Scaling up climate finance in the context of Covid-19

A science-based call for financial decision-makers

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Foreword

To avoid catastrophic climate change, 197 countries adopted the Paris Climate Agreement in 2015. It aims to limit the increase of global average temperatures since pre-industrial levels to well below 2°C, while pursuing efforts to stay within 1.5°C. Bringing all countries together to achieve this Agreement in 2015 is one of my proudest personal achievements as UN Secretary-General. Since the historic agreement, 123 countries responsible for 63% of emissions have adopted or are considering net-zero targets. These net-zero targets have put the Paris Climate Agreement's goals within striking distance.

Financing a rapid transition to a net-zero, climate-resilient economy in line with the goals of the Paris Climate Agreement will require significantly greater investments, investments in a different set of assets, and investments that address the humanitarian imperative of social inclusion and poverty alleviation. Rapid decarbonization will have an overall net benefit but also significant distributional trade-offs.

Climate change places a triple responsibility on financial decision-makers, regulators of the financial systems and governments. First, they must maintain the capacity of the financial system to support economic activity, encourage entrepreneurship, and safeguard the assets of millions of people. Second, they must channel a much larger share of world private savings towards sustainable investments and low-carbon options.

Third, they must maximize the development co-benefits of climate policies. This is a precondition to scale up climate action in the context of the Covid-19 pandemic. Decisions taken by leaders today to revive economies will either entrench our dependence on fossil fuels or put us on track to achieve the Paris Climate Agreement targets and the Sustainable Development Goals.

A clear conclusion from the IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels is that the sooner we act, the lower the physical and transition risks of climate change and the higher the synergies between climate action and other societal benefits.

However, financial actors might not fully anticipate the consequences of climate change as it initially affects geographies that represent a limited share of the market economy and capital flows. In one scenario, the financial system could ultimately disengage from threatened assets but would transfer to communities and taxpayers the costs of climate damage. In a second scenario, the financial system would not readjust on time in function of new information, endangering the stability of the entire financial system. In both cases, the financial system would fail to deliver on its triple responsibility to address climate change.

This publication is a science-based call to financial decision-makers to incorporate climate change in the valuation of financial assets and to lead the transition to net-zero, climate resilient economies. Every policy and every investment have an impact on the future. Policy makers and financiers continuously forecast future conditions. The report outlines how they can use models to understand the financial implications of climate change and capitalize on the new opportunities of a climate economy. Together, we must ensure that our response to the double tragedy of climate change and Covid-19 finances a safer, fairer, and sustainable future for us all.

Ban Ki-moon
President and Chair of the Global Green Growth Institute
8th Secretary-General of the United Nations

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Executive Summary

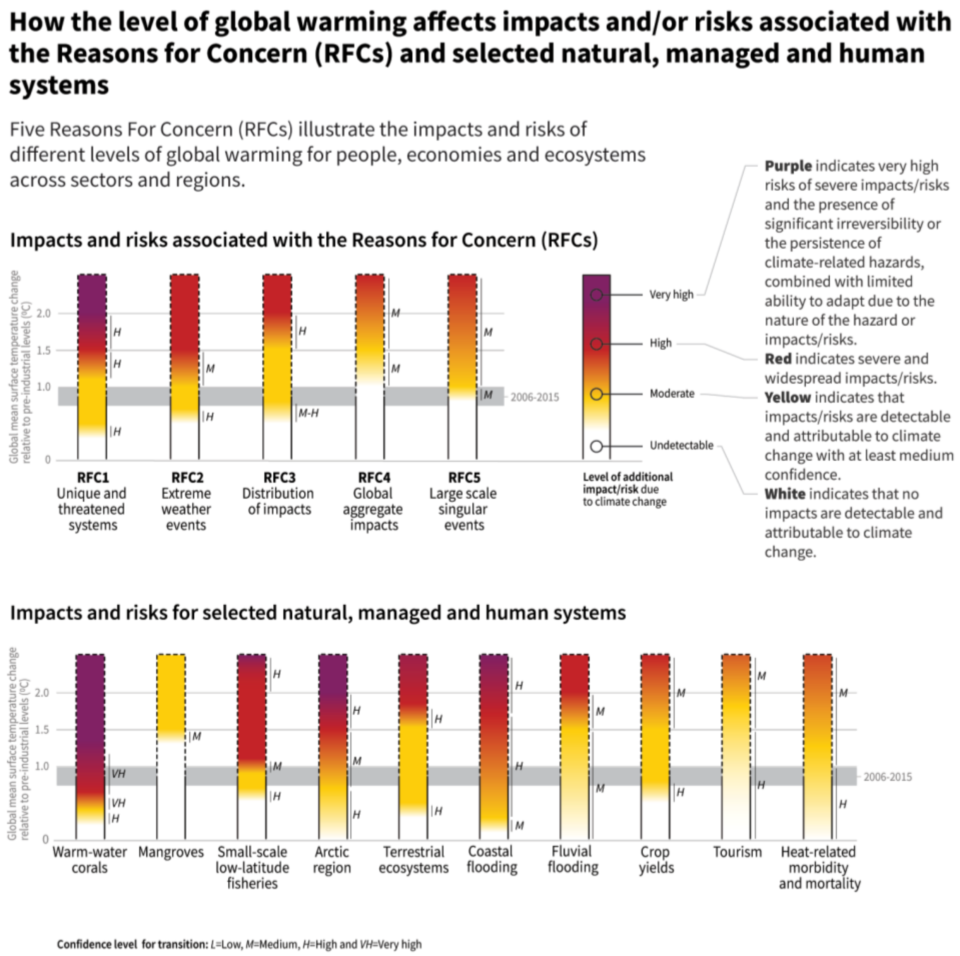
This publication aims to help financial decision-makers incorporate climate change in the valuation of financial assets and accelerate the transition to a net-zero, climate resilient economy, based on the latest scientific findings and policy developments.

What climate science says about risks associated with climate change

The earth's surface global mean temperature is currently 1.0°C higher (0.8°C - 1.2°C range) than in the pre-industrial period (1850-1900). It has increased faster in these 170 years than at any other time in the past 800,000 years. This trend is unequivocally linked to human activities responsible for the release of greenhouse gases (GHGs) (IPCC 2018). The atmospheric concentration of carbon dioxide (CO_2) has increased from 280 ppm (parts per million) in 1850-1900 to 417 ppm in 2020, predominantly due to fossil fuel combustion, cement manufacturing, and land use change (deforestation, removal of land cover and land tilling).

Multiple lines of evidence show warming is already affecting all earth systems and many human systems, and that its impacts are more severe than initially anticipated. As shown in Figure 1 below, we fear today that a 2°C increase in mean global temperatures could wipe out 90% of coral reefs and endanger the security and economic livelihoods of hundreds of millions of people.

Figure 1: Climate risks depending on global mean temperature increases.



Source: IPCC. (2018).

The net impact of warmer climates on people, ecosystems and the economy is the result not only of temperature increases, but also of the capacity to prevent damage and adapt to the changing circumstances. The impacts of a warmer world experienced so far are distributed unevenly. For most countries in the Global North, the evidence of net economic impacts so far is inconclusive, but in most poor countries global warming is already having a negative impact on gross domestic product (GDP) and wellbeing.

To avoid catastrophic climate change, 197 countries in 2015 adopted the Paris Agreement. Its aim is to limit the increase of global average temperatures since pre-industrial levels to well below 2°C, while pursuing efforts to stay within 1.5°C. Cumulative CO_2 emissions and global mean temperature increase are directly related. To stabilise the global mean temperature, global net CO_2 emissions must decline to zero. Table 1 compares global net CO_2 emission declines depending on the targeted limit to global warming.

Table 1. Global CO_2 emissions decline and year of reaching net zero CO_2 emissions associated with limiting warming to 1.5°C and 2°C. Interquartile ranges are shown in square brackets (based on table 2.4 in Rogelj et al., 2018).

Long term (2100) temperature limit	Global CO_2 emissions reduction in 2030 compared to 2010	Year of reaching net zero CO_2 emissions	Year of reaching net zero GHG emissions
1.5°C	45% [40-60%]	2050 [2045-2055]	2065 [2060-2085]
2°C	25% [10-30%]	2070 [2065-2080]	2090 or thereafter

The Nationally Determined Contributions (NDCs) as of 2018 do not yet chart a path towards net-zero CO_2 emissions. Their full implementation is projected to result in warming within about 2.9°C - 3.4°C until the end of the century. The difference in projected impacts between 1.5°C and 2°C is already significant, but the difference in impacts between 2°C and 2.5°C is projected to be even greater. This increases further at higher temperatures. The estimated impacts at 3°C or 4°C of warming are expected to trigger very large, abrupt, or irreversible changes in the climate system with cascading impacts on nature and humans.

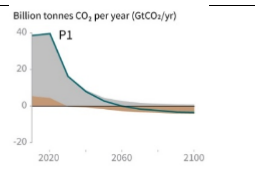
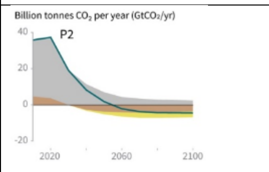
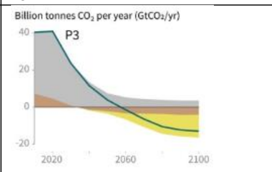
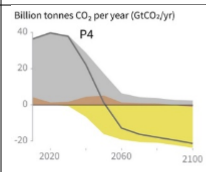
For example, chances of a major heatwave occurring in somewhere in the world in a given year increases five- to sixfold in a 1.5°C warmer world compared to the past three decades and almost twentyfold in a 4°C warmer world. For global staple foods, the chances of a damaging hot spell increases around twofold for rice and fourfold for maize in a 4°C warmer world compared to 1.5°C.

We still have choices in how we limit warming to 1.5°C. To illustrate this, the Intergovernmental Panel on Climate Change (IPCC) in its Special Report on global warming of 1.5°C (SR1.5 2018) highlighted four illustrative emission pathways that give us a 50% to 66% chance of limit warming to 1.5°C with limited or no temporary temperature overshoot (see table 2). All of them accelerate the deployment of fossil-free energies but they differ in the emphasis placed on reducing CO_2 emissions more quickly in the next decades by lowering energy demand through behavioural change compared to relying on great quantities of carbon dioxide removal (CDR) (P1 and P2 pathways versus P3 and particularly P4 in table 2).

Pathways relying on CDR have greater uncertainties on technological maturity and economic, socio-cultural, and institutional feasibility, and are likely to present greater trade-offs with food and water security, and biodiversity protection and restoration. Of the four illustrative pathways, P1 minimizes these uncertainties and trade-offs while P4 would exacerbate tensions between mitigation, adaptation and the Sustainable Development Goals (SDGs). Such tensions would represent economic and financial risks, for instance if they lead to a sudden shift in development strategies.

The longer the delays, the higher will be the adaptation needs. Fundamentally, adaptation cannot be disconnected from overall sustainable development trajectories (IPCC 2018) because the magnitude of risk climate change poses is also a result of existing vulnerabilities and capacities to anticipate and adapt. Thus, development interventions such as reducing the infrastructure investment gaps or improving health systems intrinsically build adaptive capacities and reduce risk.

Table 2: Climate risks characteristics of four illustrative pathways.

	P1	P2	P3	P4
				
	Fossil fuel and industry AFOLU BECCS			
Storyline	Social, business and technological innovations; lower energy demand by 2050; higher living standards (also in the global South); downsized energy system; rapid decarbonisation of energy supply; afforestation the only CDR option considered; no CCS.	Focus on sustainability incl. energy intensity; human development; economic convergence; international cooperation; shifts towards sustainable and healthy consumption patterns; low-carbon technology innovation; well-managed land systems; limited BECCS.	Societal and technological development follow historical patterns; emissions reductions through changing production of energy and commodities rather than through reductions in demand.	Economic growth and globalisa gas-intensive lifestyles, includin for transportation fuels and live emissions reductions mainly thr technological means; CCS and E
Temperature outcome (within 0.1°C accuracy, median estimate)	Warming limited to 1.5°C	Warming limited to 1.5°C	Warming limited to 1.6°C	Warming exceeds 1.5°C limit by assumption it can be reversed b
Risk of overshoot of 1.5°C	Small	Small	Large	Very large (designed to first mis
Alignment with sustainable development	Very strong	Strong	Medium, with potential trade-offs	Weak, with marked trade-offs
Physical climate risks to 2050	Lowest	Low	Medium	Highest
Physical climate risks after 2050*	Low	Lowest	Low	High
Transition risks & Opportunities				
Energy demand reduction/management	Very high	High	Medium	Low
Energy supply Infrastructure investments	Lowest	Medium	High	Highest
Asset stranding	Near-term retirement of fossil-fuel assets	Near-term retirement of fossil-fuel assets	Moderate stranding of fossil-fuel assets	Stranding delayed by a decade higher magnitude**
Reliance on CDR	Small	Medium	Large	Extreme
Deployment of land-based mitigation & bioenergy	Medium	Medium	High	Extreme
Discontinuation risks	Failure to achieve demand and behavioural changes may leave little time to ramp up supply-side measures like CCS.	Full portfolio of supply and demand options hedges against failures and discontinuation risks	Failure to address potential trade-offs from land-based mitigation, risks policies being reversed due to societal concerns.	High risk of necessary post-203 strongly competing with other s and hence not being implemen discontinued.

Source: IPCC. (2018).

Adaptation actions might also be maladaptive or insufficient. *Maladaptation* denotes adaptation actions that disproportionately burden the most vulnerable, have high opportunity costs, reduce the incentive to adapt or instil path dependency. In some places and for some human and ecological systems, there are *limits to adaptation* when the pace of climate change impacts makes the prevention of intolerable risks impossible (Klein et al., 2014). Such limits emerge either from situations where the technological or institutional capacity to adapt is 'by passed' by the pace of damage or from hard constraints such as thermal limits of survival for species, or sea level rise that makes permanent relocation the only viable adaptation strategy in certain low-lying areas.

Scaling up both climate mitigation and adapation is critical to reduce the physical and transition risks from climate change. Physical risks stem from the impact of climate change and transition risks are related to uncertainties about technological innovations, changes in legislation and regulation, implementation of a carbon tax and changes in consumer behaviour (e.g., a shift in attitudes towards the purchase of diesel cars, air travel or deforestation-based products).

Reducing the physical and transition climate risks on society will require an acceleration of the transition of our socio-economic systems towards zero-emission development pathways to avoid physical and detrimental social tipping points. For adaptation and mitigation, four system transitions are key: the energy system transition, the land and ecosystem transition, urban and infrastructure system transitions, and the industrial system transition.

The combination of aggregated but integral modelled pathways and a detailed assessment of the *feasibility* of mitigation and adaptation options across the four systems transitions reveals that it is still the technical feasibility space to limit warming to 1.5°C. However, the technical maturity and cost efficiency of many options need to be improved, especially in hard-to-decarbonize sectors. Furthermore, some options that are already financially attractive are hampered by systemic barriers, including those in the financial system. The systems transitions will require a dramatical scale-up of climate-related innovation and investment and a rapid decline in investments in low carbon options.

Climate Investments: proactive approaches for addressing gaps and realizing opportunities

Financing a rapid transition to a net-zero emission, climate-resilient economy will require significantly more investment in low carbon and climate resilient options. They will be scaled up at the required level only if they alleviate and do not exacerbate the short-term economic and social tensions. They must also address the imperative of social inclusion and poverty alleviation (UNFCCC, 1992).

This places a triple responsibility on financial decision-makers, financial system regulators and governments:

- Maintain the capacity of the financial system to support economic activity, encourage entrepreneurship, and safeguard the assets of millions of savers, pensioners, local public institutions, and businesses;
- Channel a much larger share of private savings towards sustainable and low carbon options; and
- Create a business environment in which climate policies alleviate today's tensions in the world economy (unemployment, poverty, inequality, trade disputes).

The Network for Greening the Financial System (NGFS, 2019) estimates that between 2% and 5% of total financial assets are directly at risk. The Sustainability Accounting Standard Board (2016) indicates that climate-related risks could impact 72 out of 79 industries assessed representing 93% of equities (or $27.5 trillion) by market capitalization in the US alone. Financial players will progressively integrate physical risks under a 'value at risk' framework, and revise them according to new information, but it is not certain that this integration will happen fast enough to maximize the chances of a P1 or P2 scenario.

Financial actors might not immediately anticipate the consequences of climate change as it is initially affecting zones that represent a limited share of the market economy and capital flows. In a first scenario, the financial system would ultimately disengage on time from threatened assets but would transfer the costs to communities and taxpayers. In a second scenario, the financial system would not readjust on time in function of new information, endangering its own entire stability. In both cases, the financial system would fail to deliver on its triple responsibility to address climate change.

Understanding the challenge of climate finance requires differentiating between global low-carbon investment needs, and the amounts needed to bridge the infrastructure investment gap (IMF, 2014). Global low-carbon investment needs are estimated between 3.9% and 8.7% of the world's GDP over the next two decades. However, the additional investments compared to a business-as-usual scenario could be funded by redirecting between 1.4% and 3.9% global savings (2.4% on average, see box 4.8

of IPCC, 2018) that currently flow towards real estate, land, and liquid financial vehicles. This task is not insurmountable macroeconomically. More challenging is that it has to be achieved together with the reduction of the infrastructure investment gap. This gap could be of 15.9% (Global Infrastructure Hub 2017) or even 32% (Arezki et al., 2017) between 2035 and 2040 for a cumulative value between $14.9 and $30 trillion worldwide.

The global infrastructure investment gap reflects risk-averse behaviours that cause a wedge between the propensity to save and the propensity to invest. It also represents a misalignment in the geographic distribution of savings, capital flows, and infrastructure investment needs. Developed countries have ageing populations, high saving capacities, established social safety nets, and the bulk of their infrastructures in place. Developing countries have a significant opportunity to leapfrog as they still must build two-thirds of their infrastructure capital. They have young populations, a wide range of savings rates (from 15% to over 40%) and underdeveloped social safety nets.

This misalignment is compounded by the limited capital flows from high-saving to low-saving regions. From a microeconomic point of view, the infrastructure investment gap looks like an economic paradox since, with current low-interest rates, infrastructure investments deliver a real return between 4% and 8% (Bhattacharya et al., 2016). With an estimated $14 trillion of negative-yielding debt in OECD countries and $26 trillion of low carbon, climate-resilient investment opportunities in developing countries by 2030, capital in search of higher results should flow from developed to developing countries to address this gap. This is not happening. Three-quarter of global climate finance is deployed in the country in which it is sourced, revealing a strong preference for home-country investments where risks are well understood. This explains why sub-Saharan Africa accounted for only 5% of climate-related financial flows in non-OECD countries, at $19 billion (CPI, 2019).

Neither financial investors nor project developers try and take advantage of what the IMF's World Economic Outlook (Abiad et al., 2014) describes as 'free lunch' opportunities because these opportunities face several political, regulatory, macroeconomic, and technical barriers. These barriers and associated business costs are magnified in developing countries because of the considerable differences in their creditworthiness. The spread between the interest rate of a bond issued by the US government and the interest rate of loans to a given country comes on top of projects' risk premium. In 2018, it was 1.30% for a five-year project and 2.5% for a ten-year project in BBB-rated countries. At the beginning of 2020 it jumped to 6% and 9%, respectively, in B-rated countries. Before the Covid-19 crisis, more than 60 countries were rated below BBB and had access to capital only at interest rates higher than 18% for two-year projects. The impact of this inequality is exacerbated by the fact that countries in this class are often those whose creditworthiness might be the most affected by climate change damages (Buhr et al., 2018).

Two approaches are advocated to incentivize the changes needed in investment, production, and consumption patterns and induce technological progress that brings down carbon abatement costs on time to avoid catastrophic climate change: market fixing and market shaping.

The market-fixing approach aims to send the right pricing and risk signals to enable financiers to better value assets and reallocate capital accordingly. To achieve these objectives, it calls on scaling up carbon pricing and promoting climate risk disclosure and taxonomies. There is a widely shared consensus in economics that, in a frictionless world with perfect capital markets and without uncertainty, carbon prices would be sufficient to secure the attractiveness of low carbon options for capital markets. In the real world, however, the carbon price signal is swamped by the noise of other signals, such as oil prices, interest rates, and currencies exchange rates in addition to business uncertainty.

The high-level commission led by Nicholas Stern and Joseph Stiglitz (Stern-Stiglitz, 2017) estimated that carbon prices should be set at a higher level than the \$40–80/tCO2 by 2020 and \$50–100/tCO2 by 2030 to be capable to cover these noises. The scaling-up and geographical expansion of carbon prices to such levels are highly uncertain. The adverse economic and distributive effects of higher energy prices and the removal of fossil fuel subsidies are more severe for low-income countries, countries with a large share of energy-intensive activities, and countries exporting fossil fuels.

The full deployment of climate risk disclosure and taxonomies faces a different set of challenges. Historically, the concerns about the implications of climate change for the financial community arose from potential fiduciary obligations of reinsurers and pension funds. The focus on liability risks responded to the advocacy strategies deployed by universities' endowments and mission-based investors such as philanthropic and religious organisations to remove the 'social license' from the fossil fuel industry and to raise the cost of its access to capital.

Marc Carney's speech (2015) on *the 'tragedy of the horizons'* broadened this perspective, adding the 'physical risks' and the 'transition risks' to the 'liability risks'. This alert from the former Governor of the Bank of England had an influence amongst financial actors who generally do not consider the future beyond a quarterly horizon. This discussion led to the creation of a Taskforce on Climate-related Financial Disclosures (TCFD) under the auspices of the Financial Stability Board (FSB) that brings together financial authorities from G20 countries to prevent new financial crises. Climate disclosure is meant to help asset managers to correct their short-term bias and send financial signals to investors by setting the cost of loans in an inverse proportion of the projects' carbon content, thereby hedging against abrupt corrections in financial markets caused by cumulated mispricing of assets.

In late 2017, the Network for Greening the Financial System (NGFS) was launched. It now has 90 members, amongst which central banks from many developed and developing countries. Observers include the IMF, the World Bank, the Bank for International Settlements, the Basel Committee for Banking Supervision, and the Green Climate Fund (GCF). Its first report established a taxonomy of green, non-green, brown, and non-brown products (NGFS, 2019) to help direct investments to sustainable options. In parallel, stress test methodologies have tried to assess the risk exposure of various asset portfolios. The concrete outcome of these processes is still uncertain, but they show an increasing demand for knowledge tools from high-level decision-makers in an uncertain environment.

While market-fixing approaches address information barriers for financiers, the market shaping approach has gradually emerged over the past 30 years to address both demand and supply barriers to climate finance. It aims to tackle several risks that deter entrepreneurs and financiers from exposing their resources:

- (i) Political and regulatory risks arising from governmental actions, including changes in policies or regulations that adversely impact infrastructure investments;
- (ii) Macroeconomic and business risks arising from the possibility that the industry and/or the economic environment are subject to change; and
- (iii) Technical risks determined by the skills of operators and managers, and related to the features of the project (e.g. its complexity, construction, and technology).

A direct consequence of these risks is the limited supply of high-quality, transparent low-carbon climate-resilient investment projects despite the unmet demand for new infrastructures.

The need to address market and investment barriers to low carbon options has inspired the development of a wide array of public measures. According to the International Energy Agency's Policies and Measures Database, over 5,500 climate policies and instruments are currently in use globally. Table 3 shows the main types of instruments.

Table 3: Environmental Policies Instruments

	Information and empowerment instruments	Control and regulatory instruments	Economic and market instruments	Institutional instruments	Financial instruments
Market Creation Instruments	Rely on knowledge, communication, and persuasion to influence behaviour and supply skilled labour.	Rely on the establishment of obligations, encouraging or prohibiting or restricting certain types of behaviour	Financial incentives and disincentives to influence private sector behaviour and investment decision-making	Create an institutional and organizational environment to facilitate policy and technology development and deployment	Direct public sector (co) investment to establish a proof of concept or commercial track record of new solutions
Demand-side instruments	▶ Information disclosure and green taxonomies (climate risks, carbon liabilities, etc.)	▶ Macro-prudential regulations (climate stress tests for banks and insurers, etc.)	▶ Carbon taxes, phase out of fossil fuel subsidies ▶ Development of new asset classes ▶ Fossil fuel divestment by public financial institutions	▶ Green finance regulatory networks, asset managers coalition and central bank coordination mechanisms	
	▶ Long-term policy commitment and targets ▶ Valuation methodologies ▶ Public awareness and persuasion	▶ Mandates ▶ Ban ▶ Zoning ▶ Building codes ▶ Norms and minimum performance standards ▶ Standards and labels	▶ Taxes/tax breaks (e.g., carbon taxes) ▶ Charges and penalties ▶ Favourable tariffs ▶ Green procurement ▶ Advanced market commitment ▶ Tradable permits and quotas	▶ Establishment / restructuring of environmental institutions ▶ Development of R&D networks and ecosystems	
Supply-side instruments	▶ Investment in education and research ▶ Technical and vocational training and retooling	▶ Streamlining licensing processes	▶ Power purchase agreements ▶ R&D commissioning ▶ Property rights agreements	▶ Dedicated financial institutions (green banks, green guarantee companies, green bond platforms, etc.)	▶ Public sector-led R&D ▶ Project concessional finance (grant and loans) ▶ Incubation grants/venture capital ▶ Guarantees ▶ Equity investment

The first four columns list environmental policy instruments that create a business context conducive to the demand for low carbon investments and the supply of low carbon projects, including by reducing their transaction costs. In contrast, financial de-risking instruments do not seek to change the overall business context to reduce risks but tackle projects' risks by transferring part of them to public actors. They blend public and private resources, often to encourage market-creating projects that will establish a proof of concept (innovation to market) or commercial track record (market deployment) for new climate solutions. The structuring approach of financial de-risking instruments is often referred to as 'blended finance'.

A common limit of these instruments lies in the fact that the tighter the public funding constraints, the lower the political credibility of their maintenance over time. Combined with the difficulty of controlling opportunistic behaviours in subsidies, this can lead public budget officers working under tight constraints and competing demands to lower support to these measures or make their administration particularly complex.

Furthermore, blended finance has proven effective for mature technologies in mature markets, but not for early-stage technologies in early-stage markets. Over 2012-18, $205.1 billion was mobilized from the private sector by official development finance interventions. But only 5.3% of these flows went to Least Developed Countries (LDCs) and other Low-Income Countries (LICs), and very little to adaptation and nature-based solutions (CPI, 2019). The role of guarantees was particularly important in these countries, as they mobilised 62% and 46% of the resources in 2015-16 and 2017-18 respectively. Direct equity investment followed, mobilizing 14% and 24% of the resources in 2015-16 and 2017-18 respectively (Attridge and Engen, 2019). However, blended finance has usually taken the form of relatively safe senior debt rather than guarantees and equity.

While blended finance aims to use public resources in a catalytic manner to align private sector flows with sustainable development, the leverage ratio of blended finance for climate change is very low. On average, every $1 of resources invested from multilateral development banks (MDBs) and development finance institutions (DFIs) leveraged just $0.37 of private finance in LICs because of a poor business context (Attridge, and Engen, 2019). The geographic and thematic concentration of blended finance and its low leverage ratio are significant obstacles to tapping into the vast private savings pool to reduce the infrastructure investment gap in emerging economies.

In theory, market-fixing approaches can be embedded within broader market-shaping efforts (see Table 3 placing key market-fixing policies within measures directed at the demand side - top line). In practice, market-fixing and market-shaping approaches tend to emphasize different sub-sets of public instruments.

Market fixing relies on price signals to create a demand for low-carbon low-climate-risk goods and services and shift financial flows towards climate-friendly investments. Market shaping intervenes at the level of sector policies and endeavours to create a demand and directly de-risk the supply of climate-friendly investments to crowd-in private finance.

Experience to date, however, shows that these two approaches are mutually supportive and should be deployed in tandem. The combination of the two sets of instruments helps overcome the constraints inherent to each approach and increases the overall efficiency and effectiveness of public policies and finance to accelerate the transition to net-zero climate-resilient economies.

Scaling Climate Finance in the context of Covid-19

The Covid-19 pandemic has pushed the global economy into the deepest recession since the Second World War. The World Economic Outlook (April 2021) estimated a 3.5% contraction in global growth in 2020, which is far higher than the 0.1% recorded after the 2008 financial crisis. The situation has been particularly devastating for developing countries. During the subprime crisis they continued growing, with a rate of 2.8% in 2008 (World Bank, 2020a), whereas their GDP in 2020 contracted by 2.6% and 5% respectively, China excluded (World Bank, 2021). In addition to the health consequences of the pandemic, these countries experienced sharp drops in commodity export prices, including oil prices, a collapse in tourism revenues, reduced exports to developed economies, and the blocking of specific nodes in the supply chain. This led to an increase of the number of people facing food insecurity from 135 million in 2010 to 272 million in 2020 and a significant transfer of the employed population into 'inactivity' (ILO, 2020). An additional 500 million people have fallen below the poverty line. This increase, the first in thirty years, was particularly acute in LDCs and Small Island Developing States (SIDS) (UNU WIDER, 2020).

To rescue their economies and support a strong recovery, governments are adopting large-scale expansionary fiscal measures. The fifty largest economies in the world have announced \$14.6 trillion in fiscal spending in 2020, of which \$1.9 trillion is for long-term economic recovery (UNEP, 2021). There is a disparity between announced spending by advanced economies (22.5% of their combined GDP), and that of emerging markets and developing countries (10.6%) - a 17 times greater amount on a per capita basis (UNEP, 2021). One of the key reasons for this disparity is the difference in the cost of additional debt. For most high-income countries, the cost of additional debt is close to 0% per annum. For developing countries, with low credit ratings, interest rates are significantly higher, increasing the cost of any new debt thus burdening fiscal budgets. The proportion of poorest countries in or at high risk of debt distress has climbed to 55% in January 2021, from 50% in 2019 and 26% in 2013 (LIC Debt Sustainability Framework).

The Covid-19 crisis has brought the world at a crossroad in the fight against climate change. Shan et al. (2020) have shown that carbon-intensive packages would increase global five-year emissions (2020 to 2024) by 16.4% (23.2 Gt) while the 'greenest' one could reduce them by 4.7% (6.6 Gt). Forster et al. (2020) show that a 'colourless' recovery would put the world on an emissions pathway that would pass the 1.5°C threshold within a decade and the 2°C limit soon after 2050, whereas the world has a

50% chance to stay below the 2°C warming target with a moderate green stimulus, and below 1.5°C with a solid green stimulus. The UN Environment Programme (2021) finds that, in the 50 largest economies, only 18% of recovery spending and only 2.5% of total spending will enhance sustainability. In 2020, G20 countries spent $208.73 billion supporting fossil fuel energy, compared with at least $143.02 billion supporting clean energy.

Advanced economies are undertaking expansionary fiscal measures, but the present low green content of their recovery packages could entrench their dependence on fossil fuels and undermine the capacity to meet their net-zero emission targets by 2050. Developing countries, on their side, are suffering from increasingly restricted monetary and fiscal spaces, which seriously undermine their ability to finance mitigation and adaption measures. A weak comeback in regions that represent (China excluded) 55% of the world markets may in turn make the world economic recovery more fragile.

The main argument not to postpone climate action in a context of competing pressures on public budgets is that bridging the infrastructure investment gap would be a blueprint for a fast and robust global recovery thanks to the strong knock-on effect on infrastructure investments, notably unlocking two-thirds of world infrastructure markets currently 'frozen' in developing economies. The public policy devices mobilised to redirect savings towards low-carbon options have the advantage, compared to untargeted recovery measures, to secure the efficiency of every unit of public money spent.

The economic and financial impacts of Covid-19 have exacerbated the four challenges developing countries were already facing to scale up climate action. These countries will need to ensure that climate action and economic recovery are mutually supportive, scale up investment without increasing the debt burden, attract large scale private financial flows in a context of perceived higher investment risk, and secure access to long-term affordable finance at a time of rising capital costs.

These challenges can be addressed through four sets of complementary actions.

1. **Integrating policies on climate action, sustainable development, and Covid-19 stimulus to minimize incremental investment requirements and optimize development co-benefits**

NDCs are at the heart of the Paris Agreement and countries' commitment to transform their development trajectories. Countries are currently in the process of submitting updated and more ambitious NDCs. Integrating policies on climate action, sustainable development and Covid-19 stimulus measures could reduce investment needs by 40% and leverage the stronger economic multiplier of climate action to build back better.

The imperative to green the Covid-19 recovery amplifies the need to translate integrated NDCs into investment plans that: (i) align, combine and sequence multiple sources of international and domestic finance from the public and private sectors; (ii) enable countries to take a more integrated value-chain investment approach, notably by acquiring the technical capacity needed to address policy and regulatory gaps to improve the bankability of the NDC project pipeline; and (iii) identify financial mechanisms and investment patterns that will not increase sovereign debt, but catalyse private funds and increase access to long-term affordable finance.

2. **Alleviating developing countries' debt burden to create fiscal space to finance their green, climate-resilient recovery plans**

Several multilateral actions are being taken to help developing countries cope with the economic crisis and creating more fiscal space. The G20 has suspended – not cancelled – official bilateral debt payments for 42 low-income countries, corresponding to approximately $5 billion. The discussion about the issuance of new special drawing rights (SDRs) has been reopened by the IMF (IMF, 2021). An even bolder action is to consider at scale 'debt-for-climate swaps' - a partial cancellation of debt by the creditor government transforming the remaining part into local currency and directing it to investment in climate action. The use of debt reduction could be a function of a country's overall climate vulnerability.

The scaling-up of new payment facilities (debt-for-climate swaps, SDRs) is complex to design and requires a pipeline of high-quality bankable climate investments, which can be capitalized in the form of credible assets, together with transparent and credible domestic spending. A direct linkage with integrated and costed NDCs and dedicated technical assistance facilities would remove some of these barriers. These unconventional debt management instruments respond to the specifics of the post-Covid-19 context and are additional, not alternatives to the commitment of developed countries to mobilize $100 billion in climate finance per year by 2020 for developing states. Reaching the $ 100 billion commitment is critical to finance essential non-market services as well as the deployment of environmental policy instruments to create a conducive business context to catalyse low carbon, climate resilient private investment.

3. **Leveraging sovereign and multi-country guarantee funds to reduce investment risk and catalyse private finance**

The experience of blended finance highlights the importance of sovereign and sub-sovereign (local governments) guarantees to overcome the barriers hindering climate-friendly investments in nascent technologies in nascent markets. They reduce upfront risks, provide a broad risk coverage, a lower cost for public budgets of donor countries, and a high leverage ratio of public to private capital (Blended Finance Taskforce, 2018).

In a context of heightened risk perception in developing countries, multi-sovereign guarantees, where developed countries rated AAA-AA join forces to provide an AAA-AA backing to developing countries, could:

- Expand developing countries' access to capital markets at a lower cost and longer maturities thanks to the reduction of creditworthiness risks, especially for small states;
- Accelerate the recognition of climate assets suitable for institutional investors seeking 'safe investments havens', thanks to the reputational effect of a selection of projects with multilateral backing and transparent assessment methods;
- Strengthen climate disclosure through high grades in the environmental notation of these climate assets;
- Increase the effectiveness of carbon pricing with more mitigation activities unlocked by a given price level, a stronger employment impact and higher funding facilities to help industries adapt;
- Free up grant capacities for SDGs and adaptation by crowding in private investments for mitigation. For non-marketable activities, grants are the key instrument to develop policy and capacity and establish a conducive investment environment that deals with risks.

4. **Increasing developing countries' access to the green bond market**

The potential of green bonds is estimated at €29.4 trillion over 2030 (Bolton et al., 2020). They can drive new public-private partnerships and increase access of developing countries to long-term affordable debt. The development of green bonds is far below this potential (only $1 trillion in the ten years since their launch and $258 billion in 2019, CBI 2020). They represent about 5% of total bonds issued globally and fell by 11% in 2020 in the aftermath of the pandemic.

Options to significantly broaden developing countries' access to the green bond markets include creating credible and standardized assessments and valuation methods to select, design, value, monitor and report on high-quality bankable climate projects; and enhancing country capacity to design, float and implement green bonds.

Some countries are already exploring the four sets of instruments discussed above. For example, Saint Lucia, one of the SIDS hardest hit by climate change, is translating its NDC into a detailed investment plan exploring financial innovations like resilience bonds and climate debt swaps to supplement public resources and finance these efforts without raising its debt.

Conclusion

Accelerating the transition to reduce emissions along a P1 or P2 pathway is required to maximize development co-benefits and achieve both the Paris Agreement and the SDGs. The P1 and P2 pathways, which entail reducing energy demand and improving energy efficiency, are technical feasible for both adaptation and mitigation. Financing a P1 or P2 pathway will require significantly more investment and investment in a different set of low emission, climate resilient assets.

However, inertia on the part of the financial system means that in the absence of policy interventions, the financial system will not be able to redirect carbon private capital on the needed scale. This will lead towards a P3 or P4 scenario with greater tension with sustainable development outcomes and more severe overshoots cannot be excluded. The Covid-19 pandemic exacerbates this inertia, and with the large fiscal stimulus measures, 'colourless' investments could tip the world beyond the 1.5°C threshold within a decade and the 2°C limit soon after 2050.

To avoid this irreversible outcome, financial flows must first be shifted towards a P1 and P2 pathway. This can be achieved through a combination of market fixing and shaping efforts. Deploying both approaches in tandem helps overcome the constraints inherent to each approach and increase the overall efficiency and effectiveness of public policies and finance to scale up climate action.

Second, four strategic interventions could enable developing countries to address the additional economic and financial challenges created by the pandemic for developing countries to realize their climate ambitions. Together these four interventions – support to integrated and costed climate policy and plans; alleviating developing countries' debt burden; leveraging sovereign and multi-country guarantee funds; and increasing developing countries' access to the green bond market – would enable developing countries to foster a green, climate resilient recovery from the Covid-19 crisis.

These four immediate actions could also have a structural positive impact on the future climate policy architecture. They could a) facilitate the deployment of carbon pricing since de-risking mechanisms will increase the volume of low-carbon investments at a given carbon price; b) magnify the impact of financial transparency and disclosure though the emergence of investments and asset classes of higher credibility; c) reduce the fragmentation of climate and development finance; and d) enhance the capacity of official climate and development assistance to support nonmarketable services.

Introduction

Earth's surface warming since the pre-industrial baseline period (1850-1900) has been faster than at any other time in the past 800,000 years. Currently, the global mean surface temperature is 1.0°C higher (0.8°C - 1.2°C range) than the baseline. Temperatures are rising at an average of 0.2°C (0.1 - 0.3°C) per decade (IPCC, 2018). Warming is unequivocally linked to human activities responsible for the release of greenhouse gases (GHGs) (IPCC, 2018). The atmospheric concentration of carbon dioxide (CO_2) has increased from 280 ppm in the pre-industrial period (1850-1900) to 417 ppm in 2020, predominantly due to fossil fuel combustion, cement manufacturing, and land use change (deforestation, removal of land cover and land tilling) (NOAA, 2019).

Multiple lines of evidence show warming is already affecting all earth systems and many human systems. The net impact of warmer climates on people, ecosystems and the economy is the result not only of temperature increases, but also of the capacity to prevent damage and adapt to the changing circumstances. Poorer countries, where access to information, mobility, infrastructure, and state support is limited, are typically most exposed.

To avoid the catastrophic impacts of climate change, 197 parties adopted the Paris Agreement in 2015, which aims to limit the increase of global average temperatures since pre-industrial levels (1850-1900) to well below 2°C, while pursuing efforts to stay within 1.5°C. The Paris Agreement also aims to increase countries' ability to adapt to the adverse impacts of climate change (United Nations, 2015). This need to be done while eradicating poverty and meeting the UN Sustainable Development Goals (SDGs).

Further rises in temperature and sea level are inevitable until GHG emissions are cut to net zero. A report from the Intergovernmental Panel on Climate Change (IPCC) - the UN body providing scientific information on human-induced climatic changes – established that limiting warming to 1.5°C over the course of the century requires steep reductions by 2030 and net zero CO_2 emissions by 2050.

Since the release of the report, 123 countries responsible for 63% of emissions have adopted or are considering net-zero targets. These net-zero targets have put the Paris Agreement's goals within striking distance (Climate Action Tracker, 2020). Rapid decarbonization will have an overall net benefit but also significant distributional trade-offs. The entire business model of countless profitable corporations will be upended by rapid and deep decarbonization and some countries and communities may be disproportionately affected.

Climate change creates a set of two inter-related challenges for the financial system. First, the impacts of climate change pose growing risk to the financial stability and its capacity to support economic activity and safeguard the assets of millions of savers, retirees, institutions, and businesses. The Network for Greening the Financial System (NGFS 2019) estimates that between 2 and 5% of total financial assets are directly at risk. The Sustainability Accounting Standard Board (2016) indicates that climate-related risks could impact 72 out of 79 industries assessed representing 93% of equities (or $27.5 trillion) by market capitalization in the US alone. Because climate risk cannot be diversified away, investors need to understand and adequately price their exposure to it.

Second, supporting the transition to a low-carbon, climate-resilient economy in line with the goals of the Paris Agreement will require significantly more investment, investment in a different set of assets, and investment that addresses the humanitarian imperative of social inclusion and poverty alleviation (de Coninck et al., 2018).

The financial system has a pivotal role to play in accelerating the transition to a net-zero economy, mitigating climate physical and transition risks, seizing the opportunities that emerge from the economic transformation and ensuring a just transition-precondition to a fast transition. The total value of the net-zero economy is estimated at $2.3 trillion (UN and UAE, 2020).

Based on an extensive review of the scientific and economic literature, the Report highlights the key climate physical and transition risks associated with different low-carbon climate resilient pathways and the imperative for financial decision-makers to integrate climate risks and net-zero opportunities into every single investment decision. While knowledge of the concept of net zero is growing, understanding of its implications for individual businesses is poor - 64% of a survey of 1,000 senior decision makers across a range of industries in all parts of the UK were not confident they fully understood the implications for their firm (Net zero barometer report, 2021).

The Report is divided into three chapters. Chapter I discusses the climate physical and transition risks associated with different climate mitigation and adaptation pathways and their financial implications. Chapter II discusses whether the financial system will be able to redirect private capital at the needed scale in the absence of policy interventions and presents past and on-going efforts to align finance with the sustainable development goals and the Paris Agreement. Chapter III proposes four interventions to achieve this objective in the context of Covid-19.

Chapter 1: What Climate Science says about climate change related risks

Every policy and every investment are a wager on the future. Policy makers and financiers continuously forecast future conditions. Since its 2nd assessment report (1996) the IPCC assesses scenarios of the consequences of business-as-usual behaviours in contrast to mitigation pathways, with the aim of informing decision-makers. This chapter outlines the state of the art of such scenarios and pathways for limiting warming to 1.5°C, identifies how they can be used to understand the financial implications of climate change and climate policies, and outlines the feasibility conditions of the systems transitions needed to avoid the worst consequences of climate change.

1.1.Carbon budgets and mitigation pathways

1.1.1.Carbon Budgets and limits to warming

The remaining carbon budget is the amount of CO_2 that can still be emitted while limiting warming to around 1.5°C or 2°C (see Box 1.1). Pathways that stay within this budget can be described by emission milestones in specific years and can be characterised by two core variables (see Table 1.1):

1. the decline in global annual net anthropogenic CO_2 emissions in 2030 compared to 2010
2. the year in which the goal of net zero CO_2 emissions is reached.

Non-CO_2 emissions in pathways that limit global warming to 1.5°C also require deep reductions, but with little variation between 1.5°C and 2°C (IPCC 2018; Rogelj et al., 2018).

Table 1.1. Global CO_2 emissions decline and year of reaching net zero CO_2 emissions associated with limiting warming to 1.5°C and 2°C. Interquartile ranges are shown in square brackets, based on Table 2.4 in (Rogelj et al., 2018).

Long term (2100) temperature limit	Global CO_2 emissions reduction in 2030 compared to 2010	Year of reaching net zero CO_2 emissions	Year of reaching net zero GHG emissions
1.5°C	45% [40-60%]	2050 [2045-2055]	2065 [2060-2085]
2°C	25% [10-30%]	2070 [2065-2080]	2090 or thereafter

Box 1.1: How the Carbon Budget Determines CO2 Emissions Limits

Cumulative CO_2 emissions and global mean temperature increase are directly related. To stabilise the global mean temperature, global CO_2 emissions must decline to zero. The amount of CO_2 that can still be emitted while keeping warming below a specific temperature is known as the remaining 'carbon budget'. To limit global warming to 1.5°C (i.e. exceeding it by no more than 0.1°C at any point during this century with some likelihood) this budget has been estimated at 420 and 580 billion tonnes of CO_2 ($GtCO_2$) from 2018 onwards in order to have a two-in-three and one-in-two chance, respectively. These estimates can increase or decrease by up to 250 $GtCO_2$ depending on how successfully non-CO_2 GHGs, e.g. methane, are limited. Earth-system feedbacks, like the release of CO_2 and methane from thawing permafrost, could further decrease the carbon budgets by 100 $GtCO_2$ over the course of this century (Rogelj et al., 2018). These numbers are subject to considerable uncertainty and in the past new insights have led to both upward and downward revisions. In addition, the temperature response to GHG concentrations shows a probability distribution.

In 2017, global CO_2 emissions were 42 Gt (Le Quéré et al., 2018; Rogelj et al., 2018). If this rate continues, the remaining carbon budget for 1.5°C will be depleted within 10 or 14 years starting from 2018. More recent years, including the emission dip in 2020 because of the Covid 19-measures, have not modified this number by much (Friedlingstein et al., 2020; Forster et al., 2021).

The Nationally Determined Contributions (NDCs) as of 2018 do not yet chart a path towards net-zero CO_2 emissions. Their full implementation is projected to result in warming within about 2.9-3.4°C until the end of the century. The annual emissions in 2030 for 1.5°C pathways would have to be 19-33 $GtCO_2e$ (or roughly 30-50%) lower than what the NDCs are projected to deliver (de Coninck et al., 2018; Rogelj et al., 2018).

1.1.2. Mitigation pathways: nature of the trade-offs

The emissions pathway until 2100 varies depending on the speed and scale of the deployment of mitigation action over time. Integrated Assessment Models (IAMs) explore the technological, economic and geophysical aspects of emissions pathways (see box 1.2 for more details).

Box 1.2: How Are Emission Pathways Constructed?

The emission pathways that the IPCC assesses are generally created with tools known as Integrated Assessment Models (IAMs). These models link the climate system with the economy, including all known sources and sinks of GHG emissions. All IAMs include emissions associated with the energy sector, and many include emissions from land use. They include energy efficiency but rarely model the specific and societal dynamics of transportation, industry and agriculture. The models are used to explore the dynamics of human-Earth systems under different scenarios for reaching certain climate targets. IAMs are internally consistent under a multitude of constraints and assumptions, and the model outcomes are often, but not exclusively, the result of a social cost optimisation over the course of the century.

IAMs utilize various model structures to represent society's behaviours. Some models start from an energy system optimisation core with a detailed representation of how various options for energy supply can meet a given level of energy demand and only to a limited degree represent the macro-economic feedbacks of climate policies. Other models start from an economic core and incorporate energy system transitions. IAMs do not represent individual companies, and only a few represent the public and private finance sectors, always in a highly aggregated way. Although they do not model capital markets and monetary policies explicitly (Espagne, 2018), the IAM have given inputs to highlight financial aspects (Bowen et al., 2014; UNEP Inquiry, 2018).

IAMs make assumptions about societal dynamics and drivers (population growth, economic growth, evolution of energy intensity), economic parameters (growth rate, discount rates) as well as international cooperation or the level of RandD. IAMs often link their assumptions to overarching socio-economic narratives. The standard in IPCC emission pathways are the five 'Shared Socio-economic Pathways' (SSPs): narratives with different premises for factors such as economic growth, population, international cooperation, and energy demand.

A pathway is then generated by a) retaining assumptions on the costs and efficiencies of different technologies and on the potentials of wind, solar or fossil fuel energy or geological CO_2 storage and

b) imposing constraints, typically on the carbon budget and certain technologies (e.g., amount of energy storage required to support a given share of intermittent renewables).

The IPCC Special Report on the impacts of global warming of 1.5°C (SR1.5) highlighted four illustrative pathways, drawn from a range of IAMs (see Table 1.2). The difference between the pathways is the emphasis placed on eliminating gross CO_2 emissions quickly in the next decades by limiting and reducing energy demand and energy efficiency improvements through behavioural change and digitalisation (P1 and P2 pathways in Table 1.2) (Grubler et al., 2018; WBGU, 2019), compared to reliance on great quantities of carbon dioxide removal (CDR) (P3 and particularly P4 in Table 1.2).

The active removal of CO_2 from the atmosphere plays two important yet distinct roles in shaping emissions trajectories. It first helps bringing global CO_2 emissions down to net zero. Mitigation strategies determine how high gross emissions will be, and therefore how much CDR is needed to reach net zero (compare the respective CO_2 emission contributions at the time global CO_2 emissions reach net zero in the illustrative pathways P1-P4 in Table 1.1). Second, CDR draws down CO_2 beyond the point of net zero to slowly revert global warming (see box 1.3).

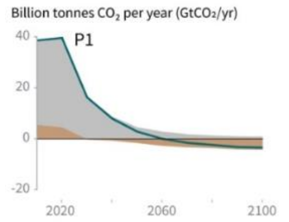
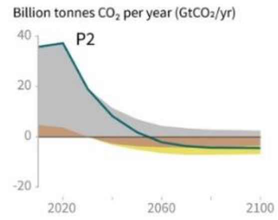
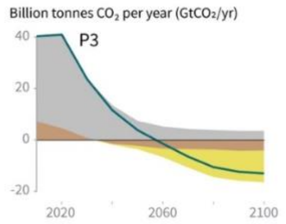
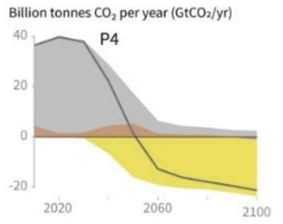
Box 1.3: The implications of 'overshooting'

'Overshoot' refers to a situation in which a) a temperature limit is first exceeded with the intention of halting warming at a later point in time, and then relying on the possibility of reducing global mean temperature through active CDR and b) there is a high likelihood that a return below the temperature limit by the end of the century will not be achieved.[i] In this strategy, the temperature limit that is considered safe can be exceeded *before* being sure that either halting or reversing global warming by CDR is possible and that the CDR will not be in conflict with food and water security or biodiversity protection. Pathway P4 further illustrates the characteristics of overshoot pathways (see Table 1.2).

A way forward in conceptualising the scenarios that increase the likelihood of meeting the Paris Agreement's temperature goal (Rogelj et al., 2019b), is to determine the cumulative amount of CO_2 emitted until emissions are net zero at a given point in time for a given target and calculate the amount of net negative CO_2 emissions needed to balance residual non-CO_2 emissions for which at present no mitigation options have been identified. This logic demonstrates that the transition challenge is situated in the next couple of decades until net-zero CO_2 emissions are achieved globally.

Strategies lowering energy demand show more synergies with other societal goals than strategies focused on the supply side (Roy et al., 2018a) which more often imply trade-offs with food and water security or biodiversity protection. Of the four illustrative pathways, P1 is most aligned with the sustainable development agenda, while P4 is projected to result in more tensions between mitigation pathways and sustainable development objectives in the medium to long term (see Table 1.2a). Such tensions would represent economic and financial risks in case of a sudden shift in strategy when the trade-offs materialise.

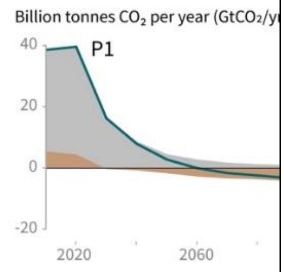
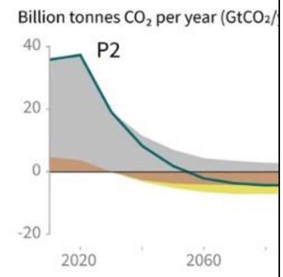
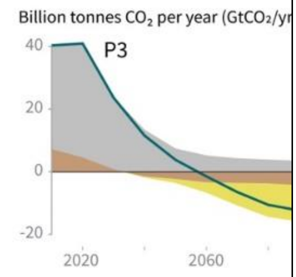
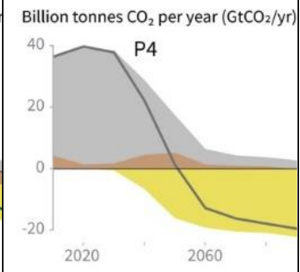
Table 1.2a | Risk characteristics of four illustrative pathways pursuing different strategies to limit warming to 1.5°C as shown in Figure SPM.3b of the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018). Darker cell colours indicate higher risk. AFOLU = Agriculture, Forests and Other Land Use, BECCS = bioenergy and carbon dioxide capture and storage.

	P1	P2	P3	P4
				
	Fossil fuel and industry AFOLU BECCS			
Storyline	Social, business and technological innovations; lower energy demand by 2050; higher living standards (also in the global South); downsized energy system; rapid decarbonisation of energy supply; afforestation the only CDR option considered; no CCS.	Focus on sustainability incl. energy intensity; human development; economic convergence; international cooperation; shifts towards sustainable and healthy consumption patterns; low-carbon technology innovation; well-managed land systems; limited BECCS.	Societal and technological development follow historical patterns; emissions reductions through changing production of energy and commodities rather than through reductions in demand.	Economic growth and globalisation; greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products; emissions reductions mainly through technological means; CCS and BECCS.
Temperature outcome (within 0.1°C accuracy, median estimate)	Warming limited to 1.5°C	Warming limited to 1.5°C	Warming limited to 1.6°C	Warming exceeds 1.5°C limit by 20% (0.3°C) with assumption it can be reversed by 2100
Risk of overshoot of 1.5°C	Small	Small	Large	Very large (designed to first miss the target)
Alignment with sustainable development	Very strong	Strong	Medium, with potential trade-offs	Weak, with marked trade-offs
Physical climate risks to 2050	Lowest	Low	Medium	Highest
Physical climate risks after 2050*	Low	Lowest	Low	High
Transition risks and Opportunities				
Energy demand reduction/management	Very high	High	Medium	Low

Energy supply *Infrastructure investments*	Lowest	Medium	High	Highest
Asset stranding	Near-term retirement of fossil-fuel assets	Near-term retirement of fossil-fuel assets	Moderate stranding of fossil-fuel assets	Stranding delayed by a decade but then with higher magnitude**
Reliance on CDR	Small	Medium	Large	Extreme
Deployment of land-based mitigation and bioenergy	Medium	Medium	High	Extreme
Discontinuation risks	Failure to achieve demand and behavioural changes may leave little time to ramp up supply-side measures like CCS.	Full portfolio of supply and demand options hedges against failures and discontinuation risks	Failure to address potential trade-offs from land-based mitigation, risks policies being reversed due to societal concerns.	High risk of necessary post-2030 climate policies strongly competing with other societal concerns and hence not being implemented or discontinued.

* P2 has the lowest post-2050 physical climate risk as it combines low peak warming with a strategy to achieve net CDR after 2050 and gradually reverse warming. ** Highest capital turnover due to short-term fossil-fuel expansion and medium-term retirement of carbon intensive infrastructure

Table 1.2b | Contributions of bioenergy with carbon capture and storage (BECCS), total carbon capture and storage (CCS) and agriculture, forestry and other land use (AFOLU) in four illustrative pathways pursuing different strategies to limit warming to 1.5°C as shown in Figure SPM.3b of the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018).

	P1	P2	P3	P4
				
Fossil fuel and industry; AFOLU; BECCS				
Bioenergy with carbon capture and storage (BECCS) (negative values = removals) (Gt CO_2 per year)				
2020-2030 average	0	0.00	- 0.03	- 0.30
2030-2040 average	0	- 0.26	- 0.22	- 3.60
2040-2050 average	0	- 0.95	- 0.84	- 11.35
2050-2060 average	0	- 1.87	- 2.30	- 17.65
Net emissions from agriculture, forestry and other land use (AFOLU, negative values = removals) (Gt CO_2 per year)				
2020-2030 average	2.03	1.77	2.60	1.48
2030-2040 average	-0.54	-1.39	-0.39	3.03
2040-2050 average	-1.24	-3.24	-1.89	4.78
2050-2060 average	-2.26	-3.95	-2.84	3.23

1.2.Risks, damages and adaptation needs under different mitigation pathways

Global warming has already had significant impacts on human and natural systems (IPCC, 2014, 2018, 2019b, 2019c) and all earth systems will continue to be impacted, due to inertia of earth systems (IPCC, 2001; 2019a). For example, even after stabilisation or reduction of GHG concentrations, sea level is projected to continue rising for centuries. Inertia related to human systems is more dependent on regional policies and actions, which in turn shape adaptation pathways and outcomes. It is important to understand the impacts associated with different levels of warming for various human, natural and managed systems and we examine first these links based on the difference between 1.5°C and 2°C temperature levels before emphasizing the risks in terms of overshoot of these levels. We do so using the five reasons of concerns due to global warming pictures in Figure 1.1.

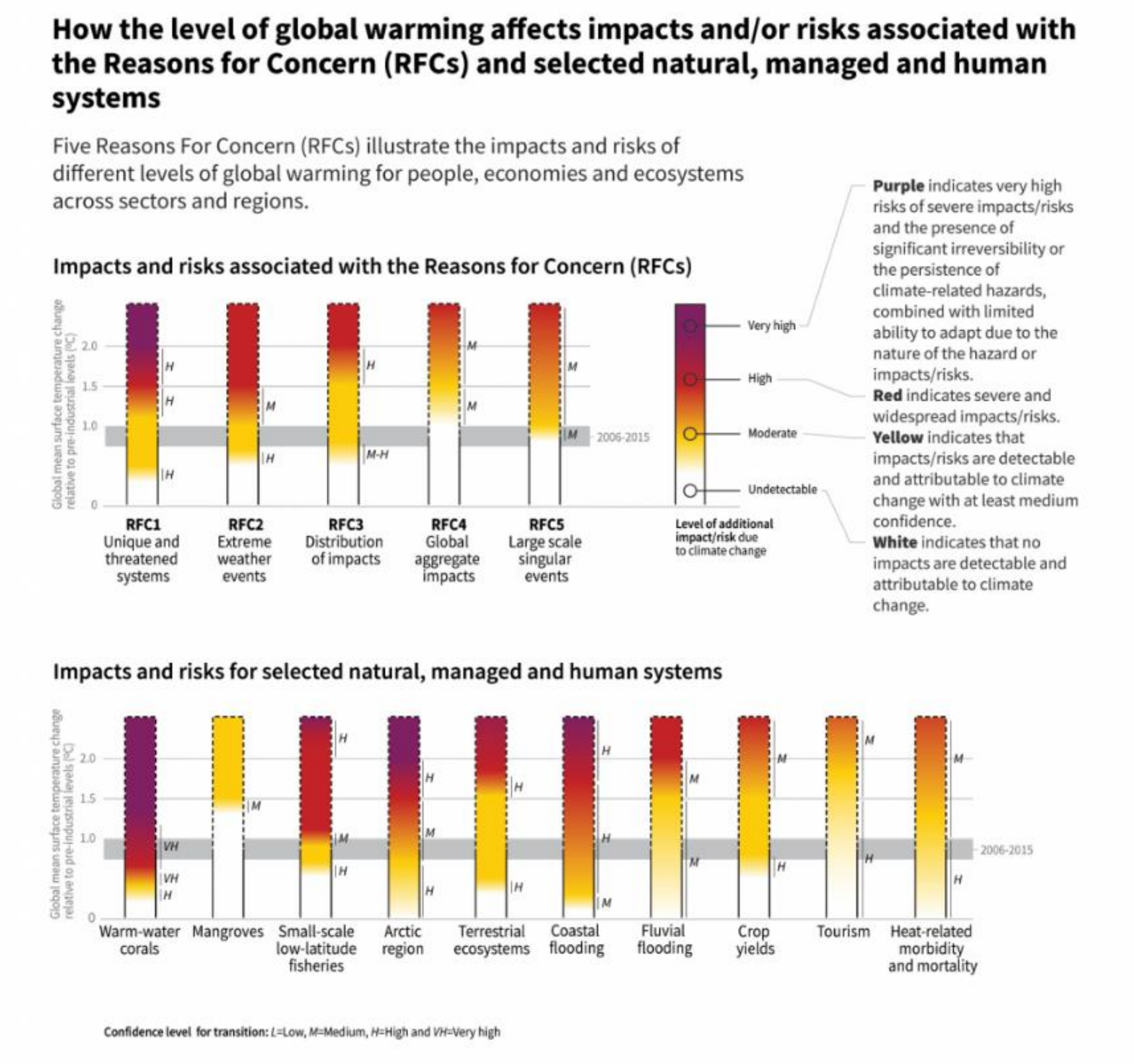


Figure 1.1. The identified reasons for concern are: threats to endangered species and unique systems, damages from extreme weather events, effects that fall most heavily on developing countries and the poor within countries, global aggregate impacts, and large-scale high-impact events. The colouring in the bars, nicknamed 'burning embers', is based on multiple lines of evidence showing that risks increase with global warming. They show that warm-water corals are heavily at risk even at 1.5°C, as well as fisheries, the Arctic and coastal regions. Terrestrial ecosystems, fluvial flooding, crop yields and the health and mortality impacts of heat waves show a contrast between 1.5 and 2°C. Source: Figure SPM.2 in (IPCC, 2018).

1.2.1. Risks and impacts to natural ecosystems at 1.5°C and 2°C

On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5°C of global warming compared to 2°C. Limiting global warming to 1.5°C is also projected to lower the impacts on freshwater and coastal ecosystems and to retain more of their services to humans (See Table 1.3). Warmer temperatures increase risks to marine biodiversity, fisheries, and ecosystems, as well as to their functions and services to humans, as illustrated by recent changes to Arctic sea ice and warm-water coral reef ecosystems.

Table 1.3 | Projected impacts of climate change at 1.5°C vs. 2°C vs. 3°C in specific regions, including impacts for human systems. Regions that were not hotspots at lower warming levels become hotspots at higher levels of warming.

Region	Warming of 1.5°C or less	Warming of 1.5° to 2°C	Warming of up to 3°C
Arctic Sea Ice	– Arctic summer sea ice likely to be maintained – Habitat losses for polar bears, whales, seals, and sea birds – Benefits for Arctic fisheries	– 50% or higher risk of ice-free Arctic in summer – Habitat losses for polar bears, whales, seals, and sea birds possibly critical if summers are ice-free – Benefits for Arctic fisheries	– Arctic very likely to be ice-free in summer – Critical habitat losses for polar bears, whales, seals, and sea birds – Global atmospheric temperature rises from 1.5° to 3.5°C increase maximum catch potential from 29.1 ± 1.6% to 55.0 ± 3.9%
Arctic Land Regions	– Cold extremes warm by a factor of 2 to 3, reaching up to 4.5°C (high confidence) – Biome shifts in the tundra and permafrost deterioration likely	– Cold extremes warm by as much as 8°C (high confidence) – Larger intrusions of trees and shrubs in the tundra than under 1.5°C of warming likely; larger but constrained losses in permafrost likely	– Drastic regional warming very likely – Collapse in permafrost possible (low confidence); – Drastic biome shift from tundra to boreal forest possible (low confidence)
Alpine Regions	– Severe shifts in biomes likely – Robust increases in runoff in Fenno-Scandinavia and the Alpine regions	– Even more severe shifts likely – Distinct increase in the changes to mean, low and high runoff at 2°C compared to 1.5°C	– Critical losses in alpine habitats likely – Increased runoff in most of Norway, Sweden and northern Poland – Decreased runoff around the entire Iberian coast, the Balkan Coast and parts of French coast.
Southeast Asia	– Risks for increased flooding related to sea level rise – Increase in heavy precipitation events – Significant risks of crop yield reductions avoided	– Higher risks of flooding related to sea level rise (medium confidence) – Stronger increase in heavy precipitation events (medium confidence) – One-third decline in per capita crop production (medium confidence)	– Substantial increases in risks related to flooding from sea level rise – Substantial increase in heavy precipitation and high-flow events – Substantial reductions in crop yield
Mediterranean	– Increase in probability of extreme drought (medium confidence) – Reduction in runoff of about 9%, with likely range 4.5 to 15.5% (medium confidence)	– Robust increase in probability of extreme drought (medium confidence) – Robust change of average maximum temperature and temperature extremes over more than	– Robust and large increases in extreme drought – Substantial reductions in precipitation and in runoff (medium confidence) – Very high risks of water deficit (medium confidence)

	– Risk of water deficit (medium confidence)	50% of land; >60% increase in the number of tropical nights in parts of the region – Further reductions (about 17%) in runoff with likely range of 8 to 28% (medium confidence) – Higher risks of water deficit (medium confidence)	
West Africa and Sahel	– Increases in the number of hot nights and longer and more frequent heatwaves likely – Reduced maize and sorghum production likely, with area suitable for maize production reduced by as much as 40%	– Further increases in number of hot nights and longer and more frequent heatwaves likely – Negative impacts on maize and sorghum production likely larger than at 1.5°C; medium confidence that vulnerabilities to food security in the African Sahel will be higher at 2.0°C compared to 1.5°C	– Substantial increases in the number of hot nights and heatwave duration and frequency (very likely) – Negative impacts on crop yield may result in major regional food insecurities (medium confidence)
Southern Africa	– Reductions in water availability with robust reduction in precipitation of up to 0.4 mm day^{-1} over parts of Zambia and South Africa under 1.5°C warming (medium confidence) – Increases in number of hot nights and longer and more frequent heatwaves (high confidence) – High risks of increased mortality from heatwaves – High risk of undernutrition in communities dependent on dryland agriculture and livestock	– Larger areas facing reductions in rainfall and water availability under 2°C warming (medium confidence) – Further increases in number of hot nights and longer and more frequent heatwaves (high confidence), associated higher risks of increased mortality from heatwaves compared to 1.5°C warming (high confidence) – Higher risk of undernutrition in communities dependent on dryland agriculture and livestock	– Large reductions in rainfall and water availability (medium confidence) – Drastic increases in the number of hot nights, hot days, and heatwave duration and frequency, with substantial impact on agriculture, livestock, and human health and mortality (high confidence) – Very high risk of undernutrition in communities dependent on dryland agriculture and livestock
Tropics	– Increases in the number of hot days and hot nights as well as longer and more frequent heatwaves (high confidence) – Risks to tropical crop yields in West Africa, Southeast Asia, Central and South America significantly lower than under 2°C of warming	– Larger increase in hot days under 2°C compared to 1.5°C is projected – Significant changes in rainfall; e.g. spatially-averaged annual mean precipitation across India increases by 2-14% under 2°C compared to 1.5°C – Risks to tropical crop yields in West Africa,	– Oppressive temperatures and accumulated heatwave duration very likely to have a direct impact on human health, mortality, and productivity – Further changes in precipitation patterns; e.g. significant decrease in rainfall across NW Indian sub-continent; increase in the frequency of extreme

		Southeast Asia, and Central and South America possibly extensive	precipitation in east India, Bangladesh. – Substantial reductions in crop yield very likely
Small Islands	– Land of 60,000 fewer people exposed by 2150 on Small Island Developing States (SIDS) compared to 2°C – Risks for coastal flooding reduced by 20 to 80% for SIDS compared to 2°C – Freshwater stress reduced by 25% as compared to 2°C – Increase in the number of warm days for SIDS in the tropics – Persistent heat stress in cattle avoided – Loss of 70 to 90% of coral reefs	– Tens of thousands of people displaced owing to inundation of SIDS – High risks for coastal flooding and increased frequency of extreme water-level events – Freshwater stress from projected aridity – Further increase of ~70 warm days/year – Persistent heat stress in cattle in SIDS – Loss of most coral reefs and weaker remaining structures owing to ocean acidification (i.e., less coastal protection)	– Substantial and widespread impacts through inundation of SIDS, coastal flooding, freshwater stress, persistent heat stress, and loss of most coral reefs (very likely) – Risk of multi-meter sea level rise due to ice sheet instability
Fynbos biome	– About 30% of suitable climate area lost (medium confidence)	– Increased losses (about 45%) of suitable climate area (medium confidence)	– Up to 80% of suitable climate area lost (medium confidence)

Source: Amended from (Cheung et al., 2016; Donnelly et al., 2017; Dosio and Fischer, 2018; Hoegh-Guldberg et al., 2018, 2019; Maúre et al., 2018; Mishra et al., 2017; Nikulin et al., 2018)

1.2.2. Risks and impacts to human systems at 1.5°C and 2°C

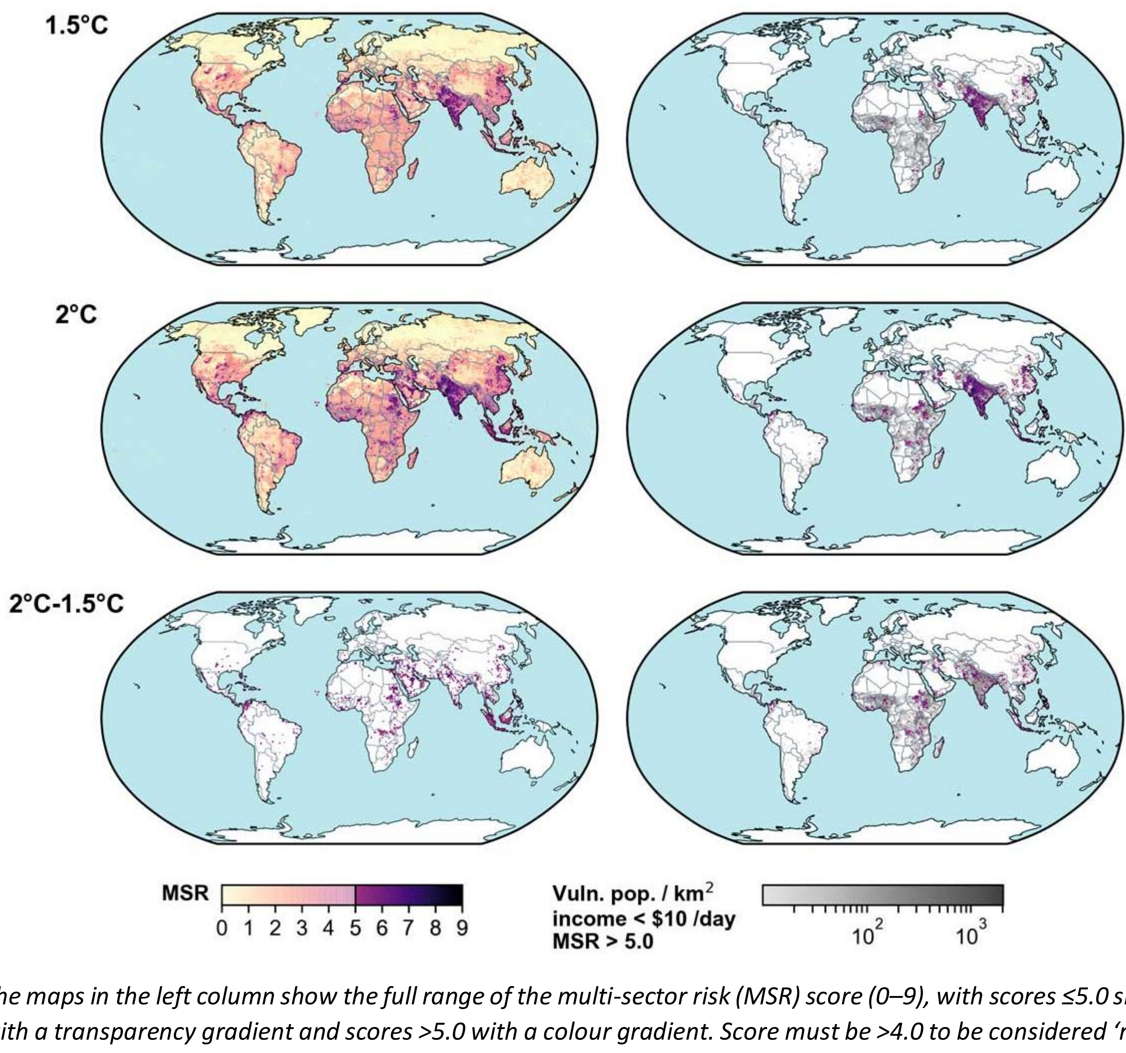
The impacts of a warmer world so far have been experienced unevenly. For countries in the Global North, the evidence of economic impacts is inconclusive, but "for most poor countries there is >90% likelihood that per capita GDP is lower today than if global warming had not occurred" (Diffenbaugh and Burke, 2019). The same imbalance exists for health impacts (Watts et al., 2019). For example, risks from malaria and dengue fever are projected to increase with warming from 1.5°C to 2°C, including shifts in their geographic range (Hoegh-Guldberg et al., 2019) and Western Pacific, South-East Asia and Africa seeing an increase of more than 10% since 1990 of the vulnerability to heat extremes (Watts et al., 2019).

Limiting global warming to 1.5°C compared to 2°C is expected to reduce the proportion of the world population exposed to climate-induced water stress by up to 50% with considerable variability between regions. For instance, many small island could experience lower water stress (Hoegh-Guldberg et al., 2019) while under SSP2 ('middle of the road' scenario), dryland populations vulnerable to water stress, drought intensity and habitat degradation could reach 178 million people by 2050 at 1.5°C warming, increasing to 220 million people at 2°C warming, and 277 million people at 3°C (IPCC, 2019a).

Global warming of 2°C would see a loss of 7-10% of global rangeland stock. Pastoral systems are particularly vulnerable. In the land sector, several climate drivers exacerbate risk exposure for agriculture and food security: shifts in climate envelopes causing shifts in crop varieties planted, seasonal changes, extreme events affecting critical growth periods (flooding/droughts), diseases and pests. Such physical impact will lead to 1) reduced crop yields, mainly in lower latitude regions; 2) reduced nutritional content of crops (carbohydrate dilution, less protein, zinc, and iron); 3) food price instability 4) supply chain disruption (due to extreme weather events) and 5) changes in crop suitability (Hurlbert et al., 2019). The forestry sector will also face risks due to higher frequency and intensity of wildfires. Recent examples in California, Australia and Portugal are obvious testimonies.

With warming, impacts across energy, food, and water sectors overlap spatially and temporally, creating new – and exacerbating current – hazards, exposures, and vulnerabilities. These could affect increasing numbers of people and regions. Exposure to multiple and compound climate impacts is projected to increase between 1.5°C and 2°C of global warming with greater proportions of people both exposed and susceptible to poverty in Africa and Asia. Such 'risk hotspots' are illustrated in Figure 1.2.

Figure 1.2 Comparing population centres of low-income people (right) to hotspots of multi-sector risk (MSR) (left).



The maps in the left column show the full range of the multi-sector risk (MSR) score (0–9), with scores ≤5.0 shown with a transparency gradient and scores >5.0 with a colour gradient. Score must be >4.0 to be considered 'multi-sector'. The maps in the right column overlay the 2050 vulnerable populations (low income) under Shared Socio-Economic Pathway (SSP)2 (greyscale) with the multi-sector risk score >5.0 (colour gradient), thus indicating the concentrations of exposed and vulnerable populations to risks in multiple sectors. Source: Figure 3.19 in Hoegh-Guldberg et al. 2018 (IPCC, 2018).

Beyond such ‘hotspots’ overshooting 1.5°C will already lock in impacts on infrastructure, livelihoods, income and biodiversity for SIDS and certain coastal cities such as Mumbai, Dhaka, Miami and New York, as well as increase disaster incidence.

1.2.3.The implications of temperature overshoots

Temperature overshoots will be associated with increased physical risks (Hoegh-Guldberg et al., 2019). What is less understood is how higher temperatures might result in specific impacts for particularly vulnerable locations, populations, or species as well as the compounding risks at higher warming levels (Lawrence et al., 2020). Estimated impacts at 3°C or 4°C of warming are expected to trigger very large, abrupt or irreversible changes in the climate system with cascading impacts on nature and humans. Estimates of the probability in examples of global average climatic events may change as follows (Arnell et al., 2019):

1) the chance of a major heatwave increases from 5% in 1981–2010 to 28% at 1.5°C and 92% at 4°C
2) the chance of an agricultural drought increases from 9 to 24% at 1.5°C and 61% at 4°C
3) the chance of a river flood occurring every 50 years increases from 2 to 2.4% at 1.5°C and 5.4% at 4°C (so it becomes a 20-year-flood)
4) the chance of a damaging hot spell for maize increases from 12.3 at 1.5°C to 50% at 4°C and for rice from 27 to 46%.

Impact assessments at higher temperatures are associated with considerable uncertainty and regional variation (Arnell et al., 2019). Estimates of changes in water availability find that the number of people exposed to freshwater vulnerability varies substantially from almost 1 billion people at 4°C in an SSP5 world to almost 3 billion people at the same temperature increase in an SSP3 world (Koutroulis et al., 2019). These estimates show how higher temperatures can trigger significant and unprecedented impacts. In addition, in certain ecosystems, overshoot might result in irreversible losses and damages (e.g. in SIDS) (Hoegh-Guldberg et al. 2018).

1.2.4.Adaptation pathways, limits to adaptation and residual risks

Adaptation pathways are sequences of adaptation decisions/interventions (Werners et al., 2021). They are characterised almost systematically by dynamic decision-making under deep uncertainty, and trade-offs across spatial and temporal scales (Wise et al., 2014; Fazey et al., 2016; Butler et al., 2014; Gajjar et al., 2019; Haasnoot et al., 2013). Although local adaptive capacities depend on the context they operate in (e.g. local development, risk, existing vulnerability), the study of local adaptation pathways is needed to prioritise decision-making and prepare for potential unintended outcomes (i.e. maladaptive outcomes) and trade-offs (Haasnoot et al. 2013; Werners et al. 2021).

Fundamentally, adaptation cannot be disconnected from overall sustainable development trajectories (Roy et al., 2018b; Gajjar et al., 2019) because the magnitude of risk climate change poses is as much a result of existing vulnerabilities and capacities to anticipate and adapt as it is the level of exposure to the physical hazard (Hallegatte et al., 2007; Simpson et al., 2021). Thus, development interventions such as reducing the infrastructure investment gaps or improving health systems intrinsically build adaptive capacities and reduce risk.

The need to include prevention and adaptation as a major dimension of development choices emerges from studies on the repetition of tropical storms and typhoons. Based on the evidence of 6,700 tropical storms since 1950, Hsiang and Jina (2014) show that the strongest 10% of them reduces per capita incomes by 7.4% two decades later, effectively undoing 3.7 years of average development. Strobl (2019) show that the repetition of typhoons can generate 3.2% GDP loss in some regions.

Adaptation actions might be insufficient, adaptive, or maladaptive (Magnan et al., 2016; Gajjar et al., 2019) (see figure 1.3). The ex-ante assessment of multiple pathways can highlight synergies and trade-offs between options (e.g. as Haasnoot et al. (2019) for coastal systems), with signposts that can be tracked and used to mark the need for a better coordination of actors' decision (Lawrence and Haasnoot, 2017; Stephens et al., 2018). *Maladaptation* denotes adaptation actions that disproportionately burden the most vulnerable, have high opportunity costs; reduce the incentive to adapt; or instil path dependency (Barnett and O'Neill, 2010). Certain adaptation actions can lead to unintended consequences and lock-ins and sequencing of actions are critical to keep the envelope of feasible adaptation strategies open.

In some places and for some human and ecological systems, there are limits to adaptation when the pace of climate change impacts accelerates, making the prevention of intolerable risks impossible even through accelerated action (Klein et al., 2014). This comes from hard limits to adaptation (McNamara and Buggy, 2017; Djalante et al., 2018). Soft ones are thresholds that represent an actual limit at the time of assessment (e.g. current availability or accessibility of technology) but can change over time (e.g. due to new technologies or institutional changes). For example, sea walls can be effective strategies under certain projects but might become insufficient over time in the face of surging higher storm. Hard limits to adaptation are those that will not change, such as thermal limits of survival for species, or sea level rise that makes permanent relocation the only viable adaptation strategy in certain low-lying areas. (See Table 1.4 for an overview.)

Table 1.4 Soft and hard limits to adaptation.

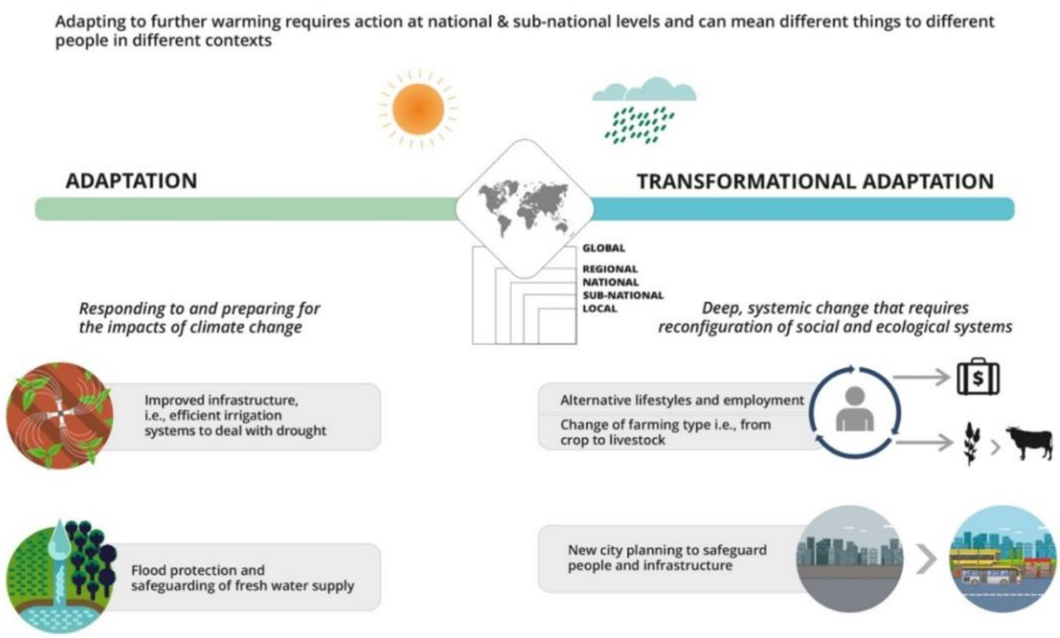
System/Region	Examples	Soft limit	Hard limit
Coral Reefs	70-90% loss of tropical coral reefs by mid-century under 1.5°C		X
Biodiversity	6% of insects, 8% of plants, 4% of vertebrates lose over 50% of the climatically determined geographic range at 1.5°C (18% insects, 16% plants, 8% invertebrates at 2°C)		X
Poverty	24-357 million people exposed to multi-sector climate risks and vulnerable to poverty at 1.5°C (86-1220 million at 2°C)	X	
Human Health	Twice as many megacities exposed to heat stress at 1.5°C compared to present, potentially exposing ~350 million additional people to deadly heat waves by 2050	X	X
Coastal Livelihoods	Large-scale changes in oceanic systems inflict damage and losses to livelihoods, income, cultural identity, and human health for coastal communities at 1.5°C with higher potential losses at 2°C.	X	X
Culture, Lifestyle, Traditions and Heritage	Climate-induced relocation or loss of livelihoods can erode shared practices, narratives and customs that provide meaning and structure to people's everyday life	X	
Small Island Developing States	Sea level rise and increased wave run up combined with increased aridity and decreased freshwater availability at 1.5°C potentially leaving several atoll islands uninhabitable.		X

Adapted from Djalante et al. (2018); McNamara and Jackson (2019); Boyd et al. (2017); Tschakert et al. (2019).

The issue is whether, as highlighted by the SR1.5, an *incremental* approach to adaptation, leading to marginal redirections of development choices will suffice or whether *transformational* adaptive changes will be needed. Transformational adaptation implies 'significant changes in structure or function that go beyond adjusting existing practices' (de Coninck et al., 2018)) and might be critical to deal with hard limits to adaptation and tipping points, which have "the potential for abrupt, non-linear and climate change-triggered shifts in the elements of the Earth system" (Garschagen and Solecki, 2017). These adaptation tipping points are situations when the consequences of physical impacts of climate change breach functioning thresholds of socio-ecological systems (Kwadijk et al. 2010).

The absence of anticipatory, transformational adaptation in the present, will make future adaptation to stay within hard limits more economically and socially costly (Werners et al., 2013). The social, political, institutional conditions for mainstreaming adaptation in current development choices remains a significant challenge (Garschagen and Solecki, 2017). What is clear, however, is that adaptation is tightly dependent on development trajectories and choices, and not undertaking anticipatory adaptation today will foreclose future options for adapting, leading to more costly future interventions. (e.g., Haasnoot et al. 2019; de Ruig et al. 2019).

Figure 1.3 Differences between 'normal' (incremental) and transformational adaptation.



Residual loss and damage occur when hard limits to adaptation are reached. For example, being unable to protect certain coastal regions from flooding or being unable to prevent health impacts of heat waves, despite adaptation, constitute residual risks. It is acknowledged that such losses and damages are differentiated across regions and populations (Boyd et al., 2017; Djalante et al., 2018; McNamara and Jackson, 2019; Tschakert et al., 2019) and include tangible deprivations, such as the loss of assets and crops, as well as non-economic ones, such as the loss of biodiversity, culture or health.

1.3.Feasibility of adaptation and mitigation options

Scaling up GHG emission reduction efforts is critical to avoid tipping points while anticipatory adaptation is critical to stay within hard limits of adaptation in the least costly manner socially and economically. Reducing the physical and transition climate risks on society will require to accelerate the transition of our socio-economic systems towards zero-emission climate resilient development pathways.

Physical risks stem from the impact of climate change and transition risks are related to uncertainties about technological innovations, changes in legislation and regulation, implementation of a carbon tax and changes in consumer behaviour (e.g. a shift in attitudes towards the purchase of diesel cars, air travel or deforestation-based products). The magnitude of implications of climate related risks on many activity domains will be determined by:

- How and when the physical impacts of climate change on natural systems result in human damages;
- How and when the human damages from physical impacts or mitigation measures translate into net economic losses; what share affect nonmarketable services and fall on population poorly included in the monetized economy; what percentage of the GDP will be dedicated to repairing the damages;
- How the net economic losses translate into financial risks, which depends on their sectoral and geographical distribution, and the degree of surprises they involve.

Here below, we summarize these implications in terms of *feasibility* of mitigation and adaptation options grouped in four categories: energy system transition, Land and (terrestrial) ecosystem transition, Urban and infrastructure system transition and Industrial system transition. The objective is to delineate the enabling conditions that will increase their feasibility space, conditions understood as consisting of six dimensions: environmental, economic, technological, institutional, socio-cultural and geophysical.

1.3.1. Feasibility of adaptation options

Twenty-three adaptation options are mapped in Table 1.5 onto the four system transitions, and their multi-dimensional feasibility was assessed, resulting in the conclusions that several adaptation options are feasible (Table 1.5; Singh et al., 2020).

Table 1.5 How feasible are adaptation options?
Feasibility assessments of 1.5°C-relevant adaptation options, with dark shading signifying the absence of barriers in the feasibility dimension, moderate shading indicating that, on average, the dimension does not have a positive or negative effect on the feasibility of the option, or the evidence is mixed, and faint shading indicating the presence of potentially blocking barriers. No shading means that there was not sufficient literature to make an assessment. NA signifies that the dimension is not applicable to that adaptation option. A confidence assessment is undertaken at the option level but not shown here (see Table 4.12 in the SR1.5 (de Coninck et al., 2018)). The context column indicates which contextual factors would change the assessment. For the methodology and literature, see the SR1.5 supplementary material 4.SM.4. Abbreviations used: Ec: Economic – Tec: Technological – Inst: Institutional – Soc: Socio-cultural – Env: Environmental/Ecological – Geo: Geophysical

SYSTEM	ADAPTATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Energy System Transitions	Power infrastructure, including water							Depends on existing power infrastructure, all generation sources and those with intensive water requirements

SYSTEM	ADAPTATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Land and Ecosystem Transitions	Conservation agriculture							Depends on irrigated/rainfed system, ecosystem characteristics, crop type, other farming practices
	Efficient irrigation							Depends on agricultural system, technology used, regional institutional and biophysical context
	Efficient livestock systems							Dependent on livestock breeds, feed practices, and biophysical context (e.g., carrying capacity)
	Agroforestry							Depends on knowledge, financial support, and market conditions
	Community-based adaptation							Focus on rural areas and combined with ecosystems-based adaptation, does not include urban settings
	Ecosystem restoration and avoided deforestation							Mostly focused on existing and evaluated REDD+ projects
	Biodiversity management							Focus on hotspots of biodiversity vulnerability and high connectivity
	Coastal defence and hardening							Depends on locations that require it as a first adaptation option
	Sustainable aquaculture							Depends on locations at risk and socio-cultural context
Urban and Infrastructure System Transitions	Sustainable land-use and urban planning							Depends on nature of planning systems and enforcement mechanisms
	Sustainable water management							Balancing sustainable water supply and rising demand, especially in low-income countries
	Green infrastructure and ecosystem services							Depends on reconciliation of urban development with green infrastructure
	Building codes and standards							Adoption requires legal, educational, and enforcement mechanisms to regulate buildings
Industrial System Transitions	Intensive industry infrastructure resilience and water management							Depends on intensive industry, existing infrastructure and using or requiring high demand of water
Overarching Adaptation Options	Disaster risk management							Requires institutional, technical, and financial capacity in frontline agencies and government
	Risk spreading and sharing: insurance							Requires well-developed financial structures and public understanding

SYSTEM	ADAPTATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
	Social safety nets							Type and mechanism of safety net, political priorities, institutional transparency
	Climate services							Depends on climate information availability and usability, local infrastructure and institutions, national priorities
	Indigenous knowledge							Dependent on recognition of indigenous rights, laws, and governance systems
	Education and learning							Existing education system, funding
	Population health and health system						NA	Requires basic health services and infrastructure
	Human migration							Hazard exposure, political and socio-cultural acceptability (in destination), migrant skills and social networks

These options are cost effective. In a frictionless world, they should mobilize investments to avoid larger costs or generate returns. In low and middle-income countries globally, based on willingness to pay for prevention, disruption in power supply (due to increased storm surges, typhoons, and cyclones) are estimated to impact firms directly (by up to $120 billion/year), with coping costs of up to $65 billion/year. For households, the direct impact and cost of coping could be between $2.3–190 billion/year (Hallegatte et al., 2019). The International Finance Corporation (IFC) reviewed climate-related sectors in 21 emerging market economies and identified almost $23 trillion of climate-resilient and climate-friendly investment opportunities, with the largest ones related to buildings and transportation. In several regions, including South Asia, climate-resilient infrastructure is a major opportunity with the potential to unlock over $2 trillion of investment (IFC, 2016). Chapter 2 will discuss how such investments could be triggered, connecting this discussion to the necessity of bridging the infrastructure investment gap (IMF 2014a) that block the fulfilment of SDGs.

1.3.2. Feasibility of mitigation options

1.3.3. Energy System Transition

The required investment for the energy supply side to limit warming to 1.5°C constitutes a small share of overall investments (McCollum et al., 2018) (see also chapter 2). However, it will involve a radical shift compared to current trends that has no precedent at the scale and spread required, comprising all countries and all economic sectors (de Coninck et al., 2018). Investments will need to move rapidly towards efficient and low-emission options. The feasibility of some of them is evaluated in Table 1.6.

Table 1.6 How feasible are mitigation options?

Feasibility assessment of 1.5°C-relevant mitigation options in energy system transitions, with dark shading signifying the absence of barriers in the feasibility dimension, moderate shading indicating that, on average, the dimension does not have a positive or negative effect on the feasibility of the option, or the evidence is mixed, and faint shading indicating the presence of potentially blocking barriers. No shading means that the literature found was not sufficient to make an assessment. A confidence assessment is undertaken at the option level but not shown here (see Table 4.11 in the SR1.5 (de Coninck et al., 2018)). The context column on the far right indicates which contextual factors would change the assessment. For the methodology and literature basis, see the SR1.5 supplementary material 4.SM.4. Abbreviations used: Ec: Economic – Tec: Technological – Inst: Institutional – Soc: Socio-cultural – Env: Environmental/Ecological – Geo: Geophysical

MITIGATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Wind energy (on-shore and off-shore)							Wind regime, economic status, space for wind farms, and the existence of a legal framework for independent power producers affect uptake; cost-effectiveness affected by incentive regime
Solar PV							Cost-effectiveness affected by solar irradiation and incentive regime. Also enhanced by legal framework for independent power producers, which affects uptake
Bioenergy							Depends on availability of biomass and land and the capability to manage sustainable land use. Distributional effects depend on the agrarian (or other) system used to produce feedstock
Electricity storage							Batteries universal, but grid-flexible resources vary with area's level of development
Power sector carbon dioxide capture and storage							Varies with local CO_2 storage capacity, presence of legal framework, level of development and quality of public engagement
Nuclear energy							Electricity market organization, legal framework, standardization and know-how, country's 'democratic fabric', institutional and technical capacity, and safety culture of public and private institutions

Current investment trends contrast with the requirements for limiting warming to 1.5°C as they are still being made in fossil fuel-intensive options and tend to increase resistance on the part of those actors 'invested in' such an energy system. Given the dramatic reduction in the use of coal, oil and gas in the next couple of decades, the transition risk for the assets based on these options is obvious. Divestment in fossil fuel-based energy for lower temperature emission pathways could grow from just over $275 billion over 2016-2023, to about $400 billion over 2016-2030, and nearly $550 billion over 2016-2050 (see box 1.4; McCollum et al., 2018). Chapter 2 will discuss a specific mix of regulation, taxation, pricing and other policy necessary to mitigate the financial, macroeconomic and political adversities and risks of such a quick and drastic redirection of investments.

Such shifts also open investment opportunities in low-emission options. Many of them (wind and photovoltaic electricity) are technologically mature and increasingly competitive with fossil fuels from a purely economic perspective. Innovation in electricity storage is moving rapidly, while less progress is reported for nuclear energy and CCS (REN21, 2017; de Coninck et al., 2018; IEA, 2017). But the pace of wide-scale implementation of fast-growing low-emission options is still hindered by regulation and planning of the system, up-front costs due to a mix of transaction costs and cost uncertainty, and other obstacles to financial access discussed in chapter 2. In many places, these factors result in a carbon lock-in (Unruh, 2002).

Investment opportunities are also important on the energy demand side, in particular in buildings. They would require investments estimated at between \$0.38 trillion per year in a 2°C scenario and \$0.45 trillion in a 1.5°C scenario yearly between 2016 and 2035 (Box 4.8 IPCC 2018). Such investment will have to be particularly significant in the short-term in P1/P2 types of scenarios in table 1.2.

Box 1.4 | A Look at Energy System Investment Estimates

Estimates of energy system investments for climate change mitigation pathways consistent with the 1.5°C limit are only sparsely covered in academic literature. Estimates are available from one multi-model study (McCollum et al., 2018), which primarily covers P3-type pathways (see Table 1.2). Because P1 and P2 pathways put greater emphasis on energy demand reductions, such futures would see reduced needs for investment in energy supply than those reported below, but demand-side investment levels roughly on par with those of the P3 pathways.

Sector-Wide Energy Supply Investments

Results from IAMs for a 'middle-of-the-road' reference scenario (i.e. SSP2 comparable to the P3 scenario in Table 1.2) indicate that mean annual energy-supply investments would have to grow from \$1.8 trillion per year in 2015 to \$2.2 trillion per year (with a \$1.4 to \$3.4 trillion range surrounding the latter across six models) between 2016 and 2050 (McCollum et al., 2018). While this is a substantial increase from the BAU scenario it will represent a declining share of global GDP, due to stable long-term economic growth in the IAMs.

Reference scenario investments: Energy supply investments in the developing world would make up most of the world energy investments forming a sizeable investment opportunity. Even in a reference, no climate policy scenario, those investments would amount to \$1.35 trillion per year (range from \$0.81 to \$2.3 trillion) on average over 2016-50, a level on average 35% higher than the \$1 trillion investment in energy systems in developing countries in 2015. Developed countries are projected to see investments in the order of \$0.8 trillion per year (range from \$0.36 to \$1.3 trillion). This is on average 10% higher than the \$0.7 trillion in energy-supply investment in 2015 (McCollum et al., 2018).

The large ranges of these estimates confirm the important uncertainties which constitute an obstacle for risk-averse investors. Chapter 2 will discuss how climate finance can help overcome this obstacle.

NDC scenario investments: According to the models, pathways that extrapolate from countries' NDCs until 2050 require very little change in investments compared to the reference scenario mentioned above. Total annual investments over 2016-2050 would increase for both developed and developing countries in the order of tens of billions USD per year. The NDCs do cause a notable reduction of investments in fossil fuel extraction and fossil power generation globally: from a share of 59% to 50% of total mean sector-wide energy supply investments between 2016 and 2050. There is an increase in the renewable investment share (by 3%, to 19%) under the NDCs, while the investment share of power transmission, distribution and storage stays roughly constant at around 21% over this period.

Well below 2°C scenario investments: this scenario requires a much more pronounced redirection of global investment flows than in NDC pathway. The total investments would increase to about \$2.5 trillion per year (range from \$1.1 to \$4.4 trillion) on average over the 2016-2050 period. The modelled transition more than halves the share of global investment in fossil fuel extraction and power generation over the 2016-2050 period, from 50% of energy supply investment under the NDCs to 22%

(with a range of 21 to 28% across models). The investment share of renewables, and power transmission, distribution and storage over the 2016-2050 period increases to about 28% each . The share of investment in developing countries for such a transition grows from 57% in 2015 to 62% over 2016-2050, not keeping pace with the share of global population, which rises to 75% over this period.

Similarly, mean investments for unabated fossil electricity generation (i.e., without carbon capture and storage) over the 2016-2050 period are also found to be considerably lower in 2°C and 1.5°C futures compared to the reference case: decreases of $0.13 trillion per year (range from $0.08 trillion to 0.17 trillion) and $0.14 trillion per year (range from $0.09 trillion to $0.17 trillion) respectively. Particularly noteworthy is the small difference in unabated fossil fuel-powered electricity investments when going from 2°C to 1.5 °C. This highlights how limited the space is for this specific class of 'brown' investments going forward.

Near-term investments: In the near term (up to 2023 and 2030), models suggest that amounts divested from fossil-based energy systems would need to be reinvested in solar photovoltaic (PV), wind, and nuclear power. Investments in bioelectricity and biofuels as well as CCS scale up less quickly initially, but increase significantly after 2030 in P3-type pathways. Meanwhile, investments into hydrogen fuel technologies would be limited in the near term in both 1.5°C and 2°C pathways (McCollum et al., 2018). In 1.5°C pathways, dependence on investment in hydrogen fuel technologies is higher, due to the more urgent need to decarbonise end-use activities such as trucking, shipping and manufacturing.

Investments in Bioenergy with Carbon Capture and Storage (BECCS)

Besides afforestation and reforestation, BECCS is the only CDR option covered in IAM pathways (See also box 1.5 on CDR). Only few pathways manage to achieve the 1.5°C limit without BECCS (e.g. the P1 pathway in Table 1.2). Pathways not relying on BECCS typically require strong demand-side emissions reductions and carbon-neutral alternatives to liquids and gases that do not rely on biomass (Grubler et al., 2018; van Vuuren et al., 2018). Potentials of CDR options other than BECCS and afforestation come with a wide uncertainty range that depends on the local context of deployment.

In the P3-type pathways investment requirements for BECCS add up to a rough mean investment of ca. $50 to 150 billion over the 2016-2050 period. In the pathways using BECCS, developed countries start out with larger BECCS investments than developing countries, but their distribution is broadly similar between developing and developed countries in absolute terms (see Table 1.7).

Table 1.7: Estimated Annual Investments in BECCS (2016-2050) in billion $ 2015/yr.

	Developing countries			Developed countries		
2015 investment	2016-2023	2016-2030	2016-2050	2016-2023	2016-2030	2016-2050
0	1.1 (0-4.4)	7.4 (0- 32.4)	26.5 (0- 75.3)	2.4 (0-11.4)	8.6 (0-25.7)	27.1 (0-73)

Source: Calculations based on McCollum et al. 2018

Energy Demand-Side Investments

For demand-side investments, specifically the portion increasing energy efficiency, it is more difficult to make estimations due to a lack of reliable statistics and issues around definitions (Grübler and Wilson, 2013). A first-order approximation of energy efficiency investments across all end-use sectors (transport, buildings, industry) indicates that the needs under 2°C and 1.5°C pathways (relative to a reference without additional climate policies) would be in the tens of billions dollars per year prior to 2030 and in the low hundreds of billions per year afterward – or around 10% of the energy supply investment estimates provided above.

Demand for primary energy has been growing at 2.5% per year since 1965, and 1.7% per year since 2009, suggesting a trend towards energy efficiency (BP, 2019). Much more rapid energy efficiency improvements or changes in consumption patterns would, however, be needed to reduce demand growth posited in the P1 and P2 pathways.

The success of energy transition depends on specific aspects of energy issues in developing countries.

The first specificity is the need scale up investment to achieve universal access to modern energy by 2030, as stated in SDG7 on clean and affordable energy. A ESMAP report shows that annual 45 billion is needed from 2019 to 2030 mostly for electricity to fulfil the IEA Sustainable Development Scenario (SDS). At the moment, the total global investment for energy access is falling short of this number, with some countries even reducing their energy access investment (ESMAP, 2020).

The second come from the divestment estimates from P3 pathways for limiting warming to 1.5°C, which show a growing pattern. Based on the model runs assessed in McCollum et al. 2018, the projected net divestment in fossil fuel-based energy in developing countries could grow from close to $130 billion a year over 2016-23, to just over $200 billion over 2016-2030 and close to $300 billion over 2016-2050. They raise particularly important challenges in countries that are dependent on fossil fuel export and import, including risks of economic and political instability.

The third are related to the financial implications of the transition for both households and firms in developing countries that must take place in a context of limited financial inclusion in large parts of Asia and the Pacific, Africa and some parts of Latin America. Chapters 2 and 3 will examine how to help developing countries in redirecting their economies and domestic finance towards climate friendly energy investments, including through transborder financial flows.

Given different trends in demography and urban/spatial dynamics over the next few decades, the absolute size of investments in low-emission options in developed countries will be half of those in developing countries (CPI, 2019). Even for present NDC pathways (which are projected to lead to 3°C of warming by 2100) the investment opportunity in developing countries ranges from close to $350 billion over 2016-23 to some $500 billion over 2016-50 (McCollum et al., 2018). For the more ambitious 2°C pathways, the amount rises to over $750 billion over 2016-50, and to close to $900 billion to enable a 1.5°C transition. This is about the same order of magnitude of current investment in oil and gas exploration.

1.3.2.2. Land and Ecosystems Transition

Any attempt to bring Agriculture, Forestry and Other Land Use (AFOLU) emissions to net zero will be closely intertwined with the pursuit of SDGs, notably ending hunger and protecting biodiversity (Roy et al., 2018), as well as the employment and livelihoods of almost 30% of the world workforce (ILOSTAT, 2019). There is a range of small-scale land-based and terrestrial ecosystem transition options to deliver 1.5°C pathways (Rogelj et al., 2018; de Coninck et al., 2018; IPCC 2019a, largely related to improved management of agriculture, forests, and soils. However, implemented in existing lands they induce competition with other land uses geared to support food security (SDG2), livelihoods and sustainable water-resource management. Risks of trade-offs can be exacerbated by growing demand for agricultural and forestry products and rising land needs for bioenergy and CDR. The feasibility of some of these options for the land and ecosystem transition are evaluated in table 1.8.

Table 1.8 Feasibility assessment of mitigation options in land- and ecosystem transitions.
For more details and the legend, see the caption of Table 1.2, based on de Coninck et al. (2018).

MITIGATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Reduced food wastage and efficient food production							Will depend on the combination of individual and institutional behaviour
Dietary shifts							Depends on individual behaviour, education, cultural factors and institutional support
Sustainable intensification of agriculture							Depends on development and deployment of new technologies
Ecosystems restoration							Depends on location and institutional factors

Radical shifts in the demand side, including waste management and decline of overconsumption of meat and milk products as today in OECD countries (Paillard *et al.*, 2014) – can alleviate the transition risks, both by reducing the pressure on agricultural land and the need for land-based negative emissions (van Vuuren et al., 2018; Arneth, 2019; Mbow et al., 2019; IPCC, 2019a). However, implementation is challenging and requires a shift in public policies and consumer behaviours. Transitions in AFOLU systems are also associated with transition risks for the associated industries.

Improved management in agricultural systems include increasing the productivity of land used for food production and avoiding the emissions that would occur if increased food demands were met through expanding agricultural land area. But the conventional intensification of land productivity through industrial technologies could both lead to a rebound effect encouraging such expansion of agricultural land (Desquilbet et al., 2017) and increases GHGs emissions related to the manufacture, distribution and application of industrial inputs. Alternative approaches, based on agroecology are increasingly proposed (Wezel et al., 2009; Perfecto I. and Vandermeer J., 2010). But it is still hard to represent them in global integrated models due to the multiplicity and complexity of the synergies between plant and animal species under and above the ground surface (Dorin and Joly, 2020).

Reducing conversion of grassland to cropland could also provide significant climate mitigation benefits by retaining soil carbon stocks that might otherwise be lost. Integrated water management provides moderate benefits for climate mitigation due to interactions with other land management strategies. Improved forest management and increasing soil organic matter stocks in mineral soils could also potentially yield mitigation benefits globally. One of the most effective and robust options for climate change mitigation is reducing deforestation and forest degradation, especially in the tropical regions. For instance, in Brazil, Rochedo et al. (2018) estimated that investments for controlling illegal deforestation in the Amazon and improving forest restoration between 2010 and 2050 would require 2-3 times less investments than those required to decarbonise the energy sector. For managed forests, the most effective mitigation strategy is through increasing biomass productivity that optimises carbon stocks (in forests and in long-lived products) as well as wood substitution. Soil-based mitigation options include increasing soil organic carbon (www.4p1000.org), control of erosion to prevent losses of organic carbon and the use of biochar.

1.3.2.3 Industrial Systems Transition

The heavy industry sectors of steel, cement, chemicals, aluminium, wood products, non-ferrous metals, glass and ceramics, have relatively high GHG emissions per unit of value-added, long facility lifespan, and low profit margins. This makes them particularly sensitive to carbon pricing and climate policies in general (Dechezleprêtre and Sato, 2018; Sato et al., 2015). The basic materials produced by these sectors are essential to the physical functioning of the economy while representing only a small part of GDP. Moreover, demand in these sectors is expected to grow in the coming decades (OECD, 2019).

Currently, these sectors represent 21.5% of non-land-use anthropogenic CO_2 emissions. Their total emissions are projected to grow, even if significant efforts towards material efficiency are pursued (IEA, 2019). Given their 20-50 year lifespan, without drastic innovation by the early 2030s, these high-carbon facilities will be locked in past mid-century and their emissions by 2050-70 will have to be offset with CDR or air-captured carbon with CCS (Bataille et al., 2018), estimated at \$100-300/t CO_2 (de Coninck et al., 2018; Keith et al., 2018). As a result, facilities that cannot be retrofitted for lower or near zero emissions and are too expensive to offset, should be prematurely retire with potential damages to workforce communities and local supply chains which might block this retirement.

The technical options to transition these sectors to very low or zero emissions are electrification, hydrogen, CO_2 capture, utilisation and storage (CCUS) or other technologies (Axelson et al., 2018; Material Economics, 2019; Energy Transitions Commission, 2018; Bataille et al., 2018). Based on expected prices for low emission electricity, hydrogen and CCUS, these technologies will cost more than current production technologies, e.g. 20–40% more for steel, 70–115% more for cement, and 15–60% for chemicals (Material Economics, 2019). Material efficiency and circularity strategies can help reduce the need for more expensive low-emission primary materials through better design for longer life, reusability and easier recycling (Allwood and Cullen, 2015). Most of the cost of decarbonising these sectors is required at the primary and intermediate producer level, and consumers are unlikely to see more than a 0.5-2% increase in the cost of buildings, infrastructure or vehicles as a consequence.

A generalised feasibility assessment can be found in table 1.9, indicating significant gaps in knowledge for institutional, socio-cultural and environmental impacts of the mitigation options. This suggests that the challenges for financing this transition are potentially greater and depend on policy instrumentation.

Table 1.9 Feasibility assessment of mitigation options in industrial system transitions.
For more details and the legend, see the caption of Table 1.6, based on de Coninck et al. (2018).

MITIGATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Energy efficiency							Potential and adoption depend on existing efficiency, energy prices and interest rates, as well as government incentives
Bio-based and circularity							Faces barriers in terms of pressure on natural resources and biodiversity. Product substitution depends on market organization and government incentivization
Electrification and hydrogen							Depends on availability of large-scale, cheap, emission-free electricity (electrification, hydrogen) or CO_2 storage nearby (hydrogen). Manufacturers' appetite to embrace disruptive innovations
Industrial carbon dioxide capture, utilization and storage							High concentration of CO_2 in exhaust gas improve economic and technical feasibility of CCUS in industry. CO_2 storage or reuse possibilities

The key policy challenge in industrial transformation towards climate neutrality is connecting the low economic impact on consumers with the high impact on producers. If well planned, and if local economics support it, there can be significant synergies between industrial decarbonisation and net-zero energy systems (Vogl et al., 2018; Bataille, 2020). For instance, industries using hydrogen could produce hydrogen when variable electricity generation is high and prices are low, and remove their demand when generation is low. If so equipped, they can also send electricity back to the grid when variable electricity generation is low using reversible fuel cells or sending surplus hydrogen to electricity generation turbines.

Transitioning heavy industry to very low or zero emissions will require carefully designed and negotiated policy packages that include: 1) clear direction, 2) transition plans prepared with the active input and acceptance of all stakeholders, 3) accelerated research and development 4) dedicated support for demonstration and lead markets (for example, through minimum content regulations or green procurement or feed-in-tariffs realised through contracts for difference (Sartor and Bataille, 2019), 5) carbon pricing with competitiveness protections, 6) infrastructure planning and support for electrification, hydrogen and CCUS (United Kingdom Committee on Climate Change (UKCCC), 2019), 7) supporting institutions and education for, amongst other things, material design and, 8) clear regulatory framework and accounting for lifecycle emissions (Wyns et al., 2019; Wesseling et al., 2017; Bataille et al., 2018). Along with these, it would require the financial system – both public and private – to de-risk the needed investments along the value chain and guarantee their transformation in credible assets.

1.3.2.4. Urban and Infrastructure

Today, 55% of the global population lives in urban areas, a number projected to reach 68% by 2050 (UNDESA, 2018). Over the next three decades, nearly 70 million people will move to urban areas every year, a majority of whom will live in small- to medium-sized cities in the developing world (Revi et al., 2014). This trend will imply large investments in urban and infrastructure sectors that are central to economic growth and have critical implications for emissions (Bazaz et al., 2018).

Urban and infrastructure sectors are highly capital intensive (Global Commission on the Economy and Climate, 2014) with investment needs consistently falling, despite discrepancies amongst assessments, in a ballpark of a few trillion dollars per year in the next decades**,** an increasing trend compared to current levels (Acclimatise, 2018; Global Infrastructure Hub, 2017; New Climate Economy, 2016).

Cities around the world are actively formulating building codes to improve energy efficiency and reduce cooling needs; planning transportation systems to reduce energy consumption; investing in green and blue infrastructure such as tree planting, green roofs, rainwater harvesting to reduce urban heat islands; regulating construction in coastal zones and other areas subject to flooding (de Coninck et al., 2018; Revi et al., 2014; Bazaz et al., 2018). Some of the mitigation options for the urban and infrastructure system transition are assessed for their feasibility in Table *1.10*, revealing that although the investment need is high, many options show high feasibility and only few gaps in literature.

Table 1.10 Feasibility assessment of mitigation options in urban and infrastructure system transitions.

For more details and the legend, see the caption of Table 1.6, based on de Coninck et al. (2018).

MITIGATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Land-use and urban planning							Varies with urban fabric, not geography or economy; requires capacitated local government and legitimate tenure system
Electric cars and buses							Varies with degree of government intervention; requires capacity to retrofit “fuelling” stations
Sharing schemes							Historic schemes universal, but new ones depend on ICT status; undermined by high crime and low levels of law enforcement
Public transport							Depends on presence of existing ‘informal’ taxi systems, which may be more cost-effective and affordable than capital-intensive new build schemes, as well as (local) government capabilities
Non-motorized transport							Viability rests on linkages with public transport, cultural factors, climate and geography
Aviation and shipping							Varies with technology, governance and accountability
Smart grids							Varies with economic status and presence or quality of existing grid
Efficient appliances							Adoption varies with economic status and policy framework
Low/zero-energy buildings							Depends on size of existing building stock and growth of building stock

The economic and financial conditions of mobilizing investments for the mitigation options in Table 1.10 differ significantly between building and transportation.

In the building sector financing low energy resilient, cool architecture is constrained by the need for several small investments with long payback times Ürge-Vorsatz et al. (2018). More critically, short-term financial 'low hanging fruits' can disincentivise longer-term systemic change – e.g. easy investments with fast returns (such as boiler replacement) can prevent holistic deeper mitigation opportunities (a whole-building retrofit becomes less financially viable after a new boiler is installed). Avoiding the lock-in of 40–80% thermal energy use in buildings would require a fundamentally different approach to traditional energy efficiency incentives through innovative financing (Ürge-Vorsatz et al., 2018).

The dynamics in the transport sector are governed by the complex interplay of diverse factors, including energy prices, transportation costs, housing costs, real estate markets, spatial organisation of human activities, mobility needs, congestion, modal choices and GHG emissions (Lampin et al., 2013; Waisman et al., 2013; Allio, 2016; Behrens et al., 2007; Anas and Xu, 1999; Choi and Sjoquist, 2015). This highlights the risks of self-reinforcing loops and lock-in within the structure of transportation systems, the localisation of activities and the demand for mobility, possibly generating a bifurcation towards more carbon intensive pathways if consistent policies are not adopted (carbon prices, housing prices, infrastructure choices) (Guivarch and Hallegatte, 2011). These risks are far higher in developing countries, where pre-Covid estimates were expecting a multiplication of mobility needs by a factor of four by 2050, against a factor of two for developed economies (ITF, 2017). Other key factors influencing investment needs are the evolution of road construction costs (Rodríguez-Alloza et al., 2019) and the future occupancy rate of rail networks (the modal shift towards rail is a lever for reducing investment only if combined with a higher rate of occupancy).

Integrating these factors in a global IAM analysis (Fisch-Romito and Guivarch, 2019) shows that the cumulative investment needs in the transportation sector (roads, rail and airports) up to 2050 are similar in climate policy scenarios for developed economies compared to a reference scenario, but that they are significantly lower in developing countries (median values of decrease are -10% for Asia, -17% for Latin America and -47% for the Middle East and Africa).

A large increase of investments in transportation by 2050 is needed in developing countries (Gaya and Campos, 2009; OECD, 2017; Jakob et al., 2016). The share of transport investment in countries' GDP would increase from 1%, on average to between 2 and 3% in Asia and Latin America, while remaining almost stable in OECD countries. This is a case of infrastructure investment gap that chapter 2 tackles in depth. The issue is that the amounts of investment generated by mobility are more sensitive to policy integration than for the electricity sector. For example, Rozenberg and Fay (2019) show that, under current urbanization trends, transportation investments in developing countries by 2030 may increase to up to 3.3% of GDP. But assuming other modes of urban transport, reduction of forced mobility in addition to higher electric mobility and higher rail mobility would limit them to around 1.3% of GDP. We come back to this in chapter 2.

1.3.2.5. Carbon Dioxide Removal

Carbon Dioxide Removal is needed in all 1.5°C pathways, but with differences in terms of options and the scale of deployment as indicated in the bottom-up SR1.5 assessment for 2050[ii]. The BECCS deployment in P1 to P3 pathways range of up to 5 $GtCO_2$ per year by 2050, while P4 exceeds the bottom-up potential by more than a factor of two.

The CDR potential depends on technological and yield developments, land availability and sustainability criteria. Under the assumption that the bulk of removals in the AFOLU category stem from afforestation measures, pathways P1 to P3 lie below the best estimate of 2050 bottom-up potential of 3.6 $GtCO_2$ per year. In P3, however, the use of BECCS exceeds the bottom-up potential around 2070.

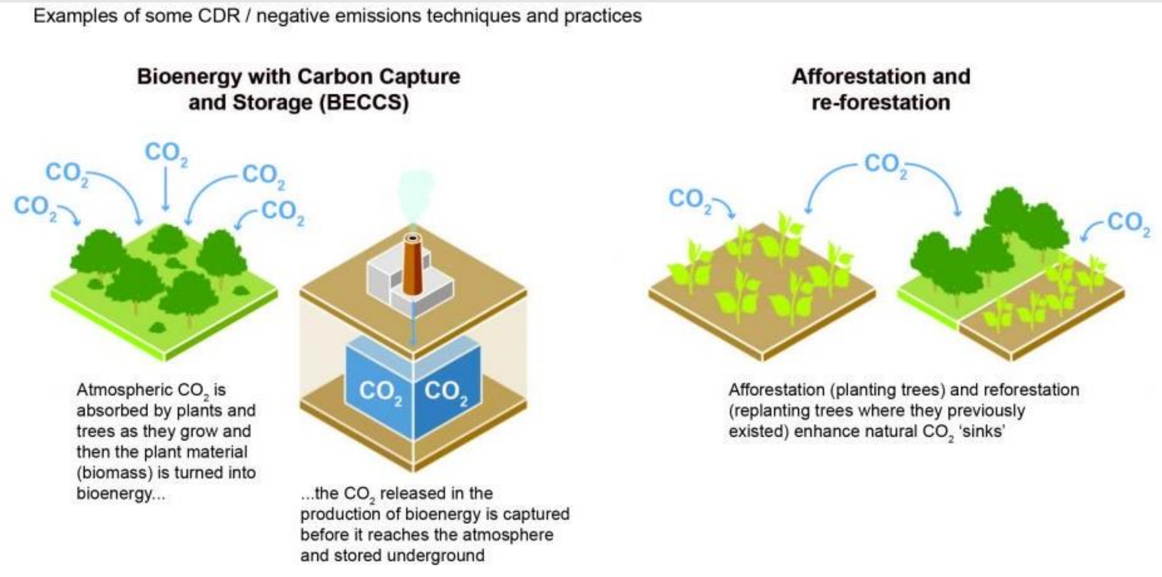
Box 1.5 | Carbon Dioxide Removal

All mitigation pathways in the Table 1.2 use CDR to offset residual or hard-to-abate CO_2 emissions on the way to the net-zero CO_2 goal, but the degree to which they can be used varies.

A distinction can be made between natural CDR options, including planting trees and the restoration of ecosystems, and technological CDR options. The pathways in the SR1.5 only consider two CDR options: planting biomass to generate bioenergy in combination with CO_2 capture and storage (BECCS), and afforestation and reforestation (both illustrated in Figure 1.4). However, various other CDR options could play a role in the order of a few billions tonnes of CO_2 removal per annum by 2050 (de Coninck et al., 2018).

Some nature-based options such as applying biochar to soils or enhancing soil carbon sequestration can have positive side-effects on soil health or sustainable energy access. The other CDR options are still very costly and energy intensive. These include Direct Air CO_2 Capture and Storage (DACCS), where CO_2 is extracted from the air through chemical processes using energy (currently in its demonstration phase), and enhanced weathering, a collection of methods to fixate CO_2 in carbonates in mineral rocks.

Figure 1.4 Two of several carbon dioxide removal options



. Source: de Coninck et al., 2018.

Uncertainties dominate the investment needs estimates of CDR options. The tentative estimates rarely consider land or water resource competition, and when they do, potentials are limited considerably (Hanssen et al., 2020). Researchers have so far hardly assessed their feasibility, given their low technological maturity. Especially for soil carbon sequestration and biochar, enhanced weathering, and Direct Air Capture with Carbon Storage (DACCS), information is sparse on their socio-cultural, institutional and environmental consequences (see table 1.11).

As for the potential for CO_2 storage, recent literature reviews (Bui et al., 2018; Fuss et al., 2018) show that even more conservative estimates of storage potential do not exceed the requirements for CCS storage considered in 1.5°C pathways. Even in P4, summing up storage in Table 1.2 up until 2060 would require storing less than 350 Gt CO_2 based on a conservative 1% of all sedimentary basins (Koide et al., 1993) or even higher recent estimates of 3,900 (Dooley, 2013) to 55,000 Gt CO_2 (Kearns et al., 2017). This compares to a needed 750 Gt CO_2. However, even if the global storage potential is ample, it is not evenly distributed, there could be bottlenecks in individual regions, which would limit the CCS potential, and it would require considerable CO_2 transport and storage infrastructure investments.

Table 1.11 Feasibility assessment of carbon dioxide removal (CDR) options.
For more details and the legend, see the caption of Table 1.6, based on de Coninck et al. (2018).

MITIGATION OPTION	EC	TEC	INST	SOC	ENV	GEO	CONTEXT
Bioenergy and carbon dioxide capture and storage							Depends on biomass availability, CO_2 storage capacity, legal framework, economic status and social acceptance
Direct air carbon dioxide capture and storage							Depends on CO_2-free energy, CO_2 storage capacity, legal framework, economic status and social acceptance
Afforestation and reforestation							Depends on location, mode of implementation, and economic and institutional factors
Soil carbon sequestration and biochar							Depends on location, soil properties, time span
Enhanced weathering							Depends on CO_2-free energy, economic status and social acceptance

These assessments show, however, many CDR options are still at a fairly early stage and that counting on multi-gigatonne scale CDR as early as 2040 poses risks that the Paris Agreement temperature limits will be out of reach (see table 1.2a). The vast majority of existing CDR literature is focused on early stages of the innovation chain and very little is known about how these technologies will eventually mature from RandD to deployment; how institutional governance can secure both their public acceptance and developing niche markets (Nemet et al., 2018).

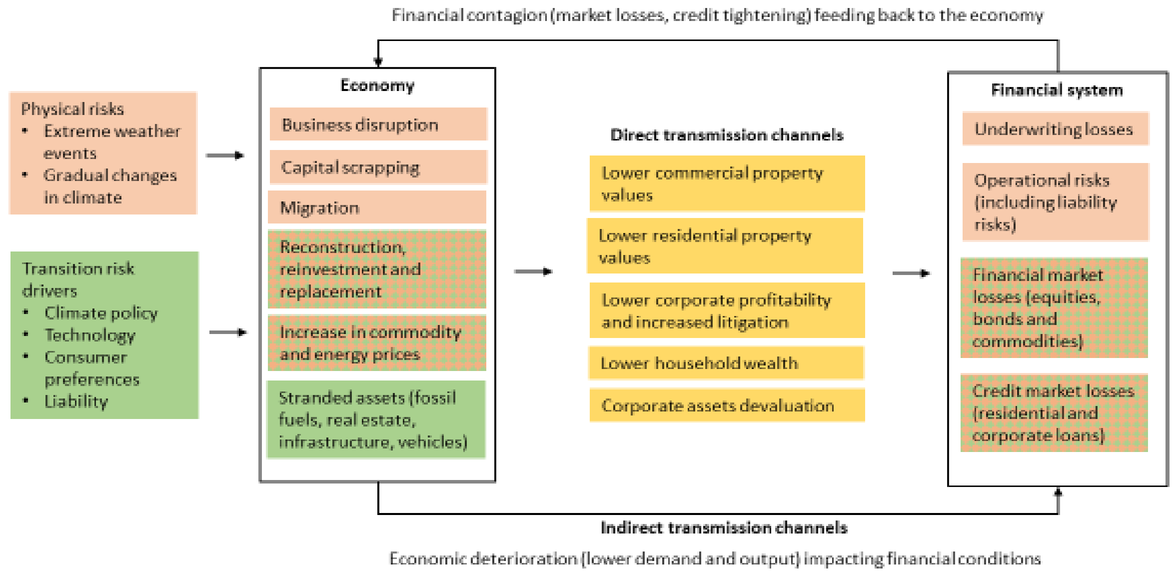
Afforestation or soil carbon sequestration would require far lower investment needs than BECCS at present and could benefit from learnings in REDD+ (Reducing Emissions from Deforestation and Forest Degradation). However, as land availability decreases, and as permanence becomes an issue because of ongoing climate change or anthropogenic disturbances, other – currently still more expensive – options could be envisaged e.g. Direct Air Carbon Capture and Storage (DACCS) (Fuss et al., 2018). But a large-scale roll out of DACCS would only make climate sense in an different energy system from today's (Creutzig et al., 2019). This is because DACCS captures CO_2 from ambient air, which requires a lot of energy. BECCS, instead, produces energy. As models are improved to incorporate these technologies (Strefler et al., 2018; Realmonte et al., 2019), we will better understand this scaling dynamic and resulting financing needs.

1.4. The financial system faced with climate change risks

There is not one unambiguous link between the physical risks induced by climate change and the resulting social and economic damages, or between claimed climate stabilisation targets and the content of mitigation strategies. Similarly, there is no unambiguous link between overall climate risks for societies and for the financial system. However, risk transmission channels can be identified, though not yet quantified.

Figure 1.5 pictures the direct and indirect channels through which transition risks and physical risks are transmitted, as well as the feedback loop that could threaten financial stability. Direct transmission happens from the economy (fragilization of some business sectors, costs of accelerated capital scrapping and reconstruction, increase of commodity prices and forced migration) to the financial system. Indirect transmission comprises the impact of overall economic deterioration on the financial system. As the financial system, via market losses and credit tightening, can affect the real economy, a feedback loop of financial contagion could emerge.

Figure 1.5 Overview of the potential system dynamics between the economy and the financial system (blue boxes) because of physical and transition climate risk drivers.



The dynamics are negotiated through direct transmission channels in the real economy and indirect economic deterioration because of economic impacts of the physical impacts. Economic deterioration and financial contagion with direct and indirect transmission channels can jointly form a feedback loop that could threaten financial stability. Adapted from: NGFS, 2019.

The indirect transmission channel is important, but it is fully dependent of the pre-existing stability of the impacted economies and of the efficacy of their policy responses. These are parameters that the actors of the financial system cannot control. The financial actors are directly hurt by and have a capacity to adapt to the signals transmitted directly. For the physical risk, these signals pass through the impairment of:

- Agriculture assets: increased uncertainty and variability in crop and fisheries yields, degradation of water and soil quality and quantity, increased virulence of pests (Taylor, et al., 2018), more frequent disruptions of distribution and processing from extreme weather (Bakker, et al., 2018), logistical constraints that prevent or delay the shipment of crops, seeds, and material.

- Infrastructure assets (transportation, water, energy, telecommunication, health care delivery): when cascading failures resulting from accelerated material degradation of concrete, steel, timber, and earthen structures in case of extreme precipitation, extreme temperatures, and changes in relative humidity and salinization (Stewart and Deng, 2015; Bastidas-Arteaga, 2018). Coastal flooding, inundation from rising sea levels, extreme heat, icing, subsidence, and forest fires also challenge nearly every component of transportation systems, from bridges and airports to pipelines and ports (Jacobs, et al., 2018) and of energy systems (dams, transmission lines, cooling systems in thermoelectricity, pipelines,). These risks do not just impact particular sites and locations but also shorten the infrastructure's lifecycle and degrade its operational reliability (Maxwell, et al., 2018). Progressively degradations in lifecycle performance and degradation in the quality of the logistics can compromise their yields and creditworthiness.

- Real estate and land: when perceptions of increased physical risk in a local housing market lead to decreasing prices of homes exposed to sea level rise, flooding, and wildfires. Any drop in the values of real estates and land, in turn, threatens the value of mortgages that play a critical role in the balance sheets of many financial market participants, including banks that hold these mortgages, investors in mortgage-backed securities, and government-backed enterprises which guarantee the default risk of the mortgages they securitize (Ouazad and Kahn, 2019).

- Financial institutions: especially insurance companies and smaller regional and local banks, are also vulnerable to claims and loan default losses from chronic and acute physical risks.

Transition risks are different in nature. They come from the interplay between the market and technological uncertainty, and the policy uncertainty due to the accelerators and inhibitors on climate policies shaped by social perceptions of climate change damages and in reaction to the unmitigated economic consequences of climate policies. One important category of these transition risks are stranded assets losses incurred by investing in carbon-intensive options whose profitability could be wiped out by accelerated climate policies and reputational effects amplified under the pro-divestment movement pressure. Stranded capital from fossil fuel assets alone suggests a potential global loss of wealth between $1 trillion and $4 trillion (Mercure et al. 2018). The risk extends to demand-side sectors, for instance sales of diesel-based cars are expected to shrink within the European market.

Another category includes the risks taken by investing in alternative low-emission and climate-resilient options. The economic viability of these options, usually capital intensive, is very sensitive to uncertainties about

i) the overall business context,

ii) how specific markets evolve as a result of policy changes (e.g. ban of high emission products, carbon tax, regulation of electricity markets, real estate policies),

iii) shifts in consumer behaviour (e.g., attitudes towards diesel cars and electric cars, air travel, plastic products versus natural fibre products, animal protein),

iv) the cost/efficiency and social acceptance of energy supply options (e.g., wind energy, nuclear, CCS (L'Orange-Seigo et al., 2014) and adaptation measures and resilience technologies (micro-irrigation, drought-and dryness tolerant biotechnology),

v) capacity of technological breakthroughs (battery or hydrogen) to survive the valley of death of innovation (Grubb et al., 2014); and

vi) feedbacks from land-use policies and ecosystems management.

These uncertainties are all the more critical as the pace and chances of success of every individual low-emission option depend on systemic changes in our energy, urban, land-use and industrial systems. In turn, these systemic changes require a re-optimization of the upstream industry and logistic chains, which adds another layer of uncertainty that might be exacerbated by the adaptation measures themselves.

The overall risks depend upon financial institutions' capacity to absorb the changes in the value of assets. These changes affect differently:

- **Credit Providing Institutions** (banks and other financial actors) that lend to entities weakened by climate risks. Credit Providing Institutions are exposed to losses from impaired loans and might become less able to provide credit to affected entities. For example, they would stick strictly to loans with a maturity of one to three years and refuse to roll over loans if they believe a company becomes high risk.

- **Institutions holding Climate Impacted Assets** that operate along a broad spectrum of investment horizons but under prudent management and hold assets that may be affected by climate risk. Examples of such assets are commercial mortgage-backed securities pooled together and secured by commercial property, such as hotels, office and retail buildings, warehouses, and municipalities' bonds. Typically, insurance companies and small regional and local banks are vulnerable to claims and loan default losses from chronic and acute physical risks.

Whether and how climate-related risks could harm these two categories of financial institutions depends on three parameters: i) the deployment pace of these risks that result not only from the direct impacts on the assets of individual financial institutions but also from the feedback loops pictured in Figure 1.5, ii) capacity of the financial institutions to internalize the risks, and iii) the efficacy of shock absorbers (Litterman, 2020) (private insurance and reinsurance, government-sponsored entities) for assistance to people and businesses during extreme events[iii].

A related question is whether, in these conditions, the financial system will evolve in such a way that it will help households, small and medium enterprises, farmers, corporations, cities and the public sector to launch the four systems transitions needed to avoid the worst of climate change. The problem is that physical climate changes are significant but ‘baked in’ for the next few decades and accelerate later. Financial players will progressively integrate physical risks under a ‘value at risk’ framework, and revise them according to new information, but it is not certain if this integration happens fast enough to motivate them to support the four systems transition and maximize the chances of realizing a P1 or P2 scenario. Chapter 2 will address this question.

Endnotes

[i] These risks could be exacerbated by societal responses to sector-scale impacts, e.g. in the form of mass migration, food riots, etc., which are not captured in the currently assessed pathways.

[ii] "Bottom-up" refers here to an assessment of deployment of a technology or practice that adds environmental and social side-effects of rapid ramp-up to technical, geophysical and economic constraints. Bottom-up assessments therefore arrive at lower estimates of potentials than what is seen in most pathways.

[iii] These shock absorbers have intrinsic limits. On the one hand, experience demonstrates that private insurers often raise premiums in the aftermath of major events to ensure that they have sufficient reserves to cover future losses or exclude coverage for too large risks to cover even at an acceptable price in the case of flood protection. On the other hand, the existence of public shock absorbers may exacerbate risk by creating a moral hazard. For example, subsidizing some properties' insurance premiums can be an incentive to excessive risk-taking in areas most exposed to flooding, inundation from sea level rise, and extreme precipitation.

Chapter 2: How to be proactive in addressing gaps and capturing opportunities?

Accelerating climate action requires over the next two decades a massive increase in low-carbon and climate-resilient investments. This places a triple responsibility on financial decision-makers, including governments and regulators:

- To maintain the capacity of the financial system to support economic activity, encourage entrepreneurship, and safeguard the assets of millions of savers, pensioners, local public institutions, and businesses
- To channel a much larger share of private savings towards sustainable and low carbon options
- To create a business environment in which climate policies contribute to alleviate today's tensions in the world economy (unemployment, poverty, inequality, trade disputes). This is, according to the IPCC 1.5° C report, an overarching pre-condition of scaled-up climate action.

We will see in chapter 3 that this responsibility is even more critical in the post-Covid-19 context. This chapter will specify the differences and interplays between climate-related risks for societies and the financial system. It will also discuss the stakes for scaling-up climate-friendly investments in the context of a structural investment gap for infrastructure, and how climate finance can help bridge this gap contributing to more sustainable and equitable development and a safer financial system.

2.1Climate-related risks for the financial sector and societies: differences and interplays

Chapters 1 highlighted that the earth system is entering a situation of non-linear consequences and 'unknowable unknowns' related to global warming (Lenton et al., 2019). For an effective framing of policy issues, a distinction must be made between these physical consequences and tipping points for the financial system, the world economy, and the human community.

For example, the 'risks hotspots' for human systems might primarily affect areas with a marginal share of the market economy and capital flows. Thus, financial actors might not immediately predict the consequences of exacerbating vulnerabilities in these societies and their impact on the world's security (Stern, 2006; Mach et al., 2019). According to the 'rational expectations and efficient markets hypothesis' (Fama, 1970, Lucas, 1972) that underpins the current functioning of the global financial system, this delay is acceptable because financial actors will readjust their choices and deploy an optimal hedging strategy for both the financial system and society when these consequences will fall upon them.

However, this hypothesis might not hold true in relation to climate change. It might lead to a trade-off between the protection of the financial system and of the collective interest.

Indeed, learning from experience, financial actors can disengage from assets exposed to physical risks as home insurers did for flood and wildfire insurance for example in California (Ouazad and Kahn, 2019). As regards transition risks, the disengagement will take the form of high coefficients applied on infrastructures and investments with a long lifespan. In both cases, the probability of 'extreme but plausible' scenarios will be progressively revised upwards in the Value at Risk (VAR) calculations reinforcing the disengagement behaviour.

The ensuing question is whether the VAR revision based on experience will lead financiers to readjust their choices quickly enough to avoid that climate change and climate policies destabilize the financial system in the coming decades. There is no need for a catastrophe on a planetary scale in the Weitzman sense (2014) for that. In the context of already-stressed balance sheets and high levels of corporate and municipal debt, a few destructive events affecting key economic hubs or revisions of technological expectations (e.g. negative surprises about low carbon options or a drop in fossil fuel prices) could trigger a sudden spike in risk aversion, and it might be difficult to restructure the portfolios in a short time". Time is of the essence. When time runs out, risks can turn into catastrophes. Investors could rush out of certain bond funds causing liquidity shortages that could dry up futures markets that are already fragile because of higher volatility in certain commodity prices, including oil.

The financial system might delay the readjustment if it misses the signal of increasingly worrying statistics of climate damages is missed during the financial cycles' upward-oriented phases with a momentum of cumulating debts and buying permanently revalued assets (Borio, 2014). At the cycle's turnaround, financiers might pay more attention to sources of risks not related to the climate, such as high corporate debt and suddenly devaluated assets based on other risk factors, and this would destabilize the system.

This leads to two opposite outcomes.

In the first scenario, a successful spontaneous adjustment due to new information would keep the financial system safe (Keenan and Bradt, 2020; Litterman, 2020), but transfer to taxpayers the onus of damage compensation and the funding of adaptation and mitigation investments. The growing fiscal pressure on public budgets already put under strain by unfunded pension obligations and rising healthcare costs (Gilmore and St. Clair, 2018) might increase the population's vulnerability and delay the scaling-up of climate mitigation activities.

In the second scenario, the financial system would not readjust on time to new information, endangering its own stability (DNB, 2017). In both cases, the 'rational expectations and efficient markets' hypothesis would be invalidated and the financial system would fail to deliver on its triple responsibility to address climate change.

Since the Nineties, the economic literature has highlighted that climate action must be undertaken before a fully-fledged assessment of damages associated to climate change becomes available because of the inertia of the earth and economic systems. 'Act then learn' is preferable to 'learn then act' (Manne and Richels, 1992; Ha-Duong et al., 1998), and there is no need to wait for a scientific consensus about global climate catastrophes (Weitzman, 2011 to justify precautionary action (Pottier et al. 2015). This is why the international community adopted the below 2° C warming target. ***But the financial system's spontaneous reaction is closer to the 'learn then act' approach and will likely lead to a P3 or P4 mitigation pathway in the absence of policy action and reforms of its internal dynamics***.

What set of public policies, self-adaptation measures, reforms of the financial regulatory framework, and international cooperation arrangements can enable the financial system to adopt a pro-active attitude towards climate change and support the scaling-up of climate-friendly investments? All these tools cannot ignore the general operating principles of the financial system (Malesky, 2017) so climate finance will have to be an adaptive market (Hallet al. 2017) embedded in, and contributing to, the evolution of these principles. The challenge is to reduce the internal vulnerability of the financial system and its consequences for societies while better aligning with climate priorities and accelerating the transition to net zero emission economies. This would reduce societies' intrinsic vulnerabilities and allow them to better resist to global warming dynamics already underway. The magnitude of damage caused by climate change depends indeed on the seriousness of physical impacts as much as on the resilience of impacted societies (Hallegatte et al., 2007)

2.2. Climate finance, investment gap and capital flows' geographical misalignment

Circulating figures on the investment requirement for a climate-friendly transition without their uncertainty ranges misrepresents the challenges ahead. It would be simple to channel capital flows towards projects whose overall volumes, technical content, and returns are easily predictable. The financier's mission is precisely to help decision-makers take manageable risks in an uncertain context.

The reasons for this uncertainty lie in the interplays between a) the baseline economic growth rates, b) the link between economic growth and energy demand, c) the evolution of low carbon options' cost efficiency, d) the level of integration between climate policies and other public policies, and their efficacy. Every scenario collected in the IPCC report incorporates various hypotheses about these parameters, except for policy uncertainty[iv], and the full range of the modelling results helps understand the orders of magnitude at play and the determinants of their uncertainty.

Understanding the challenge of climate finance requires differentiating between global low-carbon investment needs, the incremental costs of a less-than-2°C warming target, and the amounts needed to bridge the infrastructure investment gap (IMF, 2014). Global low-carbon investment needs are estimated between 3.9% and 8.7% of the world's GDP over the next two decades[v]. 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) that currently flow towards real estate, land and liquid financial vehicles[vi]. More challenging is the reduction of the infrastructure investment gap, as repeatedly pointed out in specialist literature. According to the Global Infrastructure Outlook, this gap could reach a cumulative value of $14.9 trillion worldwide in 2035, meaning a global deficit of 15,9%. Arezki et al., (2017) retain the more pessimistic projections of a 32% deficit by the Boston Consulting Group. Rozenberg and Fay (2019) find that this investment gap is even higher in low and middle-income countries, especially when SDG-related investments are included. Meeting the 2°C target and SDGs 6.1 (drinking water) and 6.2 (sanitation and hygiene) would demand to multiply by 1.24 to 2.36 investments in water supply and sanitation, flood protection, and irrigation in such countries.

Fundamentally, ***the chronic infrastructure investment gap and the geographical misalignment of capital flows are symptoms of the 'fault lines' of the current world economy***.

First, the global infrastructure investment gap reflects a ***misalignment between the geographic distribution of savings, capital flows, and infrastructure investment needs.*** This gap exists at the national level due to limited access to capital for key stakeholders of the low carbon transition (local authorities, SMEs, and households) (World Bank, 2019b) and to the diverse causes of the efficiency gap, for example energy efficiency (Ürge-Vorsatz et al., 2018). It is critical at the international level given countries' heterogeneity. Developed countries have aging populations, high savings capacities, established social safety nets, and the bulk of their infrastructures in place. Developing countries have a significant opportunity to leapfrog to low carbon infrastructure as they still have to build two-thirds of their infrastructure capital . But they have young populations, a wide range of savings rates (from 15% to over 40%) and underdeveloped social safety nets. Even regions with high savings can suffer from deficient energy access and inadequate infrastructure coverage (ADB, 2018). This misalignment is compounded by the limited capital flows from high-saving to low-saving regions. The main barriers to these capital flows are discussed later in the chapter.

A second fundamental reason behind the chronic infrastructure gap is the ***short-term bias of economic and financial decisions*** (Miles, 1993) (Bushee, 2001); (Black and Fraser, 2002). This bias results from a 'business environment' in which returns weighted on short-term risk dominate the investment horizon of both financial actors and firms working under a 'shareholder value business regime' (Roe, 1994; Froud et al., 2000) instead of the 'managerial business regime' that characterized the late 20th century (Galbraith 1967). In such an environment, risk-averse financial players tend to direct more savings towards liquid financial products and real estate and will avoid confronting the risks of early-stage technologies and markets in developing countries. We will examine more in detail later why this bias works against infrastructure investments even though they deliver returns between 4% and 8% (OECD 2017).

This behaviour results in a gap between the 'propensity to save' and the 'propensity to invest' (Summers, 2016) in which some analysts see a driver of an unstable and uncertain growth over the past and forthcoming decades, if not of a possible secular stagnation, (Krugman, 2014; Blanchard, 2019; Summers and Rachel, 2019). This has become a severe threat to the stability of the modern financial system (Christopher, 2017; Schwab, 2019 , Arezcki et al., 2019).

2.2.1. The unintended impacts of the response to the subprime crisis

After the subprime crisis, tight regulations adopted to minimize the vulnerability of the financial and monetary systems and the liquidity injections by central banks did not help reduce the infrastructure investment gap. They resulted in increased corporate debt worldwide, but not in more long-term investments. While syndicated bank loans have traditionally been an important source of funds for risky long-term projects, the tighter bank regulations under Basel III, combined with an economic context with more uncertainty and flatter yield-curve, have pushed banks to retrench from risky and less profitable asset classes (Blended Finance Taskforce, 2018). In this context, they tended to limit loan maturity to 5 or 8 years, while infrastructure projects typically require amortization of debt over 15–20 years (Arezki et al. 2017).

The private sector's recourse to debt has then largely bypassed the banking system via *'shadow banking'* actors, with bonds and equity traded through Non-Bank Financial Intermediaries (NBFI) (mutual funds, insurance, asset managers, hedge funds, exchange-traded funds) that are not subject to the same regulatory regime as banks. The percentage of global financial assets held by the NBFI sector grew from 42% in 2008 to 49.5% in 2019 (FSB 2020). Since this sector can provide, through green bonds, the easiest vehicle to mobilize savings for low-carbon investments, the question (discussed later) is how such vehicles should be built to improve and not undermine the stability of the non-bank banking system.

Between 2008 and 2019, the upward phase in the financial cycle allowed the accumulation of debt with cumulated risks concealed in the loaners' asset column preparing a slowdown in economic growth at the downturn of the cycle (Borio et al., 2018). The threats materialized in 2019 prospecting lower economic growth worldwide even before the Covid-19 crisis. This generated a loss of confidence in asset prices and revealed systemic vulnerabilities. A symptom was, in 2019, the negative 10-year to 3-month US spread (-7.6bps.[vii]

These post-2008 dynamics have had indirect negative consequences for the willingness of the private sector to invest in the low carbon transition. In particular:

- negative yields for long-term sovereign bonds reflect very risk-averse behaviours (preferring the certainty of small losses to the expectation of gains that are associated with the risk of large losses) that lead to credit rationing for projects (Stiglitz J., Weiss A., 1981) and penalize capital intensive and less mature low carbon options;
- in the investment-grade universe 50% of private companies were rated BBB end of 2019 compared with 34% in 2000, which inhibits their capacity to invest (CEIC Data stream: https://www.ceicdata.com/en/indicators); and
- average sovereign spreads in emerging economies reached 524bps on March 18, 2020 undermining their refinancing capacity. Besides, an increasing number of developing countries have been or are at risk of being downgraded at CCC, thus deprived of access to the capital market if not at usurious discount rates.

2.2.2. The investment gap for adaptation and essential goods and services

The warmer the planet, the higher the sea-level rise and the more frequent the floods, typhoons, hurricanes and heat waves. As a consequence, the investment needs will also increase in new and retrofitted resilient infrastructure, flood protections, water management, health systems, climate resilient agriculture, nature-based solutions, community-based initiatives, and early warning systems (IPCC, 2018).)

Studies indicate that adaptation investments needs are in the order of $140 to $300 billion per year for developing countries over 2016-2030 (UNEP, 2018; IFC, 2016). Only 18-25% of climate finance is currently directed to these measures in developing countries with a fragmented support and small amounts flowing through UNFCCC channels (Shine and Campillo, 2016).

The funding of specific adaptation investments is only part of the challenge because, ultimately improving societies' adaptive capacities depends on the SDGs' fulfilment (Hallegatte et al., 2015). Bridging the investment gap on irrigation, water supply, healthcare, energy access, and quality buildings is an essential enabling condition for adapting to climate change.

Investment at scale in these essential infrastructure and services is however hampered by two intrinsic features. First, it is more challenging to capture monetary revenues from beneficiaries of these projects as their benefits frequently have a local public good nature and concern activities that often do not deliver marketable goods and services. Second, adaptation projects are not easy to standardize, making financial, technological, and organizational innovations more difficult than for mitigation activities.

This is why much of adaptation mobilizes local, regional and national partnerships, including with the support of national and sub-national government budgets, supplemented by NGO and private climate funds (Nakhooda and Watson, 2016). Adaptation investments and the provision of basic infrastructure will likely continue to require public subsidies and development assistance. In 2018, the private sector brought only 5.7% of the adaptation projects to the portfolio funded by Multilateral Development Banks (MDBs), while the proportion for mitigation projects was 47%. The difficulty to monetize adaptation benefits explains why 70% of their funding by the MDBs is operated through loans, 9% through grants and only 0.04% through guarantees which cover instead 4.4% of mitigation projects (MDB, 2019).

2.3. Bridging the investment gap for low-emission, climate-resilient infrastructure: market fixing and market shaping

For decades, discussion on how to incentivize the changes needed in investment, production, and consumption patterns and induce technological progress that brings down carbon abatement costs centred on the relative merits of pricing and non-pricing instruments, and ways of articulating them. The prevailing assumption was that, with the proper carbon prices, well-defined standards, and norms supported by public funding, private finance would follow automatically. This assumption no longer holds given the variety of market failures in the infrastructure investment gap and the geographical mismatch of capital flows.

As the traditional distinction between market-based and command-and-control instruments does not capture the diversity of policy packages experimented over the past three decades to accelerate climate innovation and investments, we consider here, and interpret more broadly, the distinction between two approaches to correct market failures. This distinction has been made by several authors (Mazzucato, 2015; Ryan-Collins, 2019).

The ***market-fixing*** approach focuses on removing information barriers that hinder investments by adding financial disclosure to pricing signals with no specific demand for systemic reforms of the capital markets and no fiscal and regulatory policies to guide microeconomic choices. The ***market-shaping*** approach aims to remove investment barriers directly through a mix of self-regulatory regulatory, and financial instruments, and direct public investment to improve risk-weighted returns of low emission, climate-resilient infrastructure for a given carbon price.

2.3.1. Market fixing: sending the right signals

The market fixing approach aims to send the right pricing and risk signals to enable financiers to better value assets and reallocate capital accordingly.

Carbon Pricing, necessity, forms, and limits

There is a widely shared consensus in economics that, in a frictionless world with perfect capital markets and without uncertainty, carbon prices would be sufficient to secure the attractiveness of low carbon options for capital markets. In the real world, however, the carbon price signal is swamped by the noise of other signals, such as oil prices, interest rates, and currencies exchange rates in addition to the business uncertainty (Gross et al. 2010, Roques et al. 2008)

Carbon prices capable of covering these noises should be set at a higher level than the \$40–80/tCO2 by 2020 and \$50–100/tCO2 by 2030 recommended by the high-level commission led by Nicholas Stern and Joseph Stiglitz (Stern-Stiglitz 2017). The main reason is that the payback period of low carbon options with higher upfront capital expenditure and lower operations and maintenance costs is longer and therefore much more sensitive to uncertainty than alternatives with fuel costs dominated technologies (Hirth and J.C. Steckel,2016; Hourcade, 2017; Iyer et al. 2015; Schmidt,2014). [viii]

The scaling-up and geographical expansion of carbon prices to such levels[ix] are highly uncertain because they have to be embedded into country-specific fiscal and social policies to hedge against the regressive impact on welfare, competitiveness, and employment caused by higher energy costs propagated throughout the economy (Michaelowa et al., 2018). This impact needs to be offset using the proceeds of carbon taxes or auctioned emission allowances to reduce distortive taxation (Goulder, 1995; Mooij, 2000; Mooij and Bovenberg, 1994; 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). The adverse economic and distributive effects of higher energy prices and the removal of fossil fuel subsidies are more severe for low-income countries, countries with a large share of energy-intensive activities, and countries exporting fossil fuels. These also have a lower potential to mitigate impacts because of lower wages and lower pre-existing taxes (Lefevre et al., 2019)

The challenge is almost identical in the case of emission trading systems. A frequent misconception is to see in this mechanism a way of financing the low carbon transition through the revenues from the sale of emission permits. But this is possible only if at least part of the emissions allowances are given for free to companies. In this case, finding the rules for the allocation of allowances for a given overall carbon constraint is an uncertain exercise. It has to allow all sectors to self-finance their low carbon investments or cover the debt service of loans without generating 'carbon rents' that would impose a burden on the rest of the economy (Branger and Quirion 2015). The perspective of voluntary carbon markets growing more than 15-fold by 2030 to deliver the 1.5°C pathway envisaged by The Taskforce on Voluntary Carbon Markets (Task Force on Voluntary Carbon Markets, 2021) might confront the same obstacles, including the political pressure for auctioned permits and the difficulty of controlling the effects of linking cap and trade systems that are very heterogeneous in scope and underlying jurisdiction (Holtsmark and Weitzman, 2020).

Carbon price signals alone leave financing challenges unresolved because of the constraints on their scaling-up and the need to use a significant share of their revenues to mitigate their effects directly (recycling option) or indirectly through companion policies that tackle market failures other than greenhouse gas emissions and that involve public funding. These failures are related to knowledge spill overs, learning and RandD, information, capital markets, labour markets, and unpriced co-benefits of climate action. This is why a consensus, expressed by the High-Level Commission on Carbon Prices (Stern and Stiglitz 2017), is now emerging on the necessity of embedding carbon prices in more complex policy packages.

The Stern-Stiglitz commission also emphasizes the interest of implicit carbon pricing in complementing explicit carbon prices. The way to do so is to embed notional prices in financial instruments and public incentives that foster low-carbon programmes and projects, such as specific project-based credits and 'shadow pricing' internal to public enterprises. This link between carbon pricing and financial instruments is explored below.

Climate Risk Disclosure and taxonomies

Historically, the concerns about the implications of climate change for the financial community arose from potential fiduciary obligations of reinsurers and pension funds (Freshfields at al. 2005; Girgis and Barker, 2015; Mansley, 1994; Wilder and Curnow, 2012). The focus on liability risks responded to the advocacy strategies deployed by the universities' endowments and mission-based investors such as philanthropic and religious organisations to remove the 'social license' from the fossil fuel industry and to raise the cost of its access to capital (Ansar, A et al. 2013; Baron and Fischer, 2015). The Carbon Tracker Initiative (CTI), a UK think tank, first quantified in 2011 the climate-related risks of stranded assets in the fossil fuel industry (CTI, 2016). Since then, other tools have emerged covering other sectors and asset classes, such as the 2° Investing Initiative's PACTA.[x] Such tools demonstrate a rising interest in business circles to engage in an 'investor revolution' (Eccles and Klimenko, 2019) with climate change incorporated in the Social Responsibility of Enterprises to induce changes in companies' routine decisions, and more attention paid to alternatives with a lesser climate impact.

A few asset owners started, for example, to sell their fossil fuel-based assets. Before the recent crash of oil prices, the question was whether a divesting movement could be large enough to weigh on share prices of oil companies (Denning, 2019). The question is even more difficult if we are to disentangle the impact of such movements from other causes of oil price volatility in the Covid-19 context[xi].

Marc Carney's speech (2015) on *the 'tragedy of the horizons'* broadened this perspective, adding the 'physical risks' and the 'transition risks' to the 'liability risks". This alert from the former Governor of the Bank of England had an influence amongst financial actors who generally do not consider the future beyond a quarterly horizon [151]. It opened a discussion about the unseen build-up of climate risks across multiple companies and actors that could threaten the system's stability by suddenly writing down significant classes of assets. This discussion led to the creation of a Taskforce on Climate-related Financial Disclosures (TCFD) under the auspices of the Financial Stability Board (FSB) that brings together financial authorities from G20 countries to prevent new financial crises. The voluntary nature of the TCFD facilitated its endorsement by governments and regulators, in addition to numerous companies and investors. But it allowed for a patchy adoption of its principles.

The Sustainability Accounting Standard Board, a non-profit organisation, published in 2016 detailed technical guidelines (Sustainability Accounting Standards Board, 2016) to better understand the probability, magnitude, and timing of climate risks for each industry across the economy in the near term and to compare corporate performance among peers. In 2017, the TCFD released a universal framework (TCFD, 2017) with a set of quantitative and qualitative criteria to disclose the climate risks embedded in portfolios (See box 2.1).

There are currently five leading voluntary disclosure frameworks, which have recently begun to work together towards a joint vision: the Carbon Disclosure Project (CDP), the Climate Disclosure Standards Board (CDSB), the Global Reporting Initiative (GRI), the International Integrated Reporting Council (IIRC) and the Sustainability Accounting Standards Board (SASB). They follow the recommendations of the Inter-Agency Task Force on Financing for Development (IATF) , which includes over 60 UN and international entities on global mandatory disclosure of climate-related financial risks (UN IATF, 2020).

BOX 2.1: Examples of climate-related finance initiatives, frameworks, standards and methodologies

Disclosure-oriented platforms, scorecards, and tracking lists. These seek to provide decision-makers or institutional customers with information about the way specific companies or institutions perform in relation to climate change. Examples are the Climate Disclosure Project (CDP), the Asset Owners' Disclosure Project and the Global Coal Exit List.

Financial reporting standards. These seek to include climate and other ESG or non-financial factors into accounting standards. Examples are the Sustainability Accounting Standards Board (SASB), the Global Reporting Initiative (GRI) and Integrated Reporting. Others, such as the Partnership for Carbon Accounting Financials include features of both reporting standards and disclosure platforms.

Analytical methodologies and certification schemes. These go a step beyond disclosure-oriented platforms by analysing and seeking to incentivise possibilities for the reduction of embodied emissions and physical climate risks. Examples come from both NGO and proprietary/commercial providers, such as the 2 Degrees Investing Initiative, the Transition Pathways Initiative, the Platform for Carbon Accounting of Financials, and many commercial providers.

Scenario-related tools. A critical element of the TCFD recommendations, scenario analysis attempts to capture future risk. Examples are the Paris Agreement Capital Transition Assessment (PACTA), a tool to test entire portfolios against a scenario, and the Inevitable Policy Response, a modelled, policy-driven transition scenario with resources to apply it.

Physical risk analysis tools. These use information from climate models combined with data about the location and features of assets and business activities to estimate their vulnerability to climate impacts. Examples are the World Resources Institute (WRI)'s Aqueduct tool or 427MT's physical risk services.

The primary outcome expected from climate disclosure approaches is that banks and asset managers will correct their short-term bias and launch financial signals to investors by setting the cost of loans in an inverse proportion of the projects' carbon content.

An important macroeconomic side-benefit would be to hedge against abrupt corrections in financial markets caused by cumulated mispricing of assets (Plantinga, A; Scholtens, 2016). In late 2017, the Network for Greening the Financial System (NGFS) was launched. It now has 90 members, amongst which central banks from many developed and developing countries. Observers include the IMF, the World Bank, the Bank for International Settlements, the Basel Committee for Banking Supervision, and the Green Climate Fund (GCF). Its first report made several recommendations for central banks and other policy-makers and established a taxonomy of green, non-green, brown, and non-brown products (NGFS 2019) to help direct investments to sustainable options. The European Union recently developed a first essay of such a taxonomy (EU, 2020), and some EU companies have just launched the first application trials.

In parallel, stress test methodologies have tried to assess the risk exposure of various asset portfolios (Battiston et al., 2017). In 2019, the Bank of England and the Netherlands announced plans to conduct climate risk stress tests for banks and insurers. In March 2020, the European Central Bank (ECB) announced the preparation of a macro prudential stress test to reveal how climate risks could propagate across the financial system and the non-financial economy.

The concrete outcome of these processes is still uncertain, but they show an increasing demand for knowledge tools from high-level decision-makers in an uncertain environment.

Lessons learned from market fixing experiences

Experiences of carbon pricing started in the early nineties in Sweden. Twenty-five years later, in 2016, explicit carbon prices covered only 15% of global emissions and three-quarters of them were below \$10 per tCO_2 (World Bank, 2016), far lower than \$40 to \$80 worldwide recommended by the Stern-Stiglitz report. This has to be compared with the \$5.2 trillion (6.5% of the world GDP) dedicated in 2017 to subsidising fossil fuel consumption (Coady, et al., 2019).

The scaling-up of carbon prices and the removal of fossil fuels subsidies remain fundamental conditions for the low carbon transition, but their pace depends ultimately on each government' capacity to incorporate them into a set of public policies (fiscal reforms, regulation of the electricity and transport systems, real estate policies, safety nets) that minimize their adverse effects on development priorities and, possibly, turn them into a 'double-dividend. The design of these policies will always have to consider national and local circumstances. This explains why paragraph 136 of the Paris Agreement's decision recognizes the usefulness of a carbon price but states that it *"applies to non-Party entities and is not binding upon countries that are Parties to the convention."* There is, therefore, little chance that carbon prices can reach in the coming years the levels required to overcome the noise of other market signals.

A still underexplored area is the use of notional carbon prices to drive public policies. Such prices have been adopted in the UK and France with a 'valeur tutélaire du carbone' (safeguard carbon value) of 250€/tonne (Quinet, 2019) but with, so far, no observable consequences.

Climate transparency approaches are too recent to assess their impact. In June 2019, a TCFD survey found that most companies do not disclose sufficient information on potential financial impact of climate-related issues affecting them (TCFD, 2019). A recent report by the Climate Disclosures Standards Board also found that the adoption of the TCFD recommendations continues to be slow and that 78% of Europe's largest companies are falling short of reporting environmental and climate-related risks despite EU guidelines (Climate Disclosures Standards Board, 2020). As for the practical consequences of these efforts, an IMF study found that equity valuations across countries did not reflect any of the commonly discussed global warming scenarios nor associated projected changes in hazard occurrence or physical risk incidence.[xii]

The TCFD and taxonomy tools face three main limits:

- The methodological difficulties associated with calculating aggregated indicators of portfolios' 'greenness'. The quantification of the so-called 'scope 1', 'scope 2' and 'scope 3' of emissions to be attributed to each activity as defined by the GHG Protocol launched in 2001 by the World Business Council for Sustainable Development (WBCSD**),** and the World Resources Institute (WRI) might not be easy to resolve[xiii]. Another question is about the grades given to emissions from energy-intensive industries like cement, steel, and specific chemicals, which have high production-based emissions but are also absolutely needed to build low carbon climate-resilient infrastructures.

- Decarbonizing an asset portfolio by divesting coal or other carbon-intensive activities does not necessarily lead to investing in the technical options needed for deep decarbonisation [157]. One can decarbonize a portfolio by investing not in such options but in other non-carbon intensive activities, like health, education, or information systems, or assets like real estate that indirectly induce mobility needs contributing to higher CO_2 emissions.

- A company that gives up a carbon-intensive project may make way for a competitor less sensitive to environmental virtue, which would find support by financial institutions with a looser interpretation of climate disclosure.

Hence, even if public pressure mounts to require financial institutions and industry to disclose their climate risks and the emission embodied in their investment, disclosure and transparency alone might not effect the redirection of saving quickly enough for a 1.5°C or a 2°C warming transition (Christophers, 2017) (Ameli, 2019). Transparency is needed to address behavioural routines, what Grubb et al. (2014) call the first domain of action, but it cannot address on its own the market failures that interact with the financial system and the structural issues of climate finance, the second and third domains of action.

Thus, price mobilization and financial signals alone might fail to reduce the infrastructure investment gap in due time. Their common limit is that ***the deficit in low carbon investments depends on many market failures that improved information alone cannot reduce.*** Symptomatically, climate-related resolutions have proliferated in the past couple of years (Westcott, 2019), while investors use their power to appeal to governments directly. An example is the Global Investor Statement to Governments on Investor Expectations, a call to governments worldwide to meet the objectives of the Paris Agreement endorsed by 420 investors managing over $32 trillion2. ***Market-shaping***

2 The Global Investor Statement to governments on climate change: https://globalinvestorcoalition.org/wp-content/uploads/2019/09/190916-GISGCC-for-UNCAS.pdf

approaches aim to respond to this call by addressing directly the market and institutional failures that inhibit the efficacy of price and financial signals.

2.3.2. Market shaping: removing economic and non-economic barriers of climate-friendly investments

From a microeconomic point of view, the infrastructure investment gap looks like an economic paradox since, with current low-interest rates, infrastructure investments deliver a real return between 4% and 8% (Bhattacharya et al., 2016). With an estimated $14 trillion of negative-yielding debt in OECD countries and $26 trillion of low carbon, climate resilient investment opportunities in developing countries by 2030, capital in search of higher yields should flow from developed to developing countries to address this infrastructure investment gap. This is not happening.

Finance for projects in non-OECD countries reached $356 billion per year in 2017-2018, or 61% of global climate finance. However, 76% of these resources are deployed in the country in which they are sourced, revealing a strong preference among investors for home-country investments where risks are well understood (CPI, 2020). East Asia and Pacific was the largest regional provider of and destination for climate finance, at $238 billion. Sub-Saharan Africa accounted for only 5% of climate finance flows in non-OECD countries, at $19 billion (CPI, 2019). The bulk of climate finance in Sub-Saharan Africa originates from the public sector (MDBs, NDBs, multilateral climate funds).

Neither financial investors nor project developers try and take advantage of what the IMF's World Economic Outlook (Abiad et al. 2014) describes as 'free lunch' opportunities because these opportunities face several political and regulatory, macroeconomic and business costs, as well as technical barriers. These costs are magnified in developing countries because of the considerable differences in their creditworthiness. The spread between the interest rate of a bond issued by the US government and the interest rate of loans to a given country comes on top of projects' risk-premium. In 2018, it was 1.30% for a five-year project and 2.5% for a ten-year project in BBB-rated countries. At the beginning of 2020 it jumped to 6% and 9%, respectively, in B-rated countries. Before the Covid-19 crisis, more than 60 countries were rated below BBB and had access to capital only at interest rates higher than 18% for two-year projects. The impact of this inequality is exacerbated by the fact that countries in this class are often those whose creditworthiness might be the most affected by climate change damages (Buhr et al., 2018).

Aligning capital flows and investment needs is not just a matter of North-South aid and foreign assistance, of which flows are currently falling. It demands correcting the world economy's structural mechanisms behind the well-known Lucas' paradox, *'why doesn't capital flow from rich to poor countries'* (Lucas, 1990), and the non-negligible share of their savings flowing into the 'safe havens' of developed countries (World Bank, 2019b).

While market-fixing approaches address information barriers for financiers, a second approach gradually emerged over the past 30 years to direct private investment towards low emissions climate-resilient development pathways addressing a range of other barriers. This approach couples climate finance channels with tools designed to develop the demand for ‘green’ products, promote low-carbon technical innovation and remove the political and regulatory barriers that hinder demand and supply of climate-resilient investments. In essence, market-shaping approaches embed pricing signal into broader policy packages.

This section highlights climate-friendly investment barriers and describes how the market-shaping approach removes these barriers through policy and financial de-risking.

Barriers and risks time profiles

At the microeconomic level, the persistent infrastructure investment gap is caused by several risks that deter entrepreneurs and financiers from exposing their resources. The OECD (2016b suggests to cluster these risks into three main categories and to follow them along the four phases of the project development cycle (table 2.1).

Political and regulatory risks arise from governmental actions, including changes in policies or regulations that adversely impact infrastructure investments. For example, complex, inconsistent, or opaque licensing procedures lead to transaction delays and costs. Similarly, changes in tariff regulations or off-taking contract renegotiation can affect the profitability of investments.

Macroeconomic and business risks arise from the possibility that the industry and/or the economic environment are subject to change. These include macroeconomic variables like inflation and exchange rate fluctuations, as well as shifts in consumers' demand, access to finance, and liquidity constraints.

Technical risks are determined by the skills of operators and managers, and related to the features of the project (e.g. its complexity, construction, and technology). These risks can also arise from the lack of supporting physical infrastructure (e.g. cranes or roads to unload and transport heavy equipment).

Table 2.1: Main risks by project development phase (OECD, 2016b)

<table>
<tr><th>Risk Categories</th><th>Development Phase</th><th>Construction Phase</th><th>Operation Phase</th><th>Termination Phase</th></tr>
<tr><td rowspan="8">Political and regulatory</td><td>Environmental review</td><td>Cancellation of permits</td><td rowspan="3">Change in tariff regulation</td><td>Contract duration</td></tr>
<tr><td rowspan="3">Rise in pre-construction costs (longer permitting process)</td><td rowspan="3">Contract renegotiation</td><td>Decommission</td></tr>
<tr><td>Asset transfer</td></tr>
<tr><td colspan="2">Currency convertibility</td></tr>
<tr><td colspan="4">Change in taxation</td></tr>
<tr><td colspan="4">Social acceptance</td></tr>
<tr><td colspan="4">Change in regulatory or legal environment</td></tr>
<tr><td colspan="4">Enforceability of contracts, collateral and security</td></tr>
<tr><td rowspan="7">Macroeconomic and business</td><td>Prefunding</td><td colspan="3">Default of counterparty</td></tr>
<tr><td colspan="2" rowspan="3">Financing availability</td><td colspan="2">Refinancing risk</td></tr>
<tr><td colspan="2">Liquidity</td></tr>
<tr><td colspan="2">Volatility of demand/market risk</td></tr>
<tr><td colspan="4">Inflation</td></tr>
<tr><td colspan="4">Real interest rates</td></tr>
<tr><td colspan="4">Exchange rate fluctuation</td></tr>
<tr><td rowspan="6">Technical</td><td colspan="3">Governance and management of the project</td><td rowspan="5">Termination value different from expected</td></tr>
<tr><td colspan="3">Environmental</td></tr>
<tr><td>Project feasibility</td><td rowspan="2">Construction delays and cost overruns</td><td rowspan="2">Qualitative deficit of the physical structure/ service</td></tr>
<tr><td>Archaeological</td></tr>
<tr><td colspan="3">Technology and obsolescence</td></tr>
<tr><td colspan="4">Force majeure</td></tr>
</table>

All the four phases (development, construction, operation, and termination), including their specific risks, will count in the investment calculus of both entrepreneurs and financiers. The development phase is critical because, at this stage, entrepreneurs are particularly exposed as they engage personal equity and take the risks of sunk costs. They will therefore expect higher returns before investing their time and personal resources in an infrastructure project. Similarly, finance providers will demand a higher margin and offer less attractive terms to protect themselves from these higher risks.

This translates into higher interest rates (debt) and required returns (equity), shorter loan tenors and a larger share of costlier equity in capital structure, affecting the attractiveness of the investment. The additional financing costs are even higher in less developed countries in which infrastructure projects would not reach investment grade (Blended Finance Taskforce, 2018).

These barriers appear to restrict even further climate-friendly investments, as suggested by the limited private funds leveraged by public money for such projects, the low share of carbon saving potentials tapped by dedicated policies such as energy renovation programmes (Ürge-Vorsatz et al. 2018), and a demand for climate finance lower than the volume of economically viable projects (de Gouvello and Zelenko, 2010; Timilsina et al., 2010).

Part of the risk is primarily transactional. Risks come from the uncertain results of environmental reviews, surprises in the costs, and delays incurred in the pre-construction phase (permitting process longer than expected, difficulties raising the pre-funding and identifying credible financial partners, risks of cancellation of permits, and renegotiation of the initial contract). These factors ***combined with those of cost overruns for less mature technical options generate up-front risks that deter many initiatives***. They are very high for sub-critical project sizes, fragmentation of financing windows, limited familiarity with particular geographies, uncertain governance landscape, and weak project preparation. These parameters can be found in almost all economies but are decisive in developing countries

A direct consequence is the limited supply of high-quality, transparent low-carbon climate-resilient investment projects despite the unmet demand for new infrastructures. Hence, although the issuance of green bond reached a record high of $225 billion in 2019, it was far below the potential of low carbon investments. This ***chicken and egg problem*** explains the paradox of complaints from entrepreneurs about difficult access to capital on the one hand, and from financiers about a deficit of bankable project proposals on the other. Any green market will require addressing the barriers to both the demand and the supply of climate-friendly investments to be successful (Mazzucato, 2015).

Environmental public support instruments to create demand and supply for climate-friendly investments

The need to address market and investment barriers to low carbon options has inspired the development of a wide array of public measures modelled around the energy efficiency policies conducted since the Seventies. According to the IEA's Policies and Measures Database, over 5,500 climate policies and instruments are currently used globally today.[xiv] Table 2.2 shows the main types of instruments.

The first four columns list environmental policy instruments that create a business context conducive to the demand for low carbon investments and the supply of low carbon projects. They include information, regulatory, economic, and institutional measures that create a demand for green, climate-resilient goods and services by reducing market uncertainty. They also encourage climate-friendly investments by reducing their transaction costs.

In contrast, financial de-risking instruments do not seek to change the overall business context but tackle projects' risks by transferring part of them to public actors. They blend public and private resources, often to encourage market-creating projects that will establish a proof of concept (innovation to market) or commercial track record (market deployment) for new climate solutions.

Table 2.2: Environmental Public Support Instruments

	Information and empowerment instruments	Control and regulatory instruments	Economic and market instruments	Institutional instruments	Financial instruments
Market Creation Instruments	Rely on knowledge, communication, and persuasion to influence behaviour and supply skilled labour.	Rely on the establishment of obligations, encouraging or prohibiting or restricting certain types of behaviour	Financial incentives and disincentives to influence private sector behaviour and investment decision-making	Create an institutional and organizational environment to facilitate policy and technology development and deployment	Direct public sector (co) investment to establish a proof of concept or commercial track record of new solutions
Demand-side instruments	▶ Information disclosure and green taxonomies (climate risks, carbon liabilities, etc.)	▶ Macro-prudential regulations (climate stress tests for banks and insurers, etc.)	▶ Carbon taxes, phase out of fossil fuel subsidies ▶ Development of new asset classes ▶ Fossil fuel divestment by public financial institutions	▶ Green finance regulatory networks, asset managers coalition and central bank coordination mechanisms	
	▶ Long-term policy commitment and targets ▶ Valuation methodologies ▶ Public awareness and persuasion	▶ Mandates ▶ Ban ▶ Zoning ▶ Building codes ▶ Norms and minimum performance standards ▶ Standards and labels	▶ Taxes/tax breaks (e.g., carbon taxes) ▶ Charges and penalties ▶ Favourable tariffs ▶ Green procurement ▶ Advanced market commitment ▶ Tradable permits and quotas	▶ Establishment / restructuring of environmental institutions ▶ Development of R&D networks and ecosystems	
Supply-side instruments	▶ Investment in education and research ▶ Technical and vocational training and retooling	▶ Streamlining licensing processes	▶ Power purchase agreements ▶ R&D commissioning ▶ Property rights agreements	▶ Dedicated financial institutions (green banks, green guarantee companies, green bond platforms, etc.)	▶ Public sector-led R&D ▶ Project concessional finance (grant and loans) ▶ Incubation grants/venture capital ▶ Guarantees ▶ Equity investment

The mobilization of these two classes of instruments to address the infrastructure microeconomic paradox remains a complex exercise because it requires to find the right ***balance between three parameters: a) the social acceptability of end-use services' delivery prices, b) the coverage of costs to develop the systems, and c) the risk-weighted profitability for the private investors***.

Environmental policy de-risking: a matter of stability and policy integration

The core objective of environmental policy instruments is to create a business context conducive to markets for low carbon goods, services, and technologies that will attract investors. Their de-risking dimension stems from their adequacy to the pursued objectives and their stability.

Historically, technical standards and norms have played a dominant role. Their first important field of application has been end-use equipment energy efficiency (e.g., miles/gallon or level of CO2 emission per km). [xv] They also included building codes, retrofitting standards, and, more recently, shares of renewable energies in the electricity supply, materials recycling rates, and norms for construction materials.

These tools have been questioned repeatedly in economic literature since the early nineties (Pearce; 1991; Barde, 1994) because they result from negotiation processes necessarily influenced by lobbying interest. Therefore they cannot equate the marginal greenhouse gas emissions abatement costs throughout the economy and minimize the social costs of meeting a given environmental target. Another criticism is that they do not deliver the promised emissions reductions because of the 'rebound effect', which means that in the absence of carbon prices, efficiency gains lead to cheaper end-use services and higher consumption of these services (Sorrell,2009; Dimitropoulos et al. 2018). This typically occurs when more efficient heating systems allow for higher thermal comfort or when an annual CO2 emission target for the entire fleet sold by vehicle manufacturers leads to increasingly efficient cars but does not limit the driven distance.

However, they continue to be extensively employed because they reduce uncertainty for industry and accelerate learning by doing processes (Kahouli-Brahmi, 2009). They are also the only way to coordinate the emergence of competence networks fast enough to avoid technological lock-ins. For example, building codes are needed to avoid the lock-in of rapidly urbanizing countries to poorly performing buildings that remain in use for the next 50–100 years (Ürge-Vorsatz et al., 2014).

Technical standards and norms are increasingly supplemented by a large set of financial incentives: RandD funding (battery and hydrogen technologies), public procurement of zero-emission vehicles, feed-in tariffs based on the quantity of renewable energy produced, energy savings (Bertoldi et al., 2013; García-Álvarez et al., 2017; Pablo-Romero et al., 2017; Ritzenhofen and Spinler, 2016), feebates and 'bonus-malus' schemes that foster the penetration of low-emission options (Butler and Neuhoff, 2008), rebates on value-added tax (VAT) and trading schemes with Energy Savings Obligations (Haoqi et al., 2017) for energy retailers or Green Certificates for renewable energy portfolio standards (Upton and Snyder, 2017).

On the supply-side, environmental policies are the first part of general legal and institutional reforms that ensure an appropriate supply of skilled labour, secure a social license to operate, and reduce complex, inconsistent, or opaque permitting procedures.

Although some of these instruments have a neutral impact on public budgets by incentivizing low-emission products and penalizing high-emission ones (de Haan et al., 2009), most of them come at a cost to industry, consumers, or the taxpayer.

The limit of these instruments lies in the fact that the tighter the public funding constraints, the lower is the political credibility of their maintenance over time. Combined with the difficulty of controlling opportunistic behaviours in subsidies, ***this can lead public budget officers working under tight constraints and competing demands to lower the support to these measures or making their administration particularly complex***.

Financial de-risking and blended finance

Financial instruments include direct public investment and public co-investment to de-risk private investment. De-risking instruments include concessional finance (grant, concessional debts), loan guarantees, deferred or income-contingent repayment, political risk insurance (PRI) and public equity co-investments. They are blended with private resources to reduce the high perceived and real risks faced by private investors in early-stage climate solutions and markets.

Blended finance is a structuring approach that allows organizations with different objectives to invest alongside each other while achieving their own objectives. The main forms of blended finance include provision of: (i) concessional capital (below-market terms finance) to lower the overall cost of capital to private investors; (ii) credit enhancement through guarantees or insurance to provide an additional layer of protection to private investors; and (iii) grant-funded technical assistance facilities that can be utilized for biding and project development phases.

One lesson from the agency theory (Holmstrom 1979; Mirrless 2011) is that the optimal contract between a Principal pursuing a collective goal and an Agent involves a trade-off between risk sharing and incentives. If public budgets are the risk carriers in the last resort, one challenge is how they can play this role in a context where their position is fragile because of competing demands and they must maximize the efficacy of every currency spent.

Table 2.3 shows the main types of financial de-risking instruments as a function of the type of risks they tackle. The key information is that the ***public guarantees are neutral vis-à-vis the type of risk***, including the 'macro' country risks (currency risks, political risks). This ***broad coverage*** is the reason why public guarantees have been increasingly proposed to cut the risk-premium of low carbon investments (de Gouvello and Zelenko, 2010; Studart and Gallagher, 2015; Emin et al., 2014) (Lee et al., 2018; Schiff and Dithrich, 2017). The World Bank initiated a Partial Guarantee Scheme (Launay, 2016), and the Blended Finance Task Force called recently for the scaling up of these instruments.

Table 2.3 | Financial instruments and risks (adapted from BFTF (2018))

	MACRO		CREDIT / COMMERCIAL			TECHNICAL		FINANCE	INFRA SPECIFIC
	country risk	Currency risk	Credit worthiness risk	Liquidity risk	Demand risk	Construction risk	Operation risk	Access to capital	Lack of pipeline Off-take risks
1. Public Guarantees									
1b Guarantees									
2. Insurance									
3. Hedging									
4. Junior/ subordinated capital									
5. Contractual mechanism									
6. Grants									

Insurances also de-risk these phases of the project life cycle. For example, were insurances for an infrastructure project in Africa, unlisted in the Solvency II framework, be backed on AAA guarantees, the corresponding reserve requirement would be reduced by 30% (Déau and Touati, 2017). However, the limit of insurances is that they entitle the issuer to review claims concerning events. They thus must be combined with guarantees that cover lenders or investors against payment defaults.

Contractual arrangements like power purchase agreements (PPA) are powerful instruments to reduce market risks through a guaranteed price and a guaranteed access to the grid. They can also provide favourable tariffs to increase return on investments. However, they do not tackle directly macro and credit-worthiness risks. Moreover, the credibility of a price premium on sales might be undermined by the policy uncertainty about the ability to maintain it under strongly pressured public budgets. Private actors and government officials may not have equally good information when prices for feed-in tariff programmes are initially set so they may turn out to be too high. This can erode support for the programme and lead to unnecessary public costs.

The same pressure on public budget will be a constraint for sovereign concessional finance. The capacity of public institutions to provide concessional finance will depend on the fiscal situation of originating and receiving governments. Highly indebted governments might not be able to contract additional sovereign debt. Grant resources are by nature limited and cannot be deployed at scale to finance capital-intensive infrastructure work.

Experiences and limits of financial de-risking and blended finance

Between 2012 and 2018, $205.1 billion were mobilized from the private sector by official development finance interventions. The data show an upward trend over the period, with a significant acceleration between 2017 and 2018. Overall, guarantees catalysed the most of private finance (39% of the total), followed by direct investment in companies (DICs) and syndicated loans, accounting for 18% of the total each (OECD, 2020).

While private finance was almost evenly distributed across the other regions, 96.3% of private finance mobilized through blended finance flows to countries with a credit rating that most low-income countries do not have. It primarily benefits high and middle-income countries and catalyses investment mostly in mature technologies such as on-grid renewable energy (ODI, 2019).

Only 5.3% went to LDCs and other LICs. The role of guarantees was particularly important in these countries, as they mobilised 62% and 46% of the resources in 2015/16 and 2017/18 respectively. Direct equity investment followed, mobilizing 14% and 24% of the resources in 2015/16 and 2017/18 respectively (ODI, 2019). However, blended finance has usually taken the form of relatively safe senior debt rather than guarantees and equity.

In terms of thematic distribution, 55.5% of the amounts targeted energy and financial sectors, and only 4% critical climate adaptation priorities such as agriculture and forestry (3.3%) and general environment protection (0.7%). In terms of market creation, blended finance leveraged so far limited private funds for low carbon investments - less than 1:2 compared to a range between 1:3 and 1:15 for traditional public finance (BFTF, 2018; Ward et al., 2009).

The geographic and thematic concentration of blended finance as well as overall low leverage are significant obstacles to tapping into the vast private savings pool to reduce the infrastructure investment gap in emerging economies. On average, every $1 of MDB and DFI resources invested leveraged just $0.37 of private finance in LICs because of a poor investment climate (ODI, 2019). This observation calls for further efforts to tailor such instruments to low-income countries and the specifics of their climate management, as well as to better meet private investors' risk requirements. It will demand greater use of higher impact instruments such as guarantees and equity, particularly for market creating investments in adaptation and nature-based solutions in nascent markets. It also shows the need to combine project-level financial de-risking instruments with market-level policy instruments to enhance the investment climate and improve the catalyst role of public resources.

One symptom of this limited use of high leverage instruments such a guarantees and equity in blended finance is to gap between the potential of green bonds, estimated to €29.4 trillion over 2030 (Bolton et al., 2020) and the $1 trillion only issued the ten years since their launch (Climate Bonds Initiative, 2020). Only 50% of them are backed on sovereign and sub-sovereign guarantees.[xvi] As a result, the market for green bonds remains largely concentrated in developed and emerging markets, with the USA, China and France accounting for 44% of global issuance in 2019, and the increase in issuance in 2019 driven largely by Europe (CPI 2020). Chapter 3 will examine how to unlock such markets in developing countries, so that they contribute to reduce the geographical mismatch of capital flows.

2.3.3. Complementarity between market fixing and market shaping

In theory, market-fixing approaches can be embedded within broader market-shaping efforts (placing key market-fixing policies within measures directed at the demand side – see top line of table 2.2.) In practice, market-fixing and market-shaping approaches tend to emphasize different sub-sets of public instruments. Market fixing relies on price signals to create a demand for low-carbon low-climate-risk goods and services and shift financial flows towards climate-friendly investments. Market shaping intervenes at the level of sector policies and endeavours to create a demand and directly de-risk the supply of climate-friendly investments to crowd-in private finance. However, the above discussion shows that these two approaches are mutually supportive and should be deployed in tandem. The combination of the two sets of instruments helps overcome the constraints inherent to each approach and increase the overall efficiency and effectiveness of public policies and finance to accelerate the transition to net zero climate-resilient economies.

The four graphs below (figure 2.1) sketch the cumulated net cash flows over time of an archetypal conventional, carbon-intensive project C and a 'green' low carbon project G. The modelled policy impacts are magnified in the many low-income countries, which face high financing costs, and for early-stage technologies.

In the North-West panel, the red and green curves show the net cash flow trajectories of projects C and G that make G economically non-attractive. Its higher net operating margins (lower purchase of fossil fuels) do not compensate for its higher capital intensity, particularly in developing countries with limited access to long-term and affordable finance. This is even more the case if, during the projects' bidding, development, and construction phases, a slippage in administrative and construction costs or a site delay causes the cumulative cash flows to pass the red and green dotted lines. The risk of slippage is comparatively higher for novel green technologies and practices. If the project initiator selects C, it will earn a lower Net Present Value, but the extra costs will not threaten the project viability. If it selects G, it might be trapped in the dotted green line and touch the 'danger line' D beyond which it will lose bankers' and shareholders’ confidence when asking for additional support. It will then stop the project and lose its down payment with a potential higher penalty related to the drop of the enterprise value if not bankruptcy. A simple calculation of the expected yielded cash at the projects’ end year (50/50% probability in the panel) will lead the investor to prefer C to G.

In the North-East panel, pricing and financial signals are used to tilt the balance in favour of G. A carbon tax penalizes the conventional project C and shifts its cumulated cash-flows down from the red curves while a lower interest rate for G reduces its debt service and moves its cumulated cash upward. This is the aim of Climate Disclosure, which prices the value of loans as an inverse function of their carbon footprint.

Impact of carbon taxes, bonified interest rates, and up-front derisking on the time profile of cash flows of Conventional and Green options

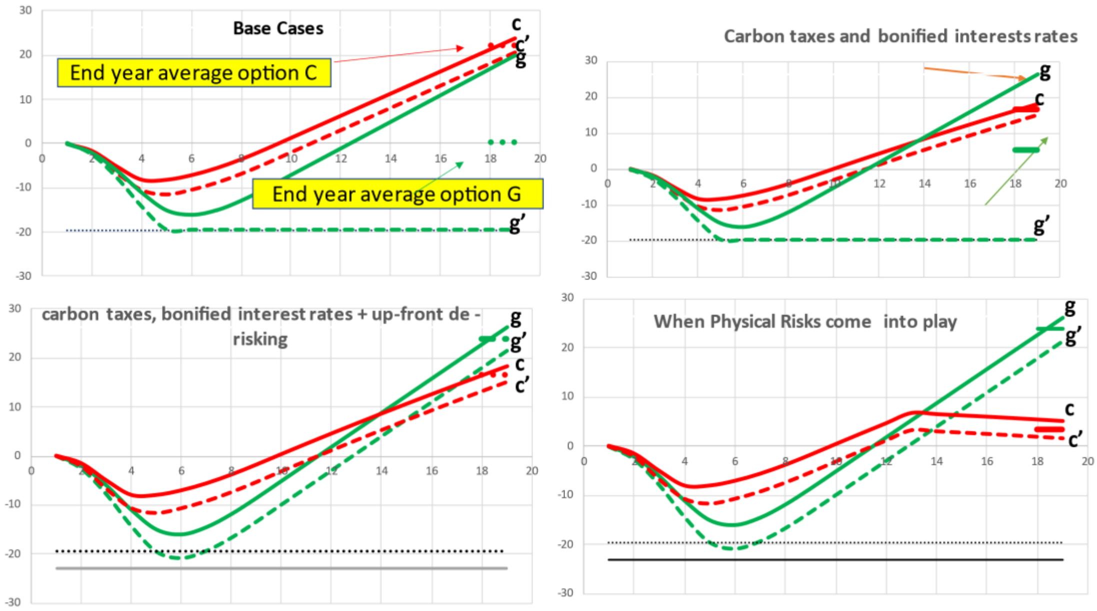


Figure 2.1

This is an illustration of the ***green infrastructure microeconomic paradox***. Even though the net present value of G becomes higher than that of C thanks to the two market-fixing tools, project initiators might refrain from selecting G because of the up-front risks of extra costs. The relative advantage given by price and financial signals to project G comes too late and will not prevent the project initiator from touching the danger line D. The average value of the end year yielded cash of G increases but stays below that of C.

In the South-West panel, the market-shaping tools come into play. This panel shows their impact pushing down the danger line from D to D' through risk-sharing between project initiators, private finance and governments, such as public pre-funding to cover project development and bidding costs. It demonstrates the ***complementarity of market-fixing and market-shaping***. Indeed, unleashing project initiatives that would have been deterred up-front, the de-risking devices ***reinforce the efficacy of the price and the financial signal.*** Project G will benefit from the bonified interest rates and reach cumulated cash (g') in the 'extra cost' case higher than this (c') of project C. It will no longer be blocked at a shallow level in the North-East panel. As a result, its average end year cumulated cash will be higher than that of the conventional option.

The South-East panel sketches how the consideration of physical risks of climate change (extreme weather events affecting operations and supply chains, etc.) and transition risks (early retirement of carbon intensive infrastructures, products, services, etc.) reinforces the economic superiority of G if C is affected directly or indirectly through a reputational effect. The curves here are purely illustrative but show an interesting case, as the consideration of physical and transition risks is not enough to establish superiority in the absence of up-front de-risking. The average end year cumulated cash of the conventional option with and without over-costs does not differ much from the 'green' option in the North-East panel. In runaway climate scenarios, these risks will lead to C crossing the danger line.

2.3.4. Paving the way for climate-friendly structural changes of the financial and monetary system

Arguably, the learning process triggered by a synergy between market shaping and market fixing tools to unlock climate friendly projects might not go very far without fundamental financial and monetary reforms (Campiglio, 2016; Schoenmaker and Tilburg, 2016; Svartzman and al, 2019, Bolton et al 2020)). The International Monetary Fund started to mainstream climate change into reflections about such reforms (Krogstrup , and Oman, 2019).

The cornerstone of such systemic reforms is that Central Banks recognize the climate remediation assets as collateral of debts. This recognition cannot be disconnected from the basic rules for the issuance of money and international payment currencies, which explains the suggestions for a new Bretton-Woods (Sirkis et al., 2015; M Stua, 2017). Many capital market-shaping proposals are made in this direction. They go beyond making compulsory the disclosure of climate-related information or taxonomies (EU, 2020) and require changes of macroprudential regulatory rules. One of them is to change the Basel III guidelines on liquidity that encourage debt issuance to any activity regardless of its emitting content but discourage investing in long-term assets even with negative long-term interest rates of AAA countries (Campiglio et al., 2018; Dikau and Volz, 2018). Others suggest imposing new prudential standards on banks and non-bank banks[xvii] (D'Orazio and Popoyan, 2019; Ryan-Collins, 2019). For example, the differentiation of minimum of reserves held by Central Banks and mandatory climate risk indicators included in the EandS assessment of the borrowers would push Central Banks to re-purchase in a preferential manner debt based on climate-friendly asset classes (Honohan, 2019; Schoenmaker and Tilburg, 2016).

All these proposals give Central Banks and the IMF a more 'activist' role (Volz, 2017) to support the 'greening' of the economy and play a 'developmental role through their regulatory oversight over money and credit. One difficulty is that this role can be perceived as violating the principle of the neutrality of monetary policies concerning microeconomic decisions (Weidmann, 2020). and extend the Central Bank's mandates beyond their traditional core responsibility of safeguarding overall macroeconomic and financial stability (Dikau and Volz, 2018; McKibbin et al., 2017; UNEP-Inquiry, 2018)). Such debates engage long-standing traditions about the banking system's independence from political influences that differ between OECD and developing countries and even within the OECD countries[xviii]. The time needed to reach a robust consensus amongst these traditions and overcome the geopolitical obstacles to significant monetary reforms makes them incompatible with climate action's urgency.

This does not mean that these reforms are not needed. This means that they are not a precondition for climate action, and one question to be explored further is to what extent ***launching a circle of trust to scale-up climate-friendly investments can pave the way for structural reforms of the financial systems claimed for reasons other than climate risks***. This might be the case because an immediate scaling-up of low carbon investment with a high credibility level could lead without political interferences, to a recognition of the underlying assets by Central Banks in their interbank payments. The conditions for this emergence are discussed in 3.2. They include multilateral sovereign guarantees and projects assessed by standard rules including a common notional value of avoided carbon emissions that Stiglitz and Stern (2018) recommend in the absence of high enough explicit carbon prices. The emergence of assets recognized in such a setting might address the concerns of high-level policy-makers about the risks of political arbitrariness of the management of Central Banks, which are crucial to reject the perspective of a move in Central Banks and the IMF mandates.

The rationale for exploring this perspective is that contrary to the rational anticipation and efficient market hypothesis this system is vulnerable due to the absence of a mechanism that automatically returns capital markets to equilibrium. The works on the link between financial intermediation, credit policies, financial cycles, and economic growth show that market finance amplifies economic fluctuations. Unlike business cycles where an excess or deficit of demand over production capacity triggers rebalancing mechanisms, the momentum of the financial cycles is driven by debt to buy assets that permanently reappreciate until the cycle's turnaround provokes their sudden devaluation when confidence vanishes.

Ultimately, scaling-up climate-friendly investments and new asset classes recognized in the interbank payments would constitute a step towards a carbon-based reserve currency, which comes back to Keynes' position about common money for international trade based on an indicator of 'real wealth.' (Jaeger et al., 2013, Hourcade et al., 2012).

Conclusion:

Understanding the basic principles of complementarity between up-front de-risking instruments, carbon prices, and lower interest rates for low-emissions options helps identify how to implement them over time given the political economy constraints on each of them. The end objective is to allow the deployment of innovative business models (Déau and Touati, 2017) that bring together public agencies and firms, local authorities, private corporates, professional cooperatives, and institutional financiers in order to both reduce legal, engineering, and overhead costs of projects and commoditize markets of low carbon options from an investor point of view.

The strategic role of up-front de-risking of low-emissions projects is to unlock many low carbon projects under current economic conditions, lower the carbon prices needed to tilt the economic balance in their favour and give the necessary time to set up enabling conditions of the deployment of market fixing tools over time. This is true for fiscal reforms capable to offset the adverse effects of higher energy prices, agreements on common assessment principles to ease voluntary international carbon trading [xix] , and the upgrading of the scope, credibility, and effectiveness of climate financial disclosure.

The scaling-up of climate finance could ultimately contribute to the emergence of a more robust financial system by hedging against the systemic risks of climate change and partially offsetting one of its endogenous sources of destabilization thanks to the reduction of '*the gulf between what markets value and what people value'*. (Carney M. 2020).

Endnotes

[iv] This caveat from the IPCC AR4 about cost assessments: "*most models use a global least cost approach to mitigation portfolios and with universal emissions trading, assuming transparent markets, no transaction costs, and thus perfect implementation of mitigation measures throughout the 21st century.' (AR4 WGIII SPM Box 3)*. Scenarios thus minimize transition costs and assume the best available options are adopted by all economic agents in all countries. They provide useful benchmarks but political uncertainty matters when designing efficient financial arrangements.

[V] These estimates aggregate energy sector information from box 4.8 of the IPCC 1°5 C report (IPCC, 2018) with results of Fisch-Romito & Guivarch (2019) on transportation infrastructure and of the OECD (2017) on other sectors.

[vi] On the basis of global private capital stock estimates in 2017 ($100 trillions in bonds, $60 trillions on equity and $226 trillions in banks loans, and assuming that half of investment are funded by public capital, Dasgupta et al. (2019) show that redirecting between 0,8% and 3% of the private capital's yearly revenues would be needed to fund the incremental costs. This wide range encompasses the range of investments needs and a pessimistic 3% to an optimistic 5% average returns of capital. This does not mean that it is an easy task since innovative financial channels and products have to be set up, but that there is no apparent global constraint for such a shift in financial portfolios. However, these assessments imply the emergence of new assets classes to compensate for the stranded assets due to early

retirement of capital stock and divestment from the fossil-fuel industry, which could amount to 32% of the carbon-intensive assets (Mercure 2018) in the case of a speedy transition.

[vii] https://tradingeconomics.com/country-list/r beasating

[viii] These studies, although conducted with different methodologies and for different contexts, deliver convergent messages. Schmidt (2014) finds that a risk premium that doubles the financial costs increases the life-cycle costs of electricity from renewable energies by 31% to 46%, while the costs of electricity from coal and gaz increase by 17% and 7% (they even decrease by 3% for diesel). As for switching carbon price, it triples for wind and biogas, more than double for small hydro and increases by 70% for photovoltaïc. Hourcade et al. 2017, for a similar risk coefficient, find that the switching carbon price almost doubles for coal plus CSS in the EU and hydro projects in Brazil. Hirth and Steckel (2016) find that the switching carbon price securing a 25% share of renewable energy in the electricity sector in Germany increases by 80% when a higher risk perception leads a weighted average capital cost of low carbon options to increase from 7.5% to 12%.

[ix] The minimum and maximum marginal costs of carbon reported in the AR6 report range between $70 and 160 for 2030 worldwide for a 2°C target and the summary for policy-makers of the IPCC 1.5° C report states that the carbon prices for a 1°5 C target should be set at a level three to four times higher than those needed for a 2°C target. These ranges might be optimistic in case of policies only focused on carbon price because they assume transparent markets and perfect mitigation of least cost measures *(AR4 WGIII SPM Box 3)*. Moreover, they do not represent the compensations needed to equate the marginal welfare costs across countries and assume implicitly that their implementation would be costless.

[x] The scientific robustness of these tools deserves scrutiny. Comparing the amounts of fossil fuels in a baseline scenario with those in a 2°C or 1.5° C target to assess stranded assets twenty years ahead comes to assume a benevolent dictator imposing a low emission path on one hand and investors ignoring its existence and never changing their decision pattern despite the costly experience of trajectory corrections on the other.

[xi] For example, BNP Paribas Asset Management is divesting from thermal coal across all its actively managed funds. Source: https://institutional.bnpparibas-am.com/divesting-coal-new-policy/. Danish pension fund MP Pension sold off shares in 10 major oil companies in part because returns were considered poor and were expected to continue to deteriorate. The Norwegian Government Pension Fund Global is divesting from some oil companies to manage its climate-related risks deriving from exposure to the sector: https://www.regjeringen.no/en/dokumenter/the-report-on-energy-stocks-in-the-government-pension-fund-global/id2662171/

As for oil companies, the difficulty to disentangle the causes of the share price changes is illustrated by the fact that the shares of Exxon Mobil plumetted from 69.89$ on 12/27/2019 to 32.74 on 03/20/2020, rose to 53.08 on 06/05/2020, fell again to 32.78 on 06/11/2020 and was 61,93 on 03/03/2021. The share price of Total followed a similar trend: 50.38 on 01/03/2020, 25 on 03/20/2020, 38.34 on 06/05/2020, 25.82 on 10/30/2020 and 42.19 on 03/12/2021.

[xii] https://blogs.imf.org/2020/05/29/equity-investors-must-pay-more-attention-to-climate-cical-risk

[xiii] Scope 1 registers Direct Emissions under the control of the activity (fuel combustion on-site, fleet vehicles); Scope 2 encompasses indirect emissions (e.g., from purchased electricity) and Scope 3 all Indirect emissions from sources that the activity does not control but incorporate (through the purchase of non-energy inputs) or induce and that is usually the most significant share of the carbon footprint. Beyond data uncertainty, which will be hopefully reduced over time, the difficulties come from two interrelated problems. The first is the 'attribution' given the complexity of the global value chains (Antras P. & al. 2017, De Loecker & al. (2016) Goldberg P. K .et al (1997); World Bank, 2020a). This complexity makes it difficult to track value-added chains in a consistent way with capital flows, the circulation of physical products and their energy content. Overcoming the risks of double-counting and controversial attribution with an acceptable level of approximation is possible for correcting the countries' emission considering the emissions content of their imports and exports. It grows rapidly at the higher level of granularity needed to track the carbon content of capital flows. The second difficulty is that any work on the alignment of portfolios towards climate targets, or any stress test, demands a set of baseline and climate constrained trajectories. One alternative option has been explored by the French Energy Agency (Ademe). This combines a top-down approach with an attribution per type of activity (Ademe 2014) but has not been replicated so far.

[xiv] https://www.iea.org/policies

[xv] In this domain, the existing diversity of command and control tools can be grouped in:

- end-use standards for domestic appliances, lighting, electric motors, water heaters, and air-conditioners) in OECD countries and, more recently, in developing countries (Brown et al., 2017; Scott et al., 2015). Mandatory efficiency labels often complement them to attract consumers' attention and stimulate the manufacture of more efficient products.
- efficiency standards (e.g. miles/gallon or level of CO_2 emission per km) in the transport sector for light and heavy-duty vehicles. In the EU (Ajanovic and Haas, 2017) and the US (Sen et al., 2017), vehicle manufacturers must meet an annual CO_2 emission target for the entire fleet they sell..
- regularly revised building codes (Evans et al., 2017) to increase their efficiency per unit of floor space. These codes are essential to avoid the lock-in of rapidly urbanizing countries to poorly performing buildings that remain in use for the next 50–100 years (Ürge-Vorsatz et al., 2014) and in OECD countries to incentivize the retrofit of existing buildings. In the context of a 1.5°C warming a new focus is placed on public and private coordination to better integrate building policies with the promotion of low-emission transportation modes (Bertoldi, 2017).
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[xvi] https://nordsip.com/2020/07/14/green-bond-issuance-to-recover-in-second-half-of-2020/

[xvii] These regulations can include leverage limits, liquidity requirements, contingent capital requirements, risk committees) on non-bank banks, on the asset purchases of central banks injecting liquidity to maintain the cash position of firm's in adverse conditions, on securities issuers, on commodities and derivatives markets and Financial Market Utilities (regulation of market participants and swap dealers).

[xviii] The first attempts to incorporate climate issues in macroprudential policies at a national level were conducted by central banks of a few developing countries: Green Credit Allocation in Bank Bangladesh and India (RBI) [220], differential reserve by Banque du Liban (2010) to allocate more credit into renewable energy and energy efficiency [243]; the process of Capital Adequacy Assessment, which originates from Pillar 2 of the Basel II accords and requires commercial banks to take the exposure to environmental damages and risks into account (Banco Central do Brasil, 2017); the Green Finance Task Force initiated by the People's Republic of China in cooperation with UNEP Inquiry with the aim of promoting green bonds (PBOC and UNEP Inquiry 2015).

[xix]Initiated by the UN Special Envoy for Climate Action and Finance, Mark Carney, the Task Force on Scaling Voluntary Carbon Markets released 20 recommendations. They include a) "Core Carbon Principles" (CCPs) and a taxonomy of attributes to ensure high integrity and market liquidity b) core carbon reference contracts that can be traded on exchanges to concentrate liquidity and unlock its associated benefits c) market infrastructure to ensure resilient, flexible markets that handle large-scale trade volumes transparently d) Improving the integrity of carbon markets through strong guidelines and frameworks and e) supporting a clear demand signal to drive the development of liquid markets and scaled-up supply

Chapter 3: Scaling up climate finance in the context of Covid-19

The main message from chapter 2 is that climate finance can help bridge the infrastructure investment gap with low-emission climate-resilient options that fulfil the objectives of the Paris Agreements and sustainable development goals. This can be achieved by embedding carbon pricing and disclosure mechanisms within a market transformation approach that removes barriers on the demand and supply of low-emission climate-resilient investments. This also help build a safer financial system.

The Covid-19 crisis has brought the world to a crossroad in the fight against climate change. On the one hand, advanced economies are undertaking expansionary fiscal measures. Depending on the content of their recovery packages, the large amount of liquidity injected into economies in the forthcoming years will either entrench our dependence on fossil fuels and put the achievement of the Paris Agreement out of reach; or create the momentum to shift towards net zero-carbon, climate-resilient and inclusive development for all. Developing countries on the other hand – already the most vulnerable to climate change – are suffering from increasingly restricted monetary and fiscal space, which seriously undermines their capacity to finance mitigation and adaption measures (Bayat-Renoux et al., 2020).

The Covid-19 crisis places two responsibilities on policy and financial decision-makers, which are in line with those identified in Chapter 2: narrowing the investment gap by greening economic stimulus measures worldwide, and facilitating access of developing countries to long-term and affordable finance to implement recovery packages without increasing their debt burden.

This chapter discusses the impact of the Covid-19 pandemic on climate action and highlights why climate investments can promote a robust and fair recovery from the crisis. It also recommends four concrete actions that enable developing countries to scale up climate finance in order to promote a climate-resilient recovery and realize their climate ambitions.

3.1. Covid-19: The world at a crossroad for economic and climate security

3.1.1. The impact of Covid-19 - A shock quantitatively and structurally different from the subprime crisis

Responses to the Covid-19 pandemic have pushed the global economy into the deepest recession since the Second World War. An estimated 81% of the global workforce has been affected by lockdown measures worldwide, leading to unprecedented job losses and furloughs (ILO, 2020). The World Economic Outlook (April 2021) estimated a 3.5% contraction in global growth in 2020, which is far higher than the 0.1% recorded after the 2008 financial crisis.[xx] Non-conventional monetary policies allowed the world GDP to almost immediately return to its pre-crisis level in 2009, even though the average growth rate for over a decade remained 0.5% lower than before the crisis. However, the IMF predicts in the context of the Covid-19 crisis that the GDP of advanced economies' will be 6.1% lower than it would have been otherwise in 2021 (IMF 2020. The last assessment by the World Bank (2021) confirms this trend with a 5% reduction, even considering some regains with the success of vaccination campaigns.

The Covid-19 pandemic has been particularly devastating for developing countries. During the subprime crisis, emerging and developing economies continued growing at a rate of 2.8% in 2008 (World Bank, 2020a), whereas their GDP in 2020 contracted by 2.6% and 5% respectively, China excluded (World Bank 2021). In addition to the humanitarian consequences of the pandemic, these countries experienced sharp drops in commodity export prices, including oil prices, a collapse in tourism revenues, reduced exports to developed economies, and supply chain blockages . This led to an increase from 135 million in 2010 to 272 million of the number of people facing food insecurity (WFP, 2020), a significant transfer of the employed population into 'inactivity' (ILO, 2020), [xxi] and 500 million additional people falling below the poverty line. This increase, the first in thirty years, was particularly acute in Least Developed Countries (LDCs) and Small Island Developing States (SIDS) (UNU WIDER, 2020).

The Covid-19 crisis and the consequent dramatic drop in economic activity have led to an 8% reduction of greenhouse gas emissions (2.6 GtCO2) from the energy sector in 2020 (IEA, 2020), which is more in absolute terms than in any other year on record (Boden et al., 2017, Le Quéré et al., 2018).[xxii] A global adaptive multiregional input-output model at constant GDP shows scenarios with lockdown and fiscal counter-measures that would lower global emissions by 3.9% to 5.6% in five years (2020 to 2024) compared to a no-pandemic baseline (Shan et al. 2020). However, these scenarios come with high economic and social costs and are not compatible with sustainable development and poverty alleviation. Without government action, once lockdowns end emissions will rebound to an extent that depends on the speed of economic recovery and the nature of recovery spending (Hepburn et al. 2020).

3.1.2. Covid-19 fiscal recovery: a green, climate resilient stimulus also accelerates global growth

In order to stimulate the economy and mitigate the impact of Covid-19, governments are undertaking large-scale expansionary fiscal measures. The fifty largest economies in the world have announced $14.6 trillion in fiscal spending in 2020, of which $1.9 trillion for long-term economic recovery (UNEP, 2021). There is a disparity between announced spending by advanced economies (22.5% of their combined GDP), and that of emerging markets and developing countries (10.6%), a 17 times greater amount on a per capital basis (UNEP, 2021). One of the key reasons for this disparity is the difference in the cost of additional debt. For most high-income countries, the cost of additional debt is close to 0% per annum. For developing countries, with low credit ratings, interest rates are significantly higher, increasing the cost of any new debt thus burdening and stretching fiscal budgets. Developing countries will build in the next two decades infrastructures that will influence their development path over the century (Hourcade and Shukla, 2013). The question is therefore whether the Covid-19 crisis will deprive them of the capacity to bridge their infrastructure investment gap taking away options compatible with a low carbon path that are generally more capital intensive.

Before the last proposals of the Biden administration, Mc Kibbin and Vines (2020) estimated that on top of the $9 trillion of recovery packages already spent or promised by advanced countries, the optimal response to the Covid-19 crisis would be nearly $2 trillion in countries that have not been able to put such rescue packages in place. But the content of these packages is not discussed and the question is whether green recovery plans will have a knock-on effect at least as strong as 'colourless' ones.

Governments' reflex might otherwise be to resort to a mix of quantitative easing monetary policies and recovery packages that will stay 'colourless' until the return to a growth rate that is deemed satisfactory (Hepburn et al., 2020). Chapter 2 has shown that the response to the subprime crises, combined with stricter regulatory interventions on the banking system, penalized risk-taking and long-term investments, including low carbon investments. The impact might be worse with oil prices at historically low levels, creating a temptation to slow down the behavioural and structural changes required by the low carbon transition.

Conventional economic discussions focus on whether the crowding out effect of 'green stimuli' on other sectors and consumption will be compensated by their spill-over effects. This framing is relevant if the economy is on a balanced growth pathway where there is no idle capacity, production factors are fully employed, and inter-temporal financial intermediation is frictionless. In this case, the "economic (Keynesian) multipliers are near zero. In contrast, during deep crises, economic multipliers of stimulus packages can be high (Hepburn et al., 2020) since capital is idle, consumers underspend, and labour skills are underutilised. Fiscal injections can then generate multipliers as high as 1.5 to 2 (Auerbach and Gorodnichenko, 2012) or even as high as 2.5 (Blanchard and Leigh, 2013). They can consist of a mix of investment funding and cash transfers to the most fragile households (Gechert and Rannenberg, 2018).

Together with the public budget constraints and difficult access of some countries to international currencies, there are six reasons why the post-Covid-19 recovery packages might have smaller multipliers than the post-2008 packages:

- the economic shock of the current crisis is bigger, and the uncertainty about its near future is deeper, leading to more precautionary behaviours
- the record levels of the global stock of non-financial corporate debt ($13.5tn at the end of 2019) is higher than during the global financial crisis (OECD, 2020)
- the lower quality of public and private debt threatens the stability of the banking system and of non-bank banks
- household demand is held back by restrictions on spending possibilities of upper middle classes (for example air travel[xxiii]), job losses, furloughs (OECD, 2020) and precautionary behaviours
- the global health scare halts sentiments with savers and investors giving priority to safe rents over risk-taking investments in productive activities. The evolution of this sentiment will be determined by the speed at which vaccination campaigns will reduce the pandemic effects and prevent new outbreaks.

Can climate-oriented packages overcome part of these obstacles and have a stronger and more certain knock-on effect? The IMF (2020) suggests that a global 'green stimulus' of 0.8% of GDP in additional fiscal spending annually between 2020 and 2030 would accelerate the emissions reduction path and boost global recovery by about 0.6% of GDP per year in the forthcoming years.

The reason why 'green stimuli' have potentially a strong knock-on effect is that the infrastructure sector represents a dominant share of the world's gross capital formation (Leduc and Wilson, 2012) and involves principally domestic industrial demand[xxiv]. The IMF has long advocated for an infrastructure push (Abiad et al. 2014), and recent studies confirmed the positive impact of transportation infrastructure investments after the 2008-2009 recession (Donaldson et al., 2016; Donaldson, 2018).

However, the strength of the green spending multiplier, compared with that of colourless recovery packages depends on its funding modalities (tax, foreign debt, domestic borrowing) (Batini et al., 2021), the overall policy environment (fiscal reforms, sectoral policies) and the synergies with other priorities, including health, poverty alleviation and security[xxv]. It will therefore differ across countries.

3.1.3. Covid-19 stimulus measures are not green enough yet

Examining the fiscal stimuli of 41 countries, Shan et al. (2020) have shown that carbon-intensive packages would increase global five-year emissions (2020 to 2024) by 16.4% (23.2 Gt) while the 'greenest' one could reduce them by 4.7% (6.6 Gt) (2020). Foster et al. (2020) show that a 'colourless' recovery would put the world on an emissions pathway that would pass the 1.5°C threshold within a decade and the 2°C limit soon after 2050, whereas the world has a 50% chance to stay below the 2°C warming target with a moderate green stimulus and below 1.5°C with a solid green stimulus.[xxvi] The distance between these trajectories would not be a problem if moving from one to another were possible without high economic costs. But because of the long lifespan of energy, transport, and building infrastructures, an abrupt change of course would be very expensive, which justifies early climate action (Grubb et al., 1995; Ha-Duong et al., 1998).

The UN Environment Programme (2021) finds that, in the 50 largest economies, only 18% of recovery spending and only 2.5% of total spending will enhance sustainability. In 2020, G20 countries spent $208.73 billion supporting fossil fuel energy, compared with at least $143.02 billion supporting clean energy.[xxvii] Considering the relative size and green characteristics of recovery spending, Denmark, Finland, Germany, France, Norway and Poland were global leaders. Spain and South Korea also introduced comprehensive green packages. The South Korean 'Green New Deal' announced in July 2020 demonstrated a commitment to sustainable recovery. But Hepburn et al. (2020) estimate that only 4% of the G20 rescue measures are 'green' and have the potential to reduce greenhouse gas emissions in the long run, 4% are 'brown' and are likely to increase net greenhouse gas emissions beyond the base case, and 92% are colourless, maintaining the status quo . In March 2021, the US President signed into law $1.9trillion Covid-19 relief package.

3.1.4. Widening Geographical mismatch of capital flows and increasing developing countries debt burdens

Since early 2020, governments and Central Banks have adopted monetary and fiscal policies that involved an unprecedented level of private and public debt outside war times in all countries (365% of GDP according to Tiftik , and Mahmood (2020) towards the end of 2020). More than two-thirds of the debt is in private hands, and a failure in economic recovery could lead to dramatic declines in equity valuations and asset values that would severely hit corporate balance sheets.

Efforts to revive economies and mitigate the impact of Covid-19 led to a sharp increase in debt, by 19.3% in developed countries, 23.6% in emerging economies, and 14.6% in low-income countries.[xxviii] A basic economic principle is that new public debt, subject to efficient use of the received funds, is not a problem for a country if a) it can be repaid by the tax revenues of the additional economic growth generated by the investments it finances; b) creditors recycle interest revenue in the economy, which is partly a function of the share of the debt held by nationals; c) the new liability is balanced by assets of credible value in public balance sheets; and d) there is no difficulty to access international currencies to pay imports and debt services to foreign entities.

Because they meet these four conditions and some have the privilege of a currency recognized as a reserve, developed countries have a debt/GDP ratio twice as high in percentage points as that of emerging and middle-income countries, and 2.5 times higher than that of low-income countries. Public debt management is easier for them than for developing countries that do not have the same latitude to adopt a counter-cyclical package stimulating demand. The Covid-19 context has reinforced this constraint in developing countries for three reasons:

- **Drop of domestic public revenue:** the plunge in economic activity has significantly reduced their tax revenues and already limited domestic public resources. Trade declined by 13-32% (WTO, 2020) and international tourist arrivals fell by 60-80%in 2020[xxix]. Plummeting commodity prices disproportionately affect countries that rely more strongly on natural resource revenues. Taken together, fiscal balances in developing countries are expected to turn sharply negative to -9.1% and -5.7% of GDP in middle-income and low-income countries respectively (UN, 2020). For sub-Saharan Africa, estimates suggest that government revenue could deteriorate by 12 to 16% compared to a non-Covid-19 baseline scenario (World Bank, 2020a). At the same time, the Covid-19 shock necessitates large public spending on health, social protection and economic relief, as well as longer-term investments to maintain the recovery. The simultaneous divergence in available funds and the increase in spending needs amplifies the 'scissor effect' of sustainable development finance identified by the OECD (2021), which means that public debt in developing countries is likely to increase further and sizeably.
- **Decline in foreign currencies inflows from exports and external private finance:** the deterioration of exports, the fall of international tourism and of commodity revenues in 2020 created a dangerous 'currency scarcity' in many countries. Simultaneously, private finance inflows were expected to decrease by $700 billion in ODA-eligible countries and remittances dropped by 20% compared to 2019 levels. During the two first months of the crisis, an exodus of capital towards countries perceived as more secure ($100 billion according to the IMF) represented the largest capital outflow in history. While debt flows to emerging markets recovered in April and May 2020, outflows of equity have continued. Overall portfolio and investment flows are not expected to recover quickly as the Covid-19 pandemic is still ongoing, which could result in a second wave of outflows, according to the Institute of International Finance (IIF, 2020). Foreign direct investment (FDI) to developing countries also slowed down in 2020, with an estimated 35% drop, particularly in terms of equity (World Bank, 2020b). This will most likely be compounded by a lower equity to debt leveraging ratios for infrastructure in the coming years. Infrastructure projects often have higher levels of leverage than non-infrastructure investments, given lower cash flow volatility. Debt instruments have historically comprised 70-90% of the total capitalization of infrastructure projects in developing countries (OECD, 2016b) whereas in high-income nations there are examples of private debt financing 100% of infrastructure projects. The increased risk perception could lead financiers to require higher equity investment to mitigate lending risks in a deteriorating macro-economic environment.

- **Solvency and liquidity crisis for SMEs:** SMEs account for over 60% of GDP and over 70% of total employment in low-income countries when considering the informal sector.[xxx] The economic lockdowns caused by containment measures have reduced demand for their products and disrupted supply chains. Given their limited resources, SMEs can survive shocks over very restricted periods[xxxi] and they are more exposed to corporate insolvency than larger firms. According to a survey by the International Trade Center (ITC 2020) in 132 countries, one-fifth of SMEs are at risk of shutting down permanently within three months.[xxxii] The SMEs sector collapse would reverse years of efforts to strengthen developing countries' capacity to invest in climate action.

Even though the G20 has suspended official bilateral debt payments from the poorest countries, freeing up about $5 billion for 42 low-income states in 2020, poor macroeconomic conditions, including currency devaluations and increased perceived country risk, led to downgrades in sovereign credit ratings, increasing the interest rate spread and cost of public borrowing. In 2018, the spread was 1.3% for a five-year project and 2.5% for a ten-year project in BBB rated countries and up to 6% and 9% respectively in B rated countries. At the low end of the creditworthiness ranking, more than 60 countries were rated below BBB and, before the Covid-19 crisis, had access to capital only at spreads higher than 18% for projects longer than two years (Buhr et al. 2018). The list of countries in debt distress has grown since then, and outright defaults have already begun (Bulow et al. 2021) with substantial downgrades in sovereign credit rating.[xxxiii] The proportion of poorest countries (assessed using the Low-Income Country Debt Sustainability Framework) in or at high risk of debt distress has climbed to 55% in January 2021, from 50% in 2019 and 26% in 2013.[xxxiv] These countries have neither deep domestic financial markets nor excess savings. The conditions are such that some financially strapped countries are now hesitant to accept debt standstills for fear of jeopardizing their credit ratings, creating issues long into the future. Notably, FDI greenfield investment, which is more important in developing economies than mergers and acquisitions, declined significantly over the first two months of 2020, and the announced inflows for such investments for 2021 are 60%, 51%, and 38% lower than in 2019 in Africa, Latin America and Asia respectively.[xxxv] There will not be a sustainable debt if such trends continue.

Developing countries will thus not be able to mount counter-cyclical climate investment paths since past experiences show that rising domestic taxes to balance public budgets slows down recovery and increases capital outflows. After the subprime crisis, macroeconomic policies did not prevent the GDP growth rates of Latin America and Low-Income Countries from falling from 3% per year and 6% per year respectively between 1997 and 2007 to 2.05% and 3.92% between 2009 and 2019. The situation might be worse in the post-Covid context because developing countries might also receive less help from the MDBs than after the subprime crisis. The World Bank, the African Development Bank (AfDB), the Asian Development Bank (ADB), and the Inter-American Development Bank (IADB)increased their total lending by $46.4 and 42.9 billion in 2009 and 2010 (compared with 2008) against $18.2 billion and $20.1 billion only in 2020 and 2021 (compared with 2019) (UN IATF 2021). Actually within this total, LDCs received a higher support than after 2008. This is the case for the World Bank's IDA commitments (an increase of 40% in 2020 against 26% in 2009), for the AfDB's concessional window which is expected to reach its $3.0 billion target, and for the ADB due to significant lending room gained from the merger of its concessional and non-concessional windows in 2017. But financial capacity constraints are limiting MDB countercyclical support for middle-income countries. The World Bank's International Bank for Reconstruction and Development (IBRD) loan commitments for middle-income countries are estimated to have increased by only 36% in 2020, compared to a 145% increase during its response in 2009. Similarly, AfDB lending through its non-concessional window is hampered by financial constraints and expected to fall compared to 2019. The situation is similar for IADB, whose 2020 response is also lower than its response to the global financial crisis (UN IATF, 2021)

If these pessimistic prospects materialise for a significant number of developing and emerging economies, OECD countries will fail to recover full employment even using robust rescue and recovery packages. In the absence of a dynamic demand from developing countries (55% of the world markets, China excluded), these packages might deepen the gap between the propensity to save and the propensity to invest worldwide. The combination of yields falling because of expansionary monetary policies, an impressive increase of households saving rates[xxxvi], and persistent risk-averse corporate saving trends (Demary et al., 2021) are indeed the key ingredients of a 'saving glut' whereby the high-income people refrain from financing productive investments (Mian et al., 2020; Chen et al. 2017). Lowering the risk-perception of such investments is a matter of domestic public policies but will not be achieved without a conducive international context.

Unconventional monetary policies (debt cancellation, debt swaps, issuance of new special drawing rights (SDRs), Gallagher et al., 2020) are currently envisaged to avoid economic collapse in many countries. They are discussed but the major difficulty to be solved is the cascading effect they will have on the world economy and the financial system. Large-scale economic stimulus packages from OECD countries pump trillions of dollars into the global financial system and lead to a series of asset price bubbles that could burst soon and undermine financial stability if the liquidity is not invested productively. The way out is to direct part of the additional debt where the greatest needs are, including low-carbon investments (Bulow et al. 2021).

Chapter 2 has shown that well-designed climate investments can create this redirection by lowering the investment risks coefficient in developing countries. Such risks currently prevent the flow of capital to solve the geographical mismatch and restricts access to the largest greenhouse gas emissions abatement opportunities and corresponding markets. The challenge is then to convince the climate agnostic decision-maker that these basic principles can be enforced and will ensure that any new payment facility will use money efficiently to create jobs and economic wealth in the short-term. The following section examines this challenge.

3.2. Immediate actions for a climate resilient Covid-19 recovery in developing countries

The economic and financial impacts of Covid-19 have exacerbated the four pre-existing challenges facing developing countries to scale up climate action. In order to address these challenges, developing countries will need to ensure that climate action and economic recovery are mutually supportive, scale up investment without increasing their debt burden, attract large scale private financial flows in a context of perceived higher investment risk, and secure access to long-term affordable finance at a time of rising capital costs.

This can be achieved through a set of four complementary actions: (i) integrating policies on climate action, sustainable development and Covid-19 stimulus measures to minimize incremental investment requirements and optimize development co-benefits; (ii) alleviating developing countries' debt burden to create fiscal space to finance their green, climate-resilient recovery plans; (iii) leveraging sovereign and multi-country guarantee funds to reduce investment risk and catalyse private finance; and (iv) increasing developing countries' access to the green bond market.

3.2.1. Policy: Integrating climate, sustainable development and Covid-19 stimulus measures

Nationally Determined Contributions (NDCs) are at the heart of the Paris Agreement and countries' commitment to transform their development trajectories. Countries are currently in the process of submitting updated and more ambitious NDCs. This process will culminate at the 26th session of the Conference of the Parties (COP 26) to the UNFCCC in November 2021 in Glasgow. This section discusses how the next generation of NDCs can promote integrated policy planning and support the development of investment plans that identify the right sources of finance and the opportunities to combine and sequence different sources of finance.

Leveraging NDCs to promote integrated policy planning between climate action, sustainable development and Covid-19 recovery measures

One pervading message throughout this report is the importance of integration between sectoral policies, adaptation measures, mitigation action, and Covid-19 recovery stimulus (Fankhauser and McDermott, 2014; Morita and Matsumoto, 2015; Adenle et al., 2017; Sovacool et al., 2015, 2017; Peake and Ekins, 2017).

An illustration of the gains deriving from policy integration is given for a 2°C scenario that also meets the targets of SDGs 6.1 (drinking water) and 6.2 (sanitation and hygiene). They find that the total annual infrastructure investment of low and middle-income countries in energy, transportation, water supply, sanitation, flood protection, and irrigation should amount to $2.7 trillion/year over the next 15 years, under current decision-making practices and fragmented policies, against $1.5 trillion/year only in case of policy coordination. For the sole investments that are critical for adaptation (water supply, sanitation, flood protection, and irrigation) the reduction would be from $0.66 trillion/year to 0.35 trillion/year.

Similarly, integrating macroeconomic policies, debt management and sectoral 'green' packages will maximize the knock-on effect of recovery strategies and their development side-benefits. For example, investment in energy efficient buildings can generate large employment opportunities, reduce energy poverty and increase resilience to extreme weather events. Investments in climate resilient agriculture and water management will preserve livelihoods and foster ecosystem restoration while investment in shovel-ready low emission, resilient infrastructure will protect people, jobs and assets.

However, at the domestic level, policy making is typically split across different government ministries, e.g. ministries of environment are responsible for developing and updating NDCs, ministries of planning are responsible for national SDG plans, and ministries of finance for economic stimulus packages and creditworthiness concerns. Experience from the first NDCs has shown that they were often siloed in environment ministries with weak alignment with national, sectoral and sub-national development planning (Riva M. et al. 2020).

Translating NDCs into investment plans

NDCs and national SDG plans are often designed as policy signals for national priorities, rather than portfolios of bankable investment projects. Few countries have completed their NDC financing plan

(Cooke et al. 2018) due to the lack of clarity on what these plans should look like and a poor understanding about the financing mechanisms available for NDC implementation. As a result, priorities expressed in NDCs are too numerous and/or too abstract to guide investments grade project development at the national/sub-national levels. This is a major obstacle to attracting the right mix of finance and using scarce public resources to catalyse private funds for climate investments with high socio-economic co-benefits.

In addition, the domestic financing landscape is complex and fragmented. Institutional partners, including international development agencies and banks tend to have their own country strategies and programming documents to identify investment priorities and different focal points in line ministries. Similar challenges also emerge at the sub-national level, where there is often no structured engagement or coordination mechanisms dedicated to municipalities for climate investment decisions.

There is a need to translate integrated NDCs into investment plans that:

- align, combine and sequence multiple sources of international and domestic finance from the public and private sectors;
- enable countries to take a more integrated value-chain investment approach, notably by acquiring the technical capacity needed to address policy and regulatory gaps in order to improve the bankability of the NDC project pipeline; and
- identify financial mechanisms and investment patterns that will not increase sovereign debt, but catalyse private funds and increase access to long-term affordable finance.

This need is amplified in order to green Covid-19 recovery efforts.

Developing NDC investment plans can take place as part of countries' efforts to update their NDCs or increase their access to climate finance. Box 3.1 highlights the Government of St. Lucia's efforts to develop and implement an NDC Financing Strategy to realize its climate and sustainable development ambitions without increasing its debt burden.

Translating NDCs into investment plans can also take place as part of a country's broader effort to finance its national sustainable development strategies. In line with the Addis Ababa Action Agenda, countries are beginning to design integrated national financing frameworks (INFFs). INFFs set out the national financial landscape and coordinate efforts to mobilise and align a wide range of financing sources with the country's sustainable development priorities (UN IATF, 2019).

Consistent with the INFF process, such policy integration and the development of NDC investment plans can be achieved through high level inter-ministerial coordination mechanisms, that also bring together institutional partners and financiers. Such mechanisms would create opportunities to jointly identify climate friendly investment priorities, map different sources of finance and strengthen synergies between public domestic resources, public international finance, including through direct budgetary support (DBS), and private finance. Identifying priority investments should also reflect the impact of non-action and how climate change may affect countries' macro-economic stability and development objectives. Priority investments could be duly costed and translated into a pipeline of bankable projects. Contributions from public resources (domestic and international through DBS) can then be integrated in annual budgets via Medium-Term Expenditure Frameworks (MTEFs), and Public Investment Programming (PIP), which create regular timeframes to embed climate investments as part of national domestic spending plans and processes. This in turn would enable institutional partners and private sources of finance to align their investments with national climate friendly investment priorities.

Within this context, , a key responsibility of the international community is to reduce the fragmentation of the current climate finance (Watson and Schalatek, 2020) and enable synergies between different sources of finance.

Box 3.1: Saint Lucia mobilizes international climate finance and private investment for low-carbon development[xxxvii]

Saint Lucia, like all Small Island Developing States, is deeply affected by the impacts of climate change. The Government is committed to global efforts to reduce greenhouse gases and has pledged in its NDC to reduce the country's emissions by 23% by 2030. The achievement of Saint Lucia's NDC targets is conditional upon external financing. While international climate finance and ODA offer some relief to Saint Lucia's growing debt-to-GDP ratio, the decreasing level of international aid undermines the long-term sustainability of this approach. Saint Lucia faces a number of barriers, including limited fiscal space and limited access to long-term, affordable finance due to high interest rates – averaging 7.7% in 2019 - and collateral requirements. Enterprises also lack capacity and a track record in climate mitigation projects.

In order to address these barriers, the Government is striving to increase access to climate finance and develop new and innovative mechanisms to de-risk mitigation projects and attract private sector investments. The Government's strategy sets out a target of $218 million in mitigation investments provided by the private sector by 2030, 90% of the total. In order to achieve this target, the Government has embarked on the development of an NDC Financing Strategy which proposes specific actions aimed at increasing and accelerating private sector participation, particularly for the development of commercial mitigation projects. The strategy includes:

- **Accessing the green bond market** by exploring their issuance and advancing go-to-market and pre-issuance activities, including the development of a Green Bond Roadmap and Green Bond Framework.
- **Developing and implementing a 'debt for climate swap strategy and roadmap'** by assessing Saint Lucia's public finance policy and external debt to assess readiness for a swap transaction, supporting engagement with priority creditors, identifying eligible projects, and developing an appropriate governance, monitoring and reporting mechanism.
- **Greening Saint Lucia's financial sector** by strengthening the capacity of local financial institutions to understand environmental and social risks and benefits, integrate environmental and social standards into processes and procedures, and develop green credit instruments.
- **Increasing the Government's capacity to implement public-private partnership projects** by developing a web-based step-by-step public-private-partnership (PPP) toolkit to be used by public officials for assessing projects against screening criteria such as environmental and social impact, scale, risk transfer, financial viability and market appetite.
- **Developing a concept for high-quality green and affordable housing** for submission to the Green Climate Fund to address the need of a housing stock that is resilient to extreme climate events and accessible.

3.2.2. Alleviating developing countries' debt burden to create fiscal space for a green, climate-resilient recovery

The sharp increase in developing countries' debt level due to the Covid-19 crisis creates a vicious cycle, whereby these countries have almost no fiscal space to spend on the economic recovery and climate action. The situation is especially critical for 55% of the poorest countries which were in or at high risk of debt distress in January 2021. For example, Fiji, a small island developing state that is highly vulnerable to climate change, has reduced government allocations to climate related projects by 32% in 2020.[xxxviii]

Several multilateral actions are being taken to support developing countries coping with the economic crisis and create more fiscal space. The G20 has suspended – not cancelled – official bilateral debt payments for 42 low-income countries, corresponding to approximately $5 billion. MDBs collectively announced over $200 billion of support to developing countries (UN IATF, 2021). The IMF will present by June 2021 a formal proposal to the Executive Board on a new Special Drawing Rights (SDR) allocation of $650 billion to help meet the global long-term need to supplement reserves and boost liquidity (IMF 2021). However, a similar initiative taken by the G20 in 2009 for an amount of $250 billion was blocked by the lack of easy country allocation rules and by the fear that greater payment facilities would lead to a lax selection of projects and generate windfall profits. These obstacles might still prevail today.

Even bolder action i is 'debt-for-climate swaps', a partial cancellation of debt by the creditor government transforming the remaining part into local currency and directing it to investment in climate action. The level of debt reduction could be a function of a country's overall climate vulnerability. Many forms of debt swap for development and environment have emerged since the 1980s. They have proven to alleviate the fiscal pressure of debt repayment, improve macroeconomic stability, generate long-term, stable streams of revenue for environmental projects, and help build capacity in managing public environmental expenditure. However, such swaps have to date resulted in relatively small amounts of debt relief, limiting their impact on the overall debt burden. Their use has been limited for two reasons. First, they are complex to design and tend to require long legal negotiations and technical assistance to support reviews of countries' policies and legislative frameworks, and formulations of contractual agreements between debtor and creditor countries. Early debt-for-environment swaps were negotiated by environmental NGOs, which did not always have the resources to implement large-scale programmes. Second, experience has also shown that such swaps require a pipeline of high-quality bankable climate investments which can be capitalized in the form of credible assets and supported with transparent and credible domestic spending.

Both 'debt-for-climate swaps' and the issuance of new SDRs, or any form of unconventional debt relief, will be scaled-up and generate development and climate benefits if they credibly target bridging the countries' infrastructure gap. Low-carbon climate-resilient options are interesting in terms of credibility as they can link the impact of mitigation and adaptation action to clear metrics (e.g. avoided emissions and number of people benefiting from increased resilience), designed using transparent assessment methods suggested below.[xxxix].

These unconventional debt management instruments (debt-climate swap, debt suspension or cancellation, SDRs) respond to the specifics of the post-Covid-19 context and are additional, not alternative to the commitment of developed countries to mobilize $100 billion in climate finance per year by 2020 for developing states. Reaching the $ 100 billion commitment is critical to finance essential non-market services as well as the deployment of environmental policy instruments to create a conducive business context to catalyze low carbon, climate resilient private investment.

These commitments, formalized at the 16th Conference of the Parties of the UNFCCC in 2010, are central to the climate accords but have not been fulfilled so far even though they have been on an upward trajectory before 2020[xl]. They are also pivotal to restore a circle of trust and creating an enabling environment by de-risking market-creating investments in early-stage climate-friendly options (see Chapter 2). Connecting the $100 billion target with access to new debt facilities and debt reliefs programmes would be an extremely powerful way to foster a green and inclusive economic recovery from the Covid-19 crisis both in developing countries and developed countries. However, according to a recent assessment by an independent group of experts, it is unlikely that the 2020 $100 billion target is reached, despite the year-on-year progress between 2015 and 2018 (Bhattacharya, A; Calland, R. et al. 2020). A concerted increase of the effort is therefore needed to bolster climate finance in 2021. The question is how to shape this concerted action at a short notice.

3.2.3. Sovereign, sub-sovereign, and multi-sovereign guarantee funds to reduce perceived investment risk

Chapter 2 has explained why sovereign and sub-sovereign (local governments) guarantees are increasingly recognised as one of the major blended finance mechanisms to overcome the barriers hindering climate-friendly investments. They reduce up-front risks, provide a broad risk coverage, a lower cost for public budgets of donor countries and a high leverage ratio of public to private capital (BFTF, 2018). Chapter 2 also explained why there is a 'glass ceiling' limiting their scale-up by MDBs (Gropp et al., 2013; Lee et al., 2018; Schiff and Dithrich, 2017).

Sovereign guarantees might circumvent this obstacle but their use in finance related to overseas aid suffers from a mix of historic finance agencies' inertia, perceived loss of control over the use of funds (compared to direct project-based financing), and politics around fiscal accountability at home. To address these challenges, 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, 2017), guarantee funds to bridge the infrastructure investment gap (Arezki et al., 2017), and multi-sovereign guarantee mechanisms (Dasgupta et al., 2019).

These proposals have in common the search of a credibility-enhancing effect provided by multilateral arrangements on capital markets for both the donor and the host country. Such an effect would overcome the lack of familiarity by public administrations with guarantees outside major projects and programmes. On the one hand, unlike multi-year budgetary commitments, pre-commitments within multi-sovereign guarantee architectures do not depend on annual legislative approvals, which can be problematic given taxpayers' fiscal conservatism (Peltzmann, 1992). On the other hand, they would support a learning process about agreed-upon assessment and monitoring methods to strengthen, at low transaction costs, the environmental and economic credibility of green investments and financial products. It could also accelerate the demand for science-based assessment tools.

In addition, a primary factor enhancing the credibility of multi-sovereign guarantees is the ability of the system to deliver immediately tangible reciprocal gains, thus securing its continuation over time despite competing demands for public support in all countries. The leverage effect of the Junker Plan in Europe, for example, has been estimated at 1 to 15. Even if such a ratio is not systematically reached, multi-sovereign guarantees are still efficient in mobilizing domestic and international resources from financial institutions, asset managers and institutional investors at a low cost and with longer maturities.

Guarantor countries can compensate the public cost of their commitments with the fiscal revenues of induced exports. Only a percentage of the guarantees has to be set aside as potential loss given the default risks, and it can be easily balanced by the positive impact of investments on tax revenues through exports. This depends on the country's foreign trade multiplier, i.e., the increase of a country's national income generated by a unit increase of its exports. USAID's extensive experience on a global guarantee fund for SMEs (known to be generally risky) over 1999-2017 shows a default rate as low as 2.4% (USAID, 2017). 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 per year (Hourcade et al., 2021).

The overall economic efficiency of the system would be higher with guarantees calibrated on an agreed notional value of the avoided ton of emission (Stiglitz et al., 2017). This value would express the "social, economic, and environmental value of mitigation actions [and] their co-benefits" (Article 108 of the Paris Agreement decision). It could be part of the assessment process discussed below, which is critical for the credibility of any climate-friendly financial architecture.

Multi-sovereign guarantees, where developed countries rated AAA-AA join forces to provide an AAA-AA backing to developing countries, thus provide a number of advantages. These include:

- ***Expanding developing countries' access to capital markets at a lower cost and longer maturities*** thanks to the reduction of creditworthiness risks, especially for small states.[xli] This also avoids the Basel III’s liquidity impediment and the EU's Solvency II directive on liquidity (Blended Finance Taskforce 2018).

- ***Accelerating the recognition of climate assets suitable for institutional investors seeking 'safe investments havens’***, thanks to the reputational effect of a selection of projects with multilateral backing and transparent assessment methods.

- ***Strengthening climate disclosure*** through high grades in the environmental notation of these climate assets. This would minimize the risks associated with the 'greening' of the portfolios by divesting from carbon-intensive activities for investing in 'carbon neutral' activities and not in more risky low carbon infrastructures.

- ***Increasing the effectiveness of carbon pricing*** with more mitigation activities unlocked by a given price level, a stronger employment impact and higher funding facilities to help industries adapt. This would not remove the need of fiscal measures to accompany the increase of carbon prices, but it would make them lighter because they would have to offset the adverse effects of lower prices for the same emission objective.

- ***Freeing up grant capacities for SDGs and adaptation*** by crowding in private investments for mitigation. For non-marketable activities, grants are the key instrument to develop policy and capacity and establish a conducive investment environment that deals with risks.

Figure 3.1 below provides an overview of a theory of change of a possible multi-sovereign guarantee fund.

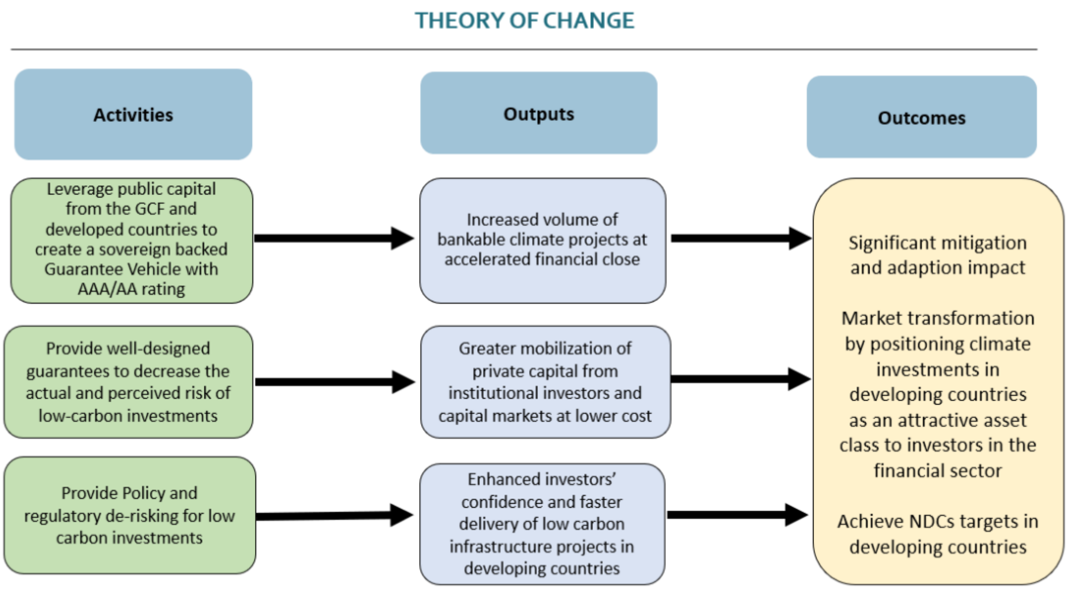

Figure 3.1

3.2.4. Increasing developing countries access to the green bond market

De-risking low carbon and climate resilient investments is a necessary but not sufficient condition to reduce the mismatch between where the savings are and where they should be directed to for a 'green' recovery. Due to their cash profiles and long-life span, infrastructure investments tend indeed to require financial backing for around 15-20 years, whereas (see chapter 2) the tighter regulations that have followed the subprime crisis have reduced the long-term risk appetite of banks and institutional investors. These regulations resulted instead in preferences for shorter loan maturities (5 to 8 years) and more secure assets. In 2015, only 5% of assets held by pension funds and public reserve funds were backed on infrastructures (OECD 2017). Covid-19 has compounded this risk aversion.

It is also necessary to transform climate-friendly infrastructures into recognised asset classes to remove this barrier. Climate resilient infrastructure as an asset class is needed to back the issuance of green bonds that can mobilize institutional finance at scale, respond to the needs of many actors in the low carbon transition, and preserve the stability of the financial system (see box 3.2). The potential of green bonds is estimated at €29.4 trillion over 2030 (Bolton et al., 2020) and has the potential to create new public-private partnerships and increase developing countries' access to long-term affordable debt. However, as noted in chapter 2 in the assessment of blended finance to date, the development of green bonds is far below this potential (only $1 trillion in the ten years since their launch and $258 billion in 2019, Climate Bonds Initiative, 2020). They represent about 5% of total bonds issued globally and they fell by 11% in 2020 in the aftermath of the pandemic. At the same time, governments and development banks globally have been actively issuing bonds to provide immediate relief amid the devastating impacts of Covid-19. In the first seven months of 2020 sustainable bonds issuance surpassed $270 billion, up by 5% from 2019. This includes the issuance of 'pandemic bonds' largely driven by China (CPI, 2021) but no significant increase of 'green' bonds.

Box 3.2: The importance of new climate resilient asset classes to preserve the stability of the financial system

In addition to its potential to unleash public-private partnerships and increase access to long-term affordable debt finance in developing countries, the creation of new asset classes for climate-resilient infrastructure is essential for:

- Project developers because the recoverable assets enter the calculation of the project's NPV (Net Present Value) and can serve as loan collateral.
- Economic actors whose capital value could also collapse. These are not only the firms engaged in fossil fuel extraction, fossil fuel-based power and heat production, but households whose floor space is reduced by insulation works, the transport sector, energy-intensive manufacturing, food production, animal husbandry, and forestry.
- Actors of the financial system (pension funds, insurance companies and asset managers) whose ability to meet their obligations might be impaired. They would consequently reduce their services (e.g. risk coverage by insurances) with detrimental effects for both mitigation and adaptation activities.
- Countries and regions highly dependent on fossil fuels, whose development capacity will be undermined by significant losses due to stranded assets. Their engagement in the low carbon transition depends on access to climate remediation assets to finance the industrial conversion.
- Host countries of any loan or bond as any new debt will be first registered as a liability on their public accounts posing creditworthiness risks. These risks can be offset if new and credible asset classes that can registered on the asset columns emerge.
- Regulators as financial products across asset classes backed by certified projects would increase liquidity and reinforce the efficacy of climate disclosure and taxonomy approaches.

Several initiatives are ongoing to broaden developing countries' access to the green bond market (see box 3.3 for the example of Jamaica). This requires creating (i) credible and standardized assessments and valuation methods to select, monitor and report on high-quality bankable climate projects; and (ii) developing capacity to design, float and implement green bonds. Details across these two elements are discussed below.

Project assessment and valuation methods

A pipeline of high-quality, bankable climate projects is a pre-condition for a strong bond market. On the part of institutional and impact investors, concerns around climate impact and possible 'greenwashing' as well as the risk of default can prove a major obstacle to the scaling-up of green bonds. From the perspective of public budgets, additional challenges for using public resources to de-risk climate friendly investments are alignment with country priorities and additionality- i.e. the risk that it will generate windfall profits to investors for projects that would have been undertaken anyway.

One way to address these concerns and to best reconcile the interests of investors, entrepreneurs, taxpayers and rate payers is to link de-risking mechanisms with transparent and rigorous project selection methods. Such methods can assess country ownership, climate impact, additionality and sustainability and hedge against arbitrary project selection or 'hold-up' problems in PPPs structures (Dewatripon and Legros, 2005; Bolton et al. 2020). The challenge is to set up these hedges without increasing the transaction costs of the project at the preparation stage, which would deter entrepreneurs' engagement. This strict selection will indeed be a *de facto* or implicit certification of bonds. While the challenges are not identical for adaptation and mitigation projects, progress is required for both.

There are several ongoing efforts in this regard. The Climate Bonds Initiative published a Climate Bond Standard and Certification Scheme to offer guarantees that funded projects fulfilling environmental objectives; and the International Market Association proposed sustainability bonds guidelines to incorporate non-climate related benefits of the projects' portfolio (ICMA 2018). However, in 2019 the issuance of green bonds certified through these standards accounted for only 17% of the green bonds volume, which is insufficient in relation to needs. UNDP recently released impacts standards for bond issuers to optimize their contribution to sustainable development (UNDP, 2021).

Several proposals also aim to build on experience of environmental funds such as GEF, CDM, GCF, and others to develop specific additionality methodologies for green bonds and guarantees. For example, in a context of imperfect knowledge of projects' performance and costs of proving additionality (Shishlov and Bellassen, 2012; Bellassen, 2015), it is possible to create statistically significant additionality through standardized assessment methodologies.

Some contributions suggest that agreed upon assessment methods can be standardised for mitigation projects thanks to the existence of a common metric - avoided ton of emission. Peer-reviewed modelled and non-modelled scientific information could help determine upper and lower bounds of avoided carbon emissions associated with a given type of project in a given country and/or region for various growth scenarios (Dasgupta et al. 2019). It would then be possible in a multilateral setting to launch pilot programs to test methods to (i) evaluate the avoided tons of emissions (in quantity and value) by type of project, sector and geography balancing rigour and cost of the assessment, and including uncertainty coefficients (Hourcade et al., 2012);[xlii] and (ii) value the avoided emissions based on an agreed value per ton [xliii] and secure the economic efficiency of the world portfolio of low carbon projects through the notional prices recommended by (Stern and Stiglitz, 2017) in the absence of an explicit and high enough carbon price. Such methods could then be used by third party expertise (Blended Finance Taskforce, 2018; Lee et al., 2018; Schiff and Dithrich, 2017) to guarantee the credibility of the bundling of project and of the bonds they back.

For adaptation, new valuation methodologies are required to better assess the benefits of climate resilient infrastructure projects and transform them into a new class of assets. Such mechanisms will enable investment decision-making to balance off risks associated with higher upfront costs of climate resilient infrastructure with their lower OandM costs and lower climate physical and transition risks. This could lead to labelling investments as climate-resilient assets, highlighting their sustainable development benefits, including improved health, food security and job creation, all of which are critical to the COVID-19 response.

To develop valuations and labelling of climate-resilient infrastructure in developing countries, the Coalition for Climate Resilient Investments (CCRI) is piloting methodologies for their structuring and financing. With the Jamaican government (see box 3.3), CCRI is developing an assessment tool to enable investment prioritisation based on the exposure of selected infrastructure networks to physical climate risks, the economic and social value at risk due to such exposure, and the potential capacity of nature-based solutions (NBS) to partially replace hard infrastructures.

This tool, the first of its kind, will integrate climate risk analytics in programmatic infrastructure decision-making enhancing cost-benefit analyses at macro-economic and asset levels. Such analysis should in turn support and incentivise the development of project pipelines for resilient infrastructure and a more efficient allocation of public and private capital for their realisation. The CRRI will also analyse cash flows of selected projects to understand the quantitative changes climate risks brings to their budgets and codify the results.

Generalising the use of this tool will speed up the emergence of an evidence-based benchmark for discussion on standardization, even for projects whose assessment necessitates metrics more complex than the tons of avoided emissions. This would make it possible to structure financial instruments that realistically embrace resilience to climate change throughout the infrastructure project pipeline, which in turn will enable its development, financing and securitization.

Capacity development to design, float and implement green bonds in developing countries

Investment in domestic capacity to design, issue and report on bonds aligned with the unique requirements of developing countries will be required to fully leverage the potential of green bonds to finance the transition to net zero climate resilient development in developing countries. For example, a strong technical capacity and standardized technical aggregation methods are needed to unlock small projects. A microgrid in a remote African village costs a few hundreds of thousands of dollars, equipping a large condominium with electricity distribution infrastructures ten thousand only. Such projects are barely significant for institutional investors and cannot respond to asset managers' calls for investments over $ 100 million in diversified asset pools. Devices facilitating their bundling, securitization, and repackaging in standardized liquid financial products can overcome this obstacle (Andersson, Bolton, and Samama, 2016; Arezki et al., 2016; Blended Finance Taskforce, 2018).

Issuing green bonds requires a regulated capital market to be in place and considerations related to liquidity apply. The bond issuer also needs to meet certain criteria for listing financial products. While there is no specific legal requirement for issuing green bonds, existing international standards such as the Green Bond Principles or Climate Bond Standards can be recognized/adopted by national financial authorities, issuers and certifying bodies.

Financial and non-financial corporate issuers have been the biggest source of green bonds in every quarter since Q3 2018. However, government backed entities experienced 35% growth in Q3 2020, compared to Q3 2019 (CBI, 2020). Publicly owned financial institutions with specific development or policy mandates – National Development Banks (NDBs) - have a critical demand creating countercyclical role to play in reviving economies in ways that are consistent with the Paris Agreement and SDGs. NDBs together with regional development banks (which together are referred to as public development banks, PDBs) represent about 10% of global investment, disbursing more than USD 2 trillion annually.

There are almost 260 PDBs in developing countries, representing USD 5 trillion in assets. PDBs have the capacity of extending more than USD 400 billion in climate finance per year, and doubling their investment capacity or leverage effect would be enough to bridge the infrastructure investment gap. However, only 58 NDBs in developing countries are accessing international capital markets to capitalize their operations. Issuing green bonds could be a game changer for NDBs and international efforts to scale up climate action.

To realize their full potential, NDBs need a clear ‘green’ mandate by policy makers and strong governance to become first tier financial institutions. They also require the skills, tools, and track record to assess the specific risks associated with investments in new climate technologies and identify the most appropriate financial structures. Finally, international public finance institutions will be key to support in accessing international climate finance and capital markets so that they have adequate capitalization to operate at the required scale and take on early investment risk.

Box 3.3: Facilitating an enabling environment for a Caribbean Green Bond listing on the Jamaica Stock Exchange[xliv]

Jamaica, a small island developing state, is highly vulnerable to the impacts of climate change, including droughts, increased intensity of extreme weather events, and higher temperatures. As an upper middle-income country, Jamaica also faces several economic challenges, including low growth, high public debt, and high energy costs. The Government is implementing an ambitious reform programme to stabilize the economy, reduce debt and fuel growth. The Government is also committed to accelerating climate investment from the private sector to implement its NDC ambitions.

Based on recommendations from a regional private sector study, the Government is taking action to increase its access to the green bond market in order to finance new and innovative business opportunities, and attract local and international institutional investors to support climate resilience and low carbon development.

The Government aims to create an enabling environment for a Caribbean green bond listing on the Jamaica Stock Exchange, which will enable it to float through a dedicated green bond facility. Specifically, it is:

- Assessing the current structure of the debt capital market for bonds and the suitability for green bond growth;
- Developing appropriate policies and guidelines based on international standards and Green Bond Principles; and
- Strengthening the capacity of key market players from across the region.

Once the green bond facility has been established, the country envisions the aggregation of project assets (from public and/or private sources) and their refinancing through proceeds of green bonds to accelerate the implementation of its NDC.

Conclusions

A key conclusion of this study is that meeting the goals of the Paris Agreement in a way that is consistent with the Cancun's mandate of an equitable access to development (COP26) depends on our capacity to use climate action to reduce today's economic and social tensions. We can do so by ***bridging the structural investment gap worldwide*** (energy, transport, building, water systems) ***with low carbon and climate resilient options.***

The quantitative evidence is that funding an ambitious low carbon transition is possible by ***redirecting a significant part of private capital*** towards climate-friendly infrastructures through reducing the mismatch between where the private savings are and where the bulk of infrastructure investment needs, and opportunities lie, i.e. in developing countries. This is in line with the common but differentiated responsibilities principle of the UNFCCC (1992).

In the absence of policy interventions, the financial system will not be able to redirect private capital on the needed scale. It might also integrate too slowly climate-related risks in the 'value at risks' calculations that guide the permanent restructuring of asset portfolios. Even if this integration is accelerated by the deployment of climate disclosure and transparency methods, the portfolios' decarbonisation could occur by investing in emission intensive activities but not in low carbon infrastructures. This would take the planet towards climate scenarios (P3 and P4) whereby limiting global warming to 1.5°C or 2°C would totally depend upon the mobilization of large amounts of carbon capture and storage although the technical feasibility of this technology and its consistency with the SGDs are still uncertain.

The policy interventions needed to increase the economic viability and bankability of climate-friendly options ***must maximize the complementarity*** of a) ***market fixing instruments*** (carbon pricing, climate disclosure and transparency rules) that incite the financial sector to offer affordable financial terms to such investments, and b) ***market-shaping approaches*** (information, regulatory, economic, and institutional measures) that reduce uncertainty on the demand for green, climate-resilient goods and services and de-risk such investments. To scale up climate action, this complementarity should be backed by risk-sharing devices, amongst which ***public guarantees that transfer to public actors part of the upfront risks currently deterring investment initiatives*** on projects that could otherwise be economically viable.

A second key conclusion is that postponing such measures can be detrimental to climate action. In the post-Covid-19 context, those measures inevitably imply support from public budgets subject to competing priorities and unprecedented debt levels. The report brings together the latest economic expertise, which emphasize the following aspects.

There is an important asymmetry between most OECD countries, which can roll out ambitious recovery packages contracting debt at almost zero interest rates, and developing countries facing the downgrading of their credit ratings and difficult access to international currencies. A weak recovery of countries representing 55% of the world's markets (China excluded) could undermine the efficacy of the unprecedented injection of liquidity in developed countries.

Bridging the infrastructure investment gap would be a blueprint for a fast and robust global recovery thanks to the strong knock-on effect on infrastructure investments, notably the unlocking of two-thirds of the world's infrastructures market currently 'frozen' in developing economies. The public policy devices mobilized to redirect savings towards low-carbon options have the advantage, compared to untargeted recovery measures, to ensure the efficiency of every unit of public money spent.

Four interrelated actions that can be taken almost immediately.

- ***Integrating policies on climate action, sustainable development and Covid-19 stimulus,*** which requires that governments transform their Nationally Determined Contributions (NDCs) into credible investment plans. Integrated national financing frameworks (INFFs) in line with the Addis Ababa Action Agenda Policy are necessary to meet the overall investment needs for a low carbon transition. This includes a mapping of financial flows which will enable countries to navigate complex financing landscapes and identify, combine and sequence the right sources of finance. The international community can help build an environment conducive to the translation of NDCs into investment plans as part of a country's effort to finance its sustainable development strategies, including by reducing the fragmentation of international climate finance.
- **Alleviating developing countries' debt burden to create the fiscal space for a green recovery**. Unconventional policies imposed in the context of the pandemic, such as emissions debts swaps, debt cancellation or the issuance of new SDRs, might not be scaled-up at the required level in the absence of mechanisms to ensure that they are targeted to activities with a strong short-term recovery potential that will allow to easily repay the debt, and that deliver a strong contribution to the decarbonation of the world's economy and the fulfillment of the SDGs.
- **Setting up multi-sovereign guarantee funds** to de-risk low carbon investments in developing countries. This is possible thanks to AAA guarantees and enhanced credibility coming from the high leverage of public funds on private capital, and the delivery of immediately tangible reciprocal gains. For guarantor countries the fiscal revenues of induced exports will quickly overcompensate the public cost of their commitments, and host countries will benefit from new capital inflows and the grants equivalent of reduced debt, which might potentially go far beyond $100 billion per year. A second credibility-enhancing factor of the multi-sovereign guarantees is to facilitate the establishment of third party assessment procedures backed on agreed-upon methods that include both the quantification of avoided emissions and the valuation of these emissions by a notional price of carbon to calibrate the amount of the guarantees. This is critical for the emergence of new asset classes and the development of credible bonds markets to hedge against arbitrary project selections and windfall profits for projects that would have been undertaken anyway.
- **Developing credible green bond markets and facilitating developing countries accessing them** It is critical to facilitate the bundling, securitization, and repackaging of climate friendly projects into standardised liquid financial products that could support the NDCs investment plans. On that basis, the key to success is enhancing domestic capacity to design bonds. Together with MDBs and the Green Climate Fund, NDBs could be the key players to realize this potential with some dedicated support to enable them to become first tier financial institutions and obtain a clear 'green' mandate. The emergence of credible and standardised projects' assessment methods is also a precondition to dispel the suspicion of greenwashing, a key reason why over the past ten years the issuance of green bonds has been far below the theoretical potential in OEDC countries.

These four immediate actions could have a structural positive impact on the future climate policy architecture. They could a) facilitate the deployment of carbon pricing since de-risking mechanisms will increase the volume of low-carbon investments at a given carbon price; b) magnify the impact of financial transparency and disclosure though the emergence of investments and asset classes of higher credibility; c) reduce the fragmentation of climate and development finance and d) enhance the capacity of MDBs and overseas assistance to support non marketable services. These are very important to boost the adaptive capacity of societies by crowding in private capital to fund mitigation activities.

To realize this potential, it is necessary and possible to ***launch a self-reinforcing circle of trust worldwide*** between project initiators, who take the risk of allocating private equity to climate-friendly investments; institutional investors, who co-invest and can redirect the pool of private savings; the banking system***,*** which sends signals through interest rates and loan maturity; and governments which can increase the bankability of climate-friendly investments through a wide range of public policies.

End note

[xx] This shock is even higher than the 3.6% GDP fall of the Great Recession in 1932.

[xxi]The category of inactivity is distinct from the category of unemployment. It includes peope who no longer search for a formal job. This group increased by 6.3% in Latin America, 3.3% in Africa and 3.1% in East Asia. https://www.ilo.org/wcmsp5/groups/public/---dgreports/--dcomm/documents/briefingnote/wcms_767028.pdf

[xxii] An interesting comparison is that annual CO2 emissions fell by an average of 4% during the Second World War (1939–45), 3% during the 1991–92 recession, 1% during the 1980–81 energy crisis, and 1% during the 2009 Global Financial Crisis (Boden et al., 2017). The decline in 2020 is significant relative to major historical wars and epidemics (Pongratz et al., 2021).

[xxiii] Air travel is a good indicator of these restrictions. After a 60% drop in air travel in 2020 (https://www.icao.int/Newsroom/Pages/FR/2020-passenger-totals-drop-60-percent-as-COVID19-assault-on-international-mobility-continues.aspx), the European Organisation for the Safety of Air Navigation, Eurocontrol forecasts that the flight numbers will return to the 2019 level only between 2023 and 2024, with worldwide vaccination in 2021, and will stay 8% below that level if global vaccination is achieved in 2022 only: https://www.eurocontrol.int/covid19.

[xxiv] Some studies conducted with models representing a world economy on a balanced growth pathway present the modest incremental investment cost of climate policies as an argument in favour of green packages (Andrijevic, et al. 2020). This argument, grounded on the moderate incremental investment costs of climate friendly options ignores the macroeconomic knock-on potential of reducing infrastructure investment in the context of an economic slump which is of the utmost interest for policy-making. At the macroeconomic level, because of their incremental investment costs, low carbon options will have a higher knock-on effect than conventional infrastructure if they are funded through higher taxes or higher debt but will reduce the volume of infrastructures that can be built within a given investment budget. The assessment by Batini N. et al (2021) of a green spending multiplier about twice as high as that of conventional spending is very recent and requires further examination, but it points out a real potential. Whether the benefits of the additional short-term knock-on effect will outweigh the drawbacks of higher investment costs over the medium and long term will depend on the capacity of innovative climate finance architectures in order to reduce the infrastructure investment gap faster than it could have been done in the present context.

[xxv] The concerned sectors are critical for social inclusion. Building efficiency spending for renovations and retrofits, including improved insulation, heating, and domestic energy storage systems, can rapidly generate extensive employment opportunities, reduce the poor's energy vulnerability, and increase resilience to extreme weather events. Similarly, investments in water management ecosystems' resilience and regeneration, including restoration of carbon-rich habitats and climate-friendly agriculture, will preserve livelihoods, while investment in shovel-ready low emission, resilient infrastructure will protect people, jobs, and assets.

[xxvi] This study does not describe the impact of the general equilibrium effect of such pathways on growth and population welfare through, for example, very high carbon prices. It describes the main elements of the behavioural and technical changes to be induced and its key message is that the degree of 'greenness' of the recovery packages makes a difference of 0.3°C in 2050's average world temperature.

[xxvii] https://www.energypolicytracker.org/region/g20/

[xxviii] https://www.imf.org/external/datamapper/G_XWDG_G01_GDP_PT@FM/ADVEC/FM_EMG/FM_LIDC
[xxix] https://www.unwto.org/international-tourism-and-covid-19
[xxx] https://bassiounigroup.com/smes-driving-growth-in-developing-countries/
[xxxi] Most small businesses in the United States are operating with fewer than 15 days in buffer cash and even healthy SMEs have less than two-month cash reserve. Federal Reserve Bank of New York (2020).
[xxxii]. A 2020 study by the London School of Economics found even more pessimistic results for financially fragile countries (Gambia, Greece, Mongolia, Myanmar, Nicaragua, and Zambia), with four out of five firms at risk of falling into insolvency (https://blogs.lse.ac.uk/businessreview/2020/09/08/firms-in-emerging-markets-fall-to-covid-19/.

[xxxiii] The observed trends suggest an increasing discrepancy amongst the developing countries with a return to positive yields curves of markets assets in East Asia, https://www.bis.org/publ/qtrpdf/r_qt2103.htm

[xxxiv] World Bank LIC DSF database.
[xxxv] Investment trends monitor : https://unctad.org/system/files/official-document/diaeiainf2021d1_en.pdf
[xxxvi] This increase of savings rates results from the fact that the high and upper-middle income households could not access certain forms of leisure consumption (restaurants, travels, cultural events) and that the middle class adopted precautionary savings behaviors. Although data are not consolidated, they show a clear trend. The European Union statistical office Eurostat has shown (own calculations) that the average increase of saving was about 7% over the three first trimesters of 2020 in the EU, representing a 56% increase by comparison with the previous year (https://ec.europa.eu/eurostat/fr/web/products-eurostat-news/-/ddn-20210202-1). In the US, after a peak of +24% in April 2021, the average savings increase was 10% between April and December (still 12% in January 2021) representing a 130% increase compared to 2019https://tradingeconomics.com/united-states/personal-savings

[xxxvii] Government of Saint Lucia; Global Green Growth Institute (2021). Readiness and Preparatory support proposal - Mobilizing international climate finance and private investment for low-carbon development in Saint Lucia.
[xxxviii] https://www.wri/org/profile/michael-westphal
[xxxix] In the context of Covid-19, Westphal and Liu (2020) have argued for a climate-health debt swap programme which would include measures to foster resilience in the climate and health systems and spending that achieves health benefits by reducing air pollution from the burning of fossil fuels. Currently about 4.2 million people die prematurely due to ambient air pollution. Simultaneously addressing climate and health needs is consistent with many countries' NDCs. Westphal and Liu also recommend using climate change trust funds to increase accountability. In the Time of COVID-19, China Could Be Pivotal in Swapping Debt for Climate and Health Action by Michael I. Westphal and Shuang Liu, November 04, 2020
[xl] Climate finance counting towards the $100 billion had been on an upward trajectory, but falls short of the $100 billion per year by 2020 target. Based on the most recent OECD assessment, total climate finance counting towards the $100 billion reached $78.9 billion in 2018 compared to $71.2 billion in 2017. Although the Biennial Assessment of the UNFCCC will only be released in 2021, it will likely reflect similar trends given the commonality of the underlying data
[xli] Any loan or bond will be first recorded as an additional national debt. The question is whether credit rating agencies will judge this debt justified by expected fiscal revenues of induced growth and the built infrastructure's value as collateral thanks to the recognition of new asset classes by capital markets. This is of importance for small and less developed economies with greater reliance on imported techniques and technical and organizational assistance. The creditworthiness risks come indeed less from the absolute level of a public deficit than from the share of debts held by foreigners, from the total public and private debt of the country and the capacity of this country to get foreign currencies for its external payments.
[xlii] A few initiatives are being launched to test innovative standardised assessment approaches within infrastructure platforms: the Global Innovation Lab for Climate Finance (https://www.climatefinancelab.org/), the Fast Infra framework of the World Bank (https://www.climatepolicyinitiative.org/wp-content/uploads/2020/12/FAST-Infra-Conference-Presentation-Slides-Nov-2020.pdf and Terrawatt J.-P. Pham-Ba, A. Legrain (2020), "Well bellow 2cts", Terrawatt Initiative, https://terrawatt.org).
[xliii] A Third Party Expertise could select a value within these bounds and assign to it an uncertainty coefficient in function of the projects' specifics (Hourcade et al., 2012). Public guarantees could be calibrated on a notional value per ton of avoided emissions, retained within the corridors of ***marginal abatement costs trajectories*** considering the scenarios reviewed by the IPCC, interpreted as the value that the international community attaches to a given climate target (Espagne, & Perrissin-Fabert, 2017a, Sirkis et al 2015). One can even envisage to incorporate sustainable development co-benefits via an agreed *'social value of mitigation activities' (SVMA)* per ton of avoided emissions (Hourcade, Shukla, & Cassen, 2015) (Shukla et al. 2015), as recommended by Article 108 of the decision of the Paris Agreement (UNFCCC, 2015). Waisman & al (2019) provides such a value for India for a climate mitigation strategy aligned with sustainable development outcomes like air pollution reduction, energy security, and mobility. A still underworked area is fixing such notional prices for elements other than avoided carbon, which are critical for sustainable development (water, forest, air quality, land, and climate resilience).
[xliv] Jamaica Ministry of Economic Growth and Job Creation (2019) Readiness proposal to the GCF Facilitating an enabling environment for a Caribbean Green Bond Listing on the Jamaica Stock Exchange.

References

Abiad, A., D. Furceri, and P. Topalova. (2014). The Time Is Right for an Infrastructure Push. World Economic Outlook 2014. Washington DC: International Monetary Fund

Acclimatise Building Climate Resilience. (2018). Lenders' guide for considering climate risk in infrastructure investments. Retrieved from https://climatefinanceadvisors.com/wp-content/uploads/2018/01/Investment-Guide_1.8-single-hi-q_17012018.pdf

ADB. (2018). 2018 Asia Development Outlook: https://www.adb.org/publications/asian-development-outlook-2018-how-technology-affects-jobs

ADEME (2014) Understanding the issues around quantifying GHGs emissions in the financial sector, sectorial guide, https://www.associationbilancarbone.fr/wp-content/uploads/2018/05/eng-volume--1.pdf

Adenle, A. A., Ford, J. D., Morton, J., Twomlow, S., Alverson, K., Cattaneo, A., … Ebinger, J. O. (2017). Managing Climate Change Risks in Africa - A Global Perspective. Ecological Economics, 141, 190–201. https://doi.org/10.1016/j.ecolecon.2017.06.004

Allio, C. (2016). Interurban population distribution and commute modes. The Annals of Regional Science, 57(1), 125-144.

Allwood, J., & Cullen, J. (2015). Sustainable materials without the hot air: Making buildings, vehicles and products efficiently and with less new material. Cambridge, UK: Cambridge University Press.

Ameli, N., Drummond, P., Bisaro, A., Grubb, & Chenet. (2019). Climate finance and disclosure for institutional investors: why transparency is not enough. Climatic Change. https://doi.org/10.1007/s10584-019-02542-2

Anas, A., & Xu, R. (1999). Congestion, land use, and job dispersion: A general equilibrium model. Journal of Urban Economics, 45(3), 451-473.

Andersson, M., Bolton, P., & Samama, F. (2016). Hedging Climate Risk (D123 & D4079, Trans.). Financial Analysts Journal, 72(3), 13–32. https://doi.org/10.2469/faj.v72.n3.4

Andrijevic M. ; Schleussner C-F, Gidden M.J. McCollum D., Rogelj J. (2020). COVID-19 recovery funds dwarf clean energy investment needs Science, Vol. 370, Issue 6514, pp. 298-300 DOI: 10.1126/science.abc9697

Ansar, A; Caldecott, B; Tilbury, J. (2013). Stranded assets and the fossil fuel divestment campaign: what does divestment mean for the valuation of fossil fuel assets?

Antràs, P., de Gortari, A., & Itskhoki, O. (2017). Globalization, inequality and welfare. Journal of International Economics, 108, 387–412. https://doi.org/10.1016/j.jinteco.2017.07.009

Arezki, R., Bolton, P., Peters, S., Samama, F., & Stiglitz, J. (2016). From Global Savings Glut to Financing Infrastructure: The Advent of Investment Platforms. IMF Working Papers, 16(18), 1. https://doi.org/10.5089/9781475591835.001

Arezki, R., P. Bolton, S. Peters, F. Samama, J. Stiglitz. (2017). From Global Savings Glut to Financing Infrastructure: The Advent of Investment Platforms. Economic Policy 2017

Arnell, N. W., Lowe, J. A., Challinor, A. J., & Osborn, T. J. (2019). Global and regional impacts of climate change at different levels of global temperature increase. Climatic Change, 155(3), 377-391. https://doi.org/10.1007/s10584-019-02464-z

Auerbach, A. and Y. Gorodnichenko .(2012). Measuring the Output Responses to Fiscal Policy, American Economic Journal: Economic Policy, 4, 1–27

Axelson, M., Robson, I., Khandekar, G., & Wyns, T. (2018). Breaking through-industrial low-CO2 technologies on the horizon. Institute for European Studies, Vrije Universiteit Brussel.

Barde, J. (1994), « Economic Instruments in Environmental Policy: Lessons from the OECD Experience and their Relevance to Developing Economies », *Documents de travail du Centre de développement de l'OCDE*, n° 92, Éditions OCDE, Paris, https://doi.org/10.1787/754416133402.

Barnett, J., & O'Neill, S. (2010). Maladaptation. Global Environmental Change, 20(2), 211–213.

Baron, R., & Fischer, D. (2015). Divestment and Stranded Assets in the Low-carbon Transition. Retrieved from https://www.oecd.org/sd-roundtable/papersandpublications/Divestment%20and%20Stranded%20Assets%20in%20the%20Low-carbon%20Economy%2032nd%20OECD%20RTSD.pdf

Bastidas-Arteaga, E. (2018). Reliability of reinforced concrete structures subjected to corrosion-fatigue and climate change, International journal of concrete structures and materials 12 (1), 1-13

Bataille, C. G. (2020). Physical and policy pathways to net-zero emissions industry. Wiley Interdisciplinary Reviews: Climate Change, 11(2), e633.

Bataille, C., Åhman, M., Neuhoff, K., Nilsson, L. J., Fischedick, M., Lechtenböhmer, S., Sartor, O. (2018). A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. Journal of Cleaner Production, 187, 960-973.

Batini N.; di Serio M.; Fragetta M.; G. ; A. Building Back Better: How Big Are Green Spending Multipliers? (2021). IMF Working Paper No. 2021/087

Battiston, S., Mandel, A., Monasterolo, I., Schutze, F., Visentin, G., Schütze, F., … Visentin, G. (2017). A climate stress-test of the financial system (D5643 & D5984, trans.). Nature Climate Change, 7(4), 283–288. https://doi.org/10.1038/nclimate3255

Bayat-Renoux F; de Coninck H; Glemarec Y; Hourcade JC: Tipping or turning point: Scaling up climate finance in the era of COVID-19 ; Green Climate Fund, Working Paper N°2, OCTOBER 2020 https://www.greenclimate.fund/sites/default/files/document/gcf-working-paper-tipping-or-turning-point-scaling-climate-finance-era-covid-19.pdf

Bazaz, A., Bertoldi, P., Buckeridge, M., Cartwright, A., de Coninck, H., Engelbrecht, F., … Waisman, H. (2018). Summary for Urban Policymakers – What the IPCC Special Report on 1.5C Means for Cities. https://doi.org/10.24943/SCPM.2018

Behrens, K., Lamorgese, A. R., Ottaviano, G. I., & Tabuchi, T. (2007). Changes in transport and non-transport costs: Local vs global impacts in a spatial network. Regional Science and Urban Economics, 37(6), 625-648. https://doi.org/10.1016/J.REGSCIURBECO.2007.08.003

Bellassen V., N. Stephan (eds). 2015. Accounting for carbon. Monitoring, reporting and verifying emissions in the climate economy. Cambridge University Press. 561 p

Bertoldi, P., Rezessy, S., & Oikonomou, V. (2013). Rewarding energy savings rather than energy efficiency: Exploring the concept of a feed-in tariff for energy savings (D305, Trans.). Energy Policy, 56, 526–535. https://doi.org/10.1016/j.enpol.2013.01.019

Blended Finance Taskforce. (2018). Better Finance, Better World. Consultation Paper of the Blended Finance Taskforce, Blended Finance Taskforce Working Paper, https://www.blendedfinance.earth/better-finance-better-world

Bhattacharya A; Calland R (Co-Chairs); A. Averchenkova, L. Gonzalez, L. Martinez-Diaz, J. Van Rooij. (2020) Delivering On The $100 Billion Climate Finance Commitment And Transforming Climate Finance, The Independent Expert Group On Climate Finance Report https://www.un.org/sites/un2.un.org/files/100_billion_climate_finance_report.pdf

Bhattacharya, A., J. Oppenheim, and N. Stern. (2015). Driving Sustainable Development through Better Infrastructure: Key Elements of a Transformation Program. Global Economy and Development Working Paper No. 91. Washington DC:

Bhattacharya, A., J.P. Meltzer, J. Oppenheim, Z. Qureshi, N. Stern. 2016. Delivering on Sustainable Infrastructure for Better Development and Better Climate. Washington DC: Brookings Institution, The New Climate Economy, Grantham Research Institute on Climate Change and Environment.

Black, A., & Fraser, P. (2002). Stock market short-termism—an international perspective. Journal of Multinational Financial Management, 12(2), 135–158. https://doi.org/10.1016/S1042-444X(01)00044-5

Blanchard, O. (2019). Public debt and low interest rates. American Economic Review, 109(4), 1197–1229.

Blanchard, O., and Leigh, D. (2013). Growth Forecast Errors and Fiscal Multipliers, IMF Working Papers, 2013(1).

Boden, T.A., Marland, G; and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2 Emissions, Oak Ridge, Tenn., USA

Bolton P., Després M., L.A., Samama F., Svartzman R. (2020). The Green Swan: Central banking and financial stability in the age of climate change, BIS, Banque de France

Bolton P., Musca X, Samama F. (2020): Global Public-Private Investment Partnerships: A Financing Innovation with Positive Social Impact, Journal of Applied Corporate Finance; https://doi.org/10.1111/jacf.12403

Borio, C. (2014). The financial cycle and macroeconomics: What have we learnt? Journal of Banking and Finance, 45(1), 182–198. https://doi.org/10.1016/j.jbankfin.2013.07.031

Borio, C., Drehmann M., Xia D. (2018). The financial cycle and recession risk, BIS Quarterly Review, December, pp 59–71.

Bowen, A., Emanuele, C., & Tavoni, M. (2014). A macroeconomic perspective climate change and mitigation: meeting the finance challenge. Climate Change Economics, 05(01), 1440005. https://doi.org/10.1142/S2010007814400053

Boyd, E., James, R. A., Jones, R. G., Young, H. R., & Otto, F. E. L. (2017). A typology of loss and damage perspectives. Nature Climate Change, 7(10), 723–729. https://doi.org/10.1038/nclimate3389

BP. (2019). BP statistical review of world energy, 68th Edition. Retrieved from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs /energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

Branger F., Quirion P. (2015). Reaping the carbon rent: Abatement and overallocation profits in the European cement industry, insights from an LMDI decomposition analysis Energy Economics 47 (2015) 189–205

Buhr B., Donovan C, Kling G., Lo Y., Murinde V., Pullin N., Volz U. (2018) Climate Change and the Cost of Capital in Developing Countries Assessing the impact of climate risks on sovereign borrowing cost; Unep, Imperial College, University of London, https://eprints.soas.ac.uk/26038/1/ClimateCostofCapital_FullReport_Final.pdf

Bui, M., Adjiman, C. S., Bardow, A., Anthony, E. J., Boston, A., Brown, S., Mac Dowell, N. (2018). Carbon capture and storage (CCS): the way forward. Energy & Environmental Science, 11(5), 1062–1176. https://doi.org/10.1039/C7EE02342A

Bulow J., Reinhart C., Rogoff K., Trebesch C. (2021). The Debt Pandemic, Finance and Development, Report https://www.imf.org/external/pubs/ft/fandd/2020/09/pdf/debt-pandemic-reinhart-rogoff-bulow-trebesch.pdf

Bushee, B. J. (2001). Do Institutional Investors Prefer Near-Term Earnings over Long-Run Value? Contemporary Accounting Research, 18(2), 207–246. https://doi.org/10.1506/J4GU-BHWH-8HME-LE0X

Butler, J. R. A., Suadnya, W., Puspadi, K., Sutaryono, Y., Wise, R. M., Skewes, T. D., Ash, A. (2014). Framing the application of adaptation pathways for rural livelihoods and global change in eastern Indonesian islands. Global Environmental Change, 28, 368–382. https://doi.org/10.1016/j.gloenvcha.2013.12.004

Butler, L., & Neuhoff, K. (2008). Comparison of feed-in tariff, quota and auction mechanisms to support wind power development. Renewable Energy, 33(8), 1854–1867.

Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy (D521 & D5504, Trans.). Ecological Economics, 121, 220–230. https://doi.org/10.1016/j.ecolecon.2015.03.020

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. Nature Climate Change, 8(6), 462–468. https://doi.org/10.1038/s41558-018-0175-0

Carbon Tracker Initiative. (2018). Mind the gap: the $1.6 trillion energy transition risk. London: Carbon Tracker Initiative.

Carney Mark (2020) How the economy must yield to human values, The Economist April 18, 2020, https://www.economist.com/by-invitation/2020/04/16/mark-carney-on-how-the-economy-must-yield-to-human-values

Carney, M. (2015). Breaking the tragedy of the horizon – climate change and financial stability. Speech. https://www.bis.org/review/r151009a.pdf

Chen, P., Karabarbounis L., Neiman B. (2017). The global rise of corporate saving, Journal of Monetary Economics, 89, 1–19.

Cheung, W. W. L., Reygondeau, G., & Frölicher, T. L. (2016). Large benefits to marine fisheries of meeting the 1.5°C global warming target. Science, 354(6319), 1591–1594. https://doi.org/10.1126/science.aag2331

Chiroleu-Assouline M. & M. Fodha (2014). From Regressive Pollution Taxes to Progressive Environmental Tax Reforms, European Economic Review, 69, pp. 126-142.

Choi, K. W., & Sjoquist, D. L. (2015). Economic and spatial effects of land value taxation in an urban area: an urban computable general equilibrium approach. Land Economics, 91(3), 536-555.

Christophers, B. (2017). Climate Change and Financial Instability: Risk Disclosure and the Problematics of Neoliberal Governance. Annals of the American Association of Geographers, 107(5), 1108–1127. https://doi.org/10.1080/24694452.2017.1293502

Climate Action Tracker. (2020). Paris Agreement turning point. https://climateactiontracker.org/documents/829/CAT_2020-12-01_Briefing_GlobalUpdate_Paris5Years_Dec2020.pdf

Climate Bonds Initiative. (2020). 2019 Green Bond Market Summary. In Market Summary. Retrieved from https://www.climatebonds.net/resources/reports/2019-green-bond-market-summary

Climate Disclosures Standards Board (2020). Falling Short? Why environmental and climate-related disclosures under the EU Non-Financial Reporting Directive must improve. https://www.cdsb.net/falling-short; https://www.eco-business.com/press-releases/78-of-europes-largest-companies-falling-short-of-adequately-reporting-environmental-and-climate-related-risks-despite-eu-guidelines/

Coady, D., Parry, I., Le, N.-P., & Shang, B. (2019). Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates. IMF Working Papers, 19(89), 1. https://doi.org/10.5089/9781484393178.001

Combet, E., Ghersi, F., Hourcade, J.-C., & Thubin, C. (2010). La fiscalité carbone au risque des enjeux d'équité. Revue Française d'économie, 25(2), 59–91. https://doi.org/10.3406/rfeco.2010.1805

Cooke K. et al. (2018), Overcoming the NDC implementation gap, lessons from experience, Oxford Policy Management Policy Brief. https://www.opml.co.uk/publications/overcoming-ndc-implementation-gap

CPI. (2019). The global landscape of climate finance 2019. Retrieved from https://climatepolicyinitiative.org/publication/global-climate-finance-2019

Creutzig, F., Breyer, C., Hilaire, J., Minx, J., Peters, G. P., & Socolow, R. (2019). The mutual dependence of negative emission technologies and energy systems. Energy & Environmental Science, 12(6), 1805-1817.https://doi.org/10.1039/c8ee03682a

Dasgupta D, Hourcade J.C., Nafo S, (2019) A Climate Finance Initiative to achieve the Paris Agreement and strengthen sustainable development, Report for the Minister of Ecological and Solidarity Transition, Paris 2018, https://hal.archives-ouvertes.fr/hal-02121231/document de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A., Dong, W., … Wollenberg, L. (2018). Strengthening and implementing the global response. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla … T. Waterfield (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (pp. 313-443). Geneva: IPCC.

de Gouvello, C., & Zelenko, I. (2010). A Financing Facility for Low-Carbon Development in Developing Countries. https://doi.org/10.1596/978-0-8213-8521-0

de Haan, P., Mueller, M. G., & Scholz, R. W. (2009). How much do incentives affect car purchase? Agent-based microsimulation of consumer choice of new cars – Part II: Forecasting effects of feebates based on energy-efficiency (D817, Trans.). Energy Policy, 37(3), 1083–1094. https://doi.org/10.1016/j.enpol.2008.11.003

De Loecker, J., Goldberg, P. K., Khandelwal, A. K., & Pavcnik, N. (2016). Prices, Markups, and Trade Reform. Econometrica, 84(2), 445–510. https://doi.org/10.3982/ECTA11042

de Ruig, L. T., Barnard, P. L., Botzen, W. W., Grifman, P., Hart, J. F., de Moel, H., ... & Aerts, J. C. (2019). An economic evaluation of adaptation pathways in coastal mega cities: An illustration for Los Angeles. *Science of the Total Environment*, *678*, 647-659.

Déau, T., J. Touati. 2017. *Financing Sustainable Infrastructure. Coping with the Climate Crisis Mitigation Policies and Global Coordination*, R. Arezki, P. Bolton, K. El Aynaoui, and M. Obstfeld, Eds., Columbia University Press, New York, NY, USA, 167–178

Dechezleprêtre, A., Sato, M. (2018). Inclusive solutions for the green transition. Paper presented at the GGSD Forum and GGKP6 Annual conference. OECD, Paris.

Demary M., Hasenclever S., Hüther M. (2021). Why the COVID-19 Pandemic Could Increase the Corporate Saving Trend in the Long Run, Intereconomics, Volume 56, Number 1, pp. 40–44, https://www.intereconomics.eu/contents/year/2021/number/1/article/why-the-covid-19-pandemic-could-increase-the-corporate-saving-trend-in-the-long-run.html

Denning, L. (2019). Energy's Dumb Money May Be Wising Up. Retrieved from Bloomberg Opinion website: https://www.bloomberg.com/opinion/articles/2019-08-13/energy-stocks-the-dumb-money-may-be-wising-up

Desquilbet M., Dorin B., Couvet D. (2017). Land Sharing vs Land Sparing to Conserve Biodiversity: How Agricultural Markets Make the Difference. Environmental Modeling & Assessment, vol. 22, n° 3, pp. 185-200.

Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. Proceedings of the National Academy of Sciences of the United States of America, 116(20), 9808–9813. https://doi.org/10.1073/pnas.1816020116

Dikau, S., & Volz, U. (2018). ADBI Working Paper Series CENTRAL BANKING, CLIMATE CHANGE AND GREEN FINANCE. (867). Retrieved from https://www.adb.org/publications/central-banking-climate-change-and-green-

Dimitropoulos A., Oueslati W, Sintek C (2018).: The rebound effect in road transport: A meta-analysis of empirical studies☆; Energy Economics Volume 75, September 2018, Pages 163-179, https://doi.org/10.1016/j.eneco.2018.07.021

Djalante, R., Mechler, R., Ley, D., & Pinho, P. (2018). Cross-Chapter Box 12: Residual risks, limits to adaptation and loss and damage. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla … T. Waterfield (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (pp. 454-456). Geneva: IPCC.

DNB (2017): Waterproof? An exploration of climate related risks for the Dutch financial sector Amsterdam https://www.dnb.nl/en/binaries/waterproof_tcm47-363851.pdf

Donaldson D. (2018) Railroads of the Raj: Estimating the impact, American Economic Review, Volume 108, 899-934.

Donaldson D. Hornbeck R. (2016) Railroads and American Economic Growth: a market access approach, Quaterly Journal of Economics, volume 131 (issue 2) pp 799-858, May 2016

Donnelly, C., Greuell, W., Andersson, J., Gerten, D., Pisacane, G., Roudier, P., & Ludwig, F. (2017). Impacts of climate change on European hydrology at 1.5, 2 and 3 degrees mean global warming above preindustrial level. Climatic Change, 143(1–2), 13–26. https://doi.org/10.1007/s10584-017-1971-7

Donner, S. D., Kandlikar, M., & Webber, S. (2016). Measuring and tracking the flow of climate change adaptation aid to the developing world. Environmental Research Letters, 11(5), 054006. https://doi.org/10.1088/1748-9326/11/5/054006

Dooley, J. J. (2013). Estimating the supply and demand for deep geologic CO2 storage capacity over the course of the 21st century: a meta-analysis of the literature. Energy Procedia, 37, 5141-5150.https://doi.org/10.1016/j.egypro.2013.06.429

D'Orazio, P & Popoyan L. (2019). Fostering green investments and tackling climate-related financial risks: Which role for macroprudential policies? Ecological Economics, 2019, vol. 160, issue C, 25-37

Dorin B., Joly P.-B. (2020). Modelling world agriculture as a learning machine? From mainstream models to Agribiom 1.0. Land Use Policy, vol. 96, n° July, pp. 103624.

Dosio, A., & Fischer, E. M. (2018). Will half a degree make a difference? Robust projections of indices of mean and extreme climate in Europe under 1.5°c, 2°c, and 3°c global warming. Geophysical Research Letters, 45(2), 935–944. https://doi.org/10.1002/2017GL076222

Eccles, R. G., & Klimenko, S. (2019). The investor revolution. Harvard Business Review, 2019(May-June), 106–116. Retrieved from https://hbr.org/2019/05/the-investor-revolution

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Kadner, S., Minx, J. C., Brunner, S., … Zwickel, T. (2014). Technical Summary. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, … J. C. Minx (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 33–107). Cambridge, UK: Cambridge University Press.

Emin, G., Lepetit, M., Grandjean, A., & Ortega, O. (2014). Massive financing of the energy transition. SFTE feasibility study: synthesis report. Energy renovation of public buildings (R. D974, trans.). Retrieved from Association for the Financing of the EneRgy Transition (A.F.T.E.R) website: http://projet-sfte.fr/wp-content/uploads/2015/02/20141118_SFTE_Synthesis_Report.pdf

Energy Transitions Commission. (2018). Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century. Energy Transitions Commission.

ESMAP (2020) Energy Sector Management Assistance Program (ESMAP) Annual Report 2020; https://www.esmap.org/energy-sector-management-assistance-program-%28esmap%29-annual-

Espagne, E. (2018). Money, Finance and Climate: The Elusive Quest for a Truly Integrated Assessment Model. Comparative Economic Studies, 60(1), 131–143. https://doi.org/10.1057/s41294-018-0055-7

EU. (2020). Taxonomy: Final report of the Technical Expert Group on Sustainable Finance.

Fama, E. (1970). "Efficient Capital Markets: A Review of Theory and Empirical Work". *Journal of Finance*. **25** (2): 383–417. doi:10.2307/2325486. JSTOR 2325486.

Fankhauser, S., & McDermott, T. K. J. (2014). Understanding the adaptation deficit: Why are poor countries more vulnerable to climate events than rich countries? (D1025, trans.). Global Environmental Change, 27(1), 9–18. https://doi.org/10.1016/j.gloenvcha.2014.04.014

Fazey, I., Wise, R. M., Lyon, C., Câmpeanu, C., Moug, P., & Davies, T. E. (2016). Past and future adaptation pathways. Climate and Development, 8(1), 26–44. https://doi.org/10.1080/17565529.2014.989192

Fisch-Romito, V., & Guivarch, C. (2019). Transportation infrastructures in a low carbon world: An evaluation of investment needs and their determinants. Transportation Research Part D: Transport and Environment, 72, 203–219. https://doi.org/10.1016/J.TRD.2019.04.014

Forster P.M.; Forster H.I., Evans M.J., Gidden M.J., Jones C.D. Keller C.A., Lamboll R.D. Le Quéré C., Rogelj J., Rosen D., Schleussner C-F, Richardson T.B., Smith C.J. Turnock S. T. (2020) Current and future global climate impacts resulting from COVID-19, Nature Climate Change 10, 913–919 (2020), https://doi.org/10.1038/s41558-020-0883-0

Freshfields Bruckhaus Deringer. (2005). A legal framework for the integration of environmental, social and governance issues into institutional investment. Retrieved from https://www.unepfi.org/fileadmin/documents/freshfields_legal_resp_20051123.pdf

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Olsen, A., … Zaehle, S. (2020). Global Carbon Budget 2020. Earth System Science Data, 12(4), 3269–3340. https://doi.org/10.5194/essd-12-3269-2020

Froud, J., C. Haslam, S. Johal, K. Williams. 2000. *Shareholder value and Financialization: consultancy promises, management moves*. Economy and Society, 29, 80–110, doi:10.1080/030851400360578.

FSB. (2020). Global Monitoring Report on Non-Bank Financial Intermediation

Fuss, S., Lamb, W. F., Callaghan, M. W., Hilaire, J., Creutzig, F., Amann, T., ... & Luderer, G. (2018). Negative emissions—Part 2: Costs, potentials and side effects. Environmental Research Letters, 13(6), 063002. https://doi.org/10.1088/1748-9326/aabf9f

Gajjar, S. P., Singh, C., & Deshpande, T. (2019). Tracing back to move ahead: A review of development pathways that constrain adaptation futures. Climate and Development, 11(3), 223–237. https://doi.org/10.1080/17565529.2018.1442793.

Galbraith, J. 1967. *The New Industrial State*. Houghton Mifflin, 576 pp.

Gallagher, K., Ocampo, A., Volz U. (2020). IMF Special Drawing Rights: A key tool for attacking a COVID-19 financial fallout in developing countries, Future Development Blog https://www.brookings.edu/blog/future-development/2020/03/26/imf-special-drawing-rights-a-key-tool-for-attacking-a-covid-19-financial-fallout-in-developing-countries/

García-Álvarez, M. T., Cabeza-García, L., & Soares, I. (2017). Analysis of the promotion of onshore wind energy in the EU: Feed-in tariff or renewable portfolio standard? (D1187, Trans.). Renewable Energy, 111, 256–264. https://doi.org/10.1016/j.renene.2017.03.067

Garschagen, M., & Solecki, W. (2017). Editorial — Tipping points in adaptive capacity and adaptation processes. Journal of Extreme Events, 04(01), 1702002. https://doi.org/10.1142/S234573761702002X

Gaya, R., & Campos, R. (2009). The transportTransport and trade infrastructure growth gapTrade Infrastructure Growth Gap in Latin America.

Gechert, S., and A. Rannenberg (2018), 'Which Fiscal Multipliers Are Regime-Dependent? A MetaRegression Analysis,' Journal of Economic Surveys, 32(4), 1160–1182

Gertler, M., & Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In Handbook of Monetary Economics.

Gilmore EA, St. Clair T Budgeting for climate change: Obstacles and opportunities at the US state level, Climate policy 18 (6), 729-741

Girgis, M., & Barker, S. (2015). Institutional investment, corporate governance and climate change: What is a trustee to do? Retrieved from https://www.minterellison.com/articles/institutional-investment-corporate-governance-and-climate-change-what-is-a-trustee-to-do

Global Commission on the Economy and Climate. (2014). Better growth, better climate: The New Climate Economy Report. Retrieved from https://newclimateeconomy.report/2016/wp-content/uploads/sites/2/2014/08/ BetterGrowth-BetterClimate_NCE_Synthesis-Report_web.pdf

Global Infrastructure Hub. (2017). Global Infrastructure Outlook: Infrastructure investment needs 50 countries, 7 sectors to 2040. Sydney. Retrieved from https://cdn.gihub.org/outlook/live/methodology/Global+Infrastructure+Outlook+-+July+2017.pdf

Goldberg, P. K., & Knetter, M. M. (1997). Goods Prices and Exchange Rates: What Have We Learned? Journal of Economic Literature, 35(3), 1243–1272.

Goulder, L. H. (1995). Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis (D4764, trans.). Journal of Environmental Economics and Management, 29(3), 271–297. https://doi.org/10.1006/jeem.1995.1047

Gouvello (de), C., I. Zelenko, 2010: A Financing Facility for Low-Carbon Development in Developing Countries. The World Bank Working Paper, doi: 10.1596/978-0-8213-8521-0

Gropp, R., C. Gruendl, A. Guettler. 2013. The impact of public guarantees on bank risk-taking: evidence from a natural experiment, Review of Finance, 18, 457–88.

Gross, R., W. Blyth, P. Heptonstall, 2010: *Risks, revenues and investment in electricity generation: Why policy needs to look beyond costs*. Energy Economics, 32, 796–804, doi:10.1016/j.eneco.2009.09.017.

Grubb M, Hourcade J.C., Neuhoff K. (2014). Planetary Economics: energy, climate change and the three domains of sustainable development, Earthcan 2014

Grubler, A., et al. 2018. A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. Nature Energy, 3, 515–527, doi:10.1038/s41560-018-0172-6. https://doi.org/10.1038/s41560-018-0172-6.

Guivarch, C., & Hallegatte, S. (2011). Existing infrastructure and the 2°C target. Climatic Change, 109(3–4), 801–805. https://doi.org/10.1007/s10584-011-0268-5

Ha-Duong M., Grubb M; Hourcade J.C. (1998) "Influence of inertia and uncertainty on optimal CO2-emission abatement". Nature, 390 :270-3.

Haasnoot, M, Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change, 23(2), 485–498. https://doi.org/10.1016/j.gloenvcha.2012.12.006

Haasnoot, M., Brown, S., Scussolini, P., Jimenez, J. A., Vafeidis, A. T., & Nicholls, R. J. (2019). Generic adaptation pathways for coastal archetypes under uncertain sea-level rise, Environmental Research Letters, 1(7), 071006. https://doi.org/10.1088/2515-7620/ab1871

Haasnoot, M., van Aalst, M., Rozenberg, J., Dominique, K., Matthews, J., Bouwer, L. M., ... & Poff, N. L. (2019). Investments under non-stationarity: economic evaluation of adaptation pathways. *Climatic Change*, 1-13.

Hall S., Foxon T.J.,Bolton R. (2017) Investing in lowcarbon transitions: energy finance as an adaptive market, Climate Policy, 17:3, 280-298, DOI: 10.1080/14693062.2015.1094731

Hallegatte S.; Hourcade J.-C.; Dumas P., "(2007), Why economic dynamics matter in assessing climate change damages: illustration on extreme events", *Ecological Economics*, volume 62, issue 2, 20 April 2007, pp. 330-340.

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., … Vogt-Schilb, A. (2015). Shock Waves: Managing the Impacts of Climate Change on Poverty (R. D1357, trans.). https://doi.org/10.1596/978-1-4648-0673-5

Hallegatte, S., Rentschler, J., & Rozenberg, J. (2019). Lifelines: The resilient infrastructure opportunity. Washington, DC: World Bank.

Hanssen, S.V., Daioglou, V., Steinmann, Z.J.N. et al. (2020). The climate change mitigation potential of bioenergy with carbon capture and storage. *Nat. Clim. Chang.* 10**,** 1023–1029: https://doi.org/10.1038/s41558-020-0885-y

Haoqi, Q., Libo, W., & Weiqi, T. (2017). “Lock-in” effect of emission standard and its impact on the choice of market-based instruments (D1393, Trans.). Energy Economics, 63, 41–50. https://doi.org/10.1016/j.eneco.2017.01.005

Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D. (2020), et al (2020). Will COVIDCOvid-19 fiscal recovery packages accelerate or retard progress on climate change? Smith School Working Paper 20-02. Oxford Review of Economic Policy, Volume 36. Number S1.pp. 359-381.

Hirth, l., J.C. Steckel. 2016. The Role of Capital Costs in Decarbonizing the Electricity Sector. Environmental Research Letters 11 (11): 114010. doi:10.1088/1748-9326/11/11/114010.

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., Zhou, G. (2018). Impacts of 1.5oC global warming on natural and human systems. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, T. Waterfield (Eds.), Global Warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change (pp. 175-311). Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC).

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Guillén Bolaños, T., Bindi, M., Brown, S., … Zhou, G. (2019). The human imperative of stabilizing global climate change at 1.5°C. Science, 365(6459), eaaw6974. https://doi.org/10.1126/science.aaw6974

Holmstrom, B. (1979). Moral Hazard and Observability. The Bell Journal of Economics, 10(1), 74. https://doi.org/10.2307/3003320

Holtsmark, B., Weitzman, M. L. (2020). On the Effects of Linking Cap-and-Trade Systems for CO2 Emissions. Environmental and Resource Economics, 75(3), 615-630

Honohan, P. (2019). Currency, Credit and Crisis. https://doi.org/10.1017/9781108680325

Hourcade J. C., B. Perrissin Fabert B, J. Rozenberg. Venturing into uncharted financial waters: an essay on climate-friendly finance, International environmental agreements: politics, law, and economics, (2012) 12, 165–186, doi:10.1007/s10784-012-9169-y

Hourcade J.-C., Shukla P.R., 2013. Triggering the low-carbon transition in the aftermath of the global financial crisis, Climate Policy : Supplement 1 : Low Carbon Drivers for a Sustainable World, Volume 13, 2013 : pages 22-35.

Hourcade J.C., Shukla P., La Rovere E, Dahr S., Espagne E., Finon D, Pereira A., Pottier A. (2017) How to use SVMAs to reduce the Carbon Pricing and Climate Finance Gap: numerical illustrations WP CIRED N° 2017-61, Background Paper of the High Level Commission on Carbon Prices (Stern-Stiglitz), https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices

Hourcade J.C., Dasgupta D., Ghersi F. (2021) Accelerating the speed and scale of climate finance in the post-Covid context, to be published in Climate Policy

Hsiang, S. M., & Jina, A. S. (2014). The causal effect of environmental catastrophe on long-run economic growth: evidence from 6,700 cyclones.

Hurlbert, M., Krishnaswamy, J., Davin, E. L., Johnson, F. X., Mena, C. F., Morton, J., … Zommers, Z. (2019). Risk management and decision making in relation to sustainable development. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, ... J. Malley, (Eds.), Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (pp. 673-800). Geneva: IPCC.

ICMA (2018): Sustainability Bonds Guidelines (SBG), International Capital Markets Association https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/sustainability-bond-guidelines-sbg/

IEA. (2017). Energy technology perspectives 2017: Catalysing energy technology transformations. Paris: IEA. Retrieved from https://www.iea.org/reports/energy-technology-perspectives-2017

IEA. (2019). Material efficiency in clean energy transitions. Retrieved from https://www.iea.org/reports/material-efficiency-in-clean-energy-transitions

IEA (2020) World Energy Outlook, Paris IEA retrieved from https://www.iea.org/reports/world-energy-outlook-2020

IFC. (2016). Climate investment opportunities in emerging markets: An IFC analysis. Washington, D.C.: IFC.

IIF (2020), Capital Flows Report – Sudden Stop in Emerging Markets.

ILO (2020): ILO Monitor 2nd edition: Covid-19 and the world of work.

ILOSTAT (2019). Employment distribution by economic activity. Geneva, International Labour Organization.

IMF (2021): IMF Executive Directors Discuss a New SDR Allocation of US$650 billion to Boost Reserves, Help Global Recovery from COVID-19 March 23, 2021, https://www.imf.org/en/News/Articles/2021/03/23/pr2177-imf-execdir-discuss-new-sdr-allocation-us-650b-boost-reserves-help-global-recovery-covid19

IMF. (2020) World Economic Outlook, October, 2020

IMF. (2014a). World Economic Outlook October 2014: Legacies, Clouds, Uncertainties (R. D1581, trans.). Retrieved from International Monetary Fund (IMF) website: https://www.imf.org/en/Publications/WEO/Issues/2016/12/31/World-Economic-Outlook-October-2014-Legacies-Clouds-Uncertainties-41632

IMF. (2014b). Is it Time for an Infrastructure Push? The Macroeconomic Effects of Public Investment, World Economic Outlook, October 2014: Legacies, Clouds, Uncertainties. Washington DC: International Monetary Fund, doi:10.5089/9781498331555.081

IMF (2020) World Economic Outlook 2020

IPCC. (2001). Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Integovernmental Panel on Climate Change (R. Watson, ed.). Cambridge University Press.

IPCC. (2014). Climate Change 2014: Mitigation of Climate Change. Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

IPCC. (2018). Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: IPCC.

IPCC. (2019a). IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Geneva: IPCC.

IPCC. (2019b). Summary for Policymakers. In P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, … J. Malley (Eds.), Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Geneva: IPCC.

IPCC. (2019c). IPCC Special report on the ocean and cryosphere in a changing climate. Retrieved from https://www.ipcc.ch/srocc/

IRENA. (2020). Tracking SDG 7: The energy progress report 2020. Retrieved from https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020Retrieved from https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020

ITC: (2020) SME Competitiveness Outlook: Covid-19: The great lockdown and its impact on small businesses, International Trade Center (2020)

ITF. (2017). ITF transport outlook 2017. Retrieved from https://doi.org/10.1787/9789282108000-en

Iyer, G., Clarke, L., Edmonds, J. et al. Improved representation of investment decisions in assessments of CO2 mitigation. Nature Climate Change 5, 436–440 (2015). https://doi.org/10.1038/nclimate2553

Jaccard, M. (2012). The political acceptability of carbon taxes: Lessons from british columbia. Handbook of Research on Environmental Taxation, 175–191. https://doi.org/10.4337/9781781952146.00019

Jacobs J., M. Culp M. Cattaneo L. Chinowsky P., Choate A., DesRoches S., Douglass S & Miller R (2018) Transportation in in Impacts, Risks and Adaptation in the United-States: Fourth National Climate Assessment, Volume II, Reimiller D.R., Avery C.W., Easterling, D.R., Kunkel K.E., Lewis K.L.M., Maycock T.K. & Stewart B.C. (eds) Washington D.C. U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH10

Jakob, M., Chen, C., Fuss, S., Marxen, A., Rao, N. D., & Edenhofer, O. (2016). Carbon Pricing Revenues Could Close Infrastructure Access Gaps. World Development, 84, 254–265. https://doi.org/10.1016/J.WORLDDEV.2016.03.001https://doi.org/10.1016/J.WORLDDEV.2016.03.001

Jordà, O., Schularick & Taylor A.M. (2017): Macrofinancial History and the New Business Cycles Facts. NBER Macroecon. Annu, 31, 213-263, https://doi.org/10.1086/690241

Jordà, O., Schularick, Taylor A.M & Ward (2019): Global Financial Cycles and Risks Premiums; IMF Economic Review, 67, 109-150, https://doi.org/10.1057/s41308-019-00077-1

Kahouli-Brahmi S (2009) Testing for the presence of some features in increasing returns to adoption factors in energy systems dynamics: an analysis via the learning curve approach' Ecological Economics 68 (4): 1195-212

Kearns, J., Teletzke, G., Palmer, J., Thomann, H., Kheshgi, H., Chen, Y.-H. H., … Herzog, H. (2017). Developing a consistent database for regional geologic CO2 storage capacity worldwide. Energy Procedia, 114, 4697–4709. https://doi.org/https://doi.org/10.1016/j.egypro.2017.03.1603

Keenan J.M. & Bradt J.T. (2020) Underwaterwriting: From Theory to Empiricism in Regional, S. Coastal Mortgage Markets Climatic Change doi: 10.1007/s10584-020-02734-1

Keith, D. W., Holmes, G., St. Angelo, D., & Heidel, K. (2018). A process for Capturing CO2 from the Atmosphere. Joule, 2(8), 1573-1594. https://doi.org/10.1016/j.joule.2018.05.006

Kennedy, C., & Corfee-Morlot, J. (2013). Past performance and future needs for low carbon climate resilient infrastructure– An investment perspective. Energy Policy, 59, 773–783. https://doi.org/10.1016/J.ENPOL.2013.04.031

Kirtman, B., Power, S. B., Adedoyin, J. A., Boer, G. J., Bojariu, R., Camilloni, I., … Wang, H.-J. (2013). Near-term climate change: Projections and predictability. In T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, … P. M. Midgley (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 953–1028). Cambridge, UK: Cambridge University Press.

Klein, R. J. T., Midgley, G. F., Preston, B. L., Alam, M., Berkhout, F. G. H., Dow, K., & Shaw, M. R. (2014). Adaptation opportunities, constraints, and limits. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, … L. L. White (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change (pp. 899–943). Cambridge, UK: Cambridge University Press.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. Nature Climate Change, 8(8), 669–677. https://doi.org/10.1038/s41558-018-0201-2

Koide, H., Tazaki, Y., Noguchi, Y., Iijima, M., Ito, K., & Shindo, Y. (1993). Underground storage of carbon dioxide in depleted natural gas reservoirs and in useless aquifers. Engineering Geology, 34(3–4), 175–179. https://doi.org/10.1016/0013-7952(93)90086-R

Koutroulis, A. G., Papadimitriou, L. V., Grillakis, M. G., Tsanis, I. K., Warren, R., & Betts, R. A. (2019). Global water availability under high-end climate change: A vulnerability-based assessment. Global and Planetary Change, 175, 52–63. https://doi.org/10.1016/j.gloplacha.2019.01.013

Krogstrup, S., & Oman, W. (2019). Macroeconomic and Financial Policies for Climate Change Mitigation: A Review of the Literature.

Krