018) *(high confidence)*. We use the term REDD+ broadly, not limited to REDD+ implemented under the UNFCCC decisions, including Warsaw Framework for REDD+ (see Chapter 14), but include voluntary REDD+ projects, such as projects which utilise voluntary carbon markets. Finance is a core element that incentivise and implement REDD+ activities. Various financial sources are financing REDD+ activities, including bilateral and multilateral, public and private, and international and domestic sources, with linking with several finance approaches/mechanisms including results-based finance and voluntary carbon markets (FAO 2018). However, there is lack of sufficient finance for REDD+ (Lujan and Silva-Chávez 2018; Maguire et al. 2021). REDD+ under the UNFCCC are implemented in three phases, readiness, implementation, and results-based payment phases. The Ecosystem Marketplace identified that at least USD 5.4 billion in REDD+ in three phases funding committed through multiple development finance institutions so far (Maguire et al. 2021), and public funds are main sources that are supporting three phases, and most of the REDD+ finance were spent to the readiness phase (Atmadja et al. 2018; Lujan and Silva-Chávez 2018; Watson and Schalatek 2021). There is significant gap between the existing finance and finance needs of REDD+ in each phase (Lujan and Silva-Chávez 2018). Furthermore, private sector contribution to REDD+ is currently limited mostly to the project-scale payments for carbon offsets/units through voluntary carbon market (McFarland 2015; Lujan and Silva-Chávez 2018).

Current main challenges of REDD+ finance include the uncertainty of compliance carbon markets (which allow regulated entities to obtain and surrender emissions allowances or offsets to meet regulatory emissions reduction targets) (Maguire et al. 2021), as well as limited engagement of private sector in REDD+ finance *(high confidence)*. With regard to the compliance carbon markets, at the international level, integrating climate cooperation through carbon markets into Article 6 of the Paris Agreement and including REDD+ has potential to enable emission reduction in more cost-effective way, while the links between carbon markets and REDD+ under the Article 6 is under discussion at the

UNFCCC (Environmental Defense Fund 2019; Maguire et al. 2021) (see Chapter 14). At the national and subnational levels, although compliance carbon markets such as in New Zealand, Australia and Colombia allow forest carbon units, how REDD+ will be dealt in the national and subnational government- led compliance carbon markets are uncertain (Streck 2020; Maguire et al. 2021). As for limited engagement of private sector in REDD+ finance, there are various reasons why mobilising more private finance in REDD+ is difficult (Dixon and Challies 2015; Laing et al. 2016; Golub et al. 2018; Ehara et al. 2019; Streck 2020). The challenges include the needs of a clear understanding of carbon rights and transparent regulation on who can benefit from national REDD+ (Streck 2020); a clear regulatory framework and market certainty (Dixon and Challies 2015; Laing et al. 2016; Golub et al. 2018; Ehara et al. 2019); strong forest governance (Streck 2020), and implementation of REDD+ activities in different levels, national and subnational levels. Other challenges are associated with the nature of forest-based mitigation activities, the costs and complexity for monitoring, reporting and verification of REDD+ activities, because of the need to consider the risks of permanence, carbon leakage, and precisely determine and monitor the forest carbon sinks (van der Gaast et al. 2018; Yanai et al. 2020). Although REDD+ has many challenges to mobilise more private finance, there is discussion on exploring other finance opportunities for forest 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 mitigation activities (World Bank 2017).

Private finance opportunities for nature-based solutions. 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 sustainable sources of public/private finance to tap into (Toxopeus and Polzin 2017; Mok et al. 2021) *(high confidence)*. However, the demand of establishing new finance and business models to attract both public and private finance to nature-based solutions is increasing in a wide range of topics such as urban areas, forestry and agriculture sectors, and blue natural capital including mangroves and coral reefs (Toxopeus and Polzin 2017; EIB 2019; Cziesielski et al. 2021; Mok et al. 2021; Thiele et al. 2021; UNEP et al. 2021) 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; Dasgupta 2021; TNFD 2021). Development of finance and business models for nature-based solutions need to be explored, for example through utilizing a wide range of financial instruments (e.g. equity, loans, bonds, and insurance), and creating standard metrics, baselines and common characteristics for nature-based solutions to promote the creation of a new asset class (Thiele et al. 2021; UNEP et al. 2021).

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 (*high confidence*). 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). This gender gap is the percent of men and women with bank accounts as measured and reported in the Global Financial Inclusion (Global Findex) database. Policies and framework to expand and enhance financial inclusion also extend to the area of climate finance (*high confidence*). 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 (Williams 2015a; Chan et al. 2018; Wong et al. 2019). Nonetheless, the existing global policy framework (entry points, policy priorities etc.) of climate funds is gradually improving in order to support women's financial inclusion in both the public and the private dimensions of climate finance/investment (Schalatek 2015; Chan et al. 2018; Schalatek 2020). 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 such as the UNFCCC's funds managed by the Global Environment Facility, the Green Climate Fund and the World

Bank's CIFs (Schalatek 2015; Williams 2015a; GGCA 2016; GCF 2017) (*high confidence*). But according to a recent evaluation report, 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' (GEF Independent Evaluation Office 2017; Schalatek 2018). 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 Least Developed Countries Fund adaptation projects' (GEF Independent Evaluation Office 2017; Schalatek 2018). While the GCF requires funding proposals to consider gender impact as part of their investment framework[7], 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).

Overall, efforts to promote gender responsive/sensitive climate finance, at national and local levels, both in the public and private dimensions and more specifically in mitigation-oriented sectors such as clean and renewable energy remains deficient (*high confidence*). Recent developments in the capital markets in the areas of social bond are focused around gender bonds -- debt instruments targeted to activities and behaviours that are relevant to gender equality and women's empowerment. These bonds are aligned with Sustainability-linked Bonds as well as Social Bonds Principles of the International Capital Market Association. Issuances of gender-labelled bonds are increasing in the Asia Pacific region (the most comprehensive initiative is the Impact Investment Exchange's (IIX) multi-country USD150 million Women's Livelihood Bond[8]) and in Latin America, Columbia, Mexico and Panama each have gender bond issuances). Additionally, a few developing countries, such as Pakistan (May 2021) and Morocco (March 2021) have issued gender bond guidelines for financial market participants.

Linkage to sectoral climate change issues and gender and climate finance. Subsets of actions designed to enhance women's more formal integration into climate policies, programmes and actions by the global private sector include: investment in clean energy, redirecting funds to support women and vulnerable region as a component of social and green bonds as well as insurance for climate risk management. In the latter context, 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 Group et al. 2015; GIZ et al. 2017). However, across the board and in particular with regard to public funds, despite improvements in the substantive gender sensitization and operational gender responsiveness of multilateral and bilateral climate finance funds operations, current flows of public and climate finance do not seem to be going

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[7] FOOTNOTE[7] Notably, the GCF provides guidance to Accredited Entities submitting funding proposals on the inclusion of an initial gender and social assessment during the project planning, preparation and development stage and a gender and social inclusion action plan at the project preparation stage.

[8] FOOTNOTE[8] The WLB series has been on the market since 2017 when WLB1 was launched. WLB2 issuance of $12 million arrived January 2020. WLB 3was launched December 2020 **to** support 180,000 underserved women and women entrepreneurs in the Asia Pacific to respond, to recover from, and to build resilience in the aftermath of the COVID-19 pandemic. See (IIX 2020) and (Rockfeller Foundation and Shujog 2016).

to women and the local communities in significant amounts (Chan et al. 2018; Schalatek 2020). 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 local response in ensuring effective and sustainable climate strategies that can contribute to the global goals of the Paris Agreement (Minniti and Naudé 2010; Bird et al. 2013; Barrett 2014; Eastin 2018). 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 role of climate finance and the finance sector for a transformation towards a sustainable future?

The Paris Agreement has widened the scope of all 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 on that goes much beyond traditional flows and relates to all sectors and actors. Finance flows are consistent when the effects are either neutral with or without positive climate co-benefits to climate objectives; or explicitly targeted on climate benefits in adaptation and/or mitigation result areas. 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 strengthen the financial sector as enabler.

FAQ 15.2 What's the current status of global climate finance and the alignment of global financial flows with the Paris Agreement?

There is no agreed definition of climate finance. The term 'climate finance' is applied to the financial resources devoted to addressing climate change by all public and private actors from global to local scales, including international financial flows to developing countries to assist them in addressing climate change. Total climate finance includes all financial flows whose expected effect aims to reduce net greenhouse gas (GHG) emissions and/or to enhance resilience to the impacts of current and projected climate change. This includes private and public funds, domestic and international flows and expenditures. Tracking of climate finance flows faces limitations, in particular for national climate finance flows.

Progress on the alignment of financial flows with low GHG emissions pathways remains slow. Annual global climate finance flows are on an upward trend since the fifth Assessment Report, according to CPI reaching more than 630 billion USD in 2019/2020, however, growth has likely slowed down and flows remain significantly below needs. This is driven by barriers within and outside the financial sector. More than 90% of financing is allocated to mitigation activities despite the strong economic rationale of adaptation action. Adjusting for higher estimates on current flows for energy efficiency based on IEA data, the dominance of mitigation becomes even stronger. Persistently high levels of both public and private fossil-fuel related financing as well as other misaligned flows continue to be of major concern despite promising recent commitments. 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.

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

A financing gap is defined as the difference between current flows and average needs to meet the long term goals of the Paris Agreement. Gaps are driven by various barriers inside (short-termism, information gaps, home bias, limited visibility of future pipelines) and outside (e.g. missing pricing of externalities, missing regulatory frameworks) of the financial sector. Current mitigation financing flows come in significantly below average needs across all regions and sectors despite the availability of sufficient capital on a global basis. Globally, yearly climate finance flows have to increase by factor between 3 to 6 to meet average annual needs until 2030.

Gaps are in particular concerning for many developing countries with COVID-19 exacerbating the macroeconomic outlook and fiscal space for governments. Also, limited institutional capacity represents a key barrier for many developing countries burdening risk perceptions and access to appropriately priced financing as well as limiting their ability to actively manage the transformation. Existing fundamental inequities in access to finance as well as its terms and conditions, and countries exposure to physical impacts of climate change overall result in a worsening outlook for a global just transition.

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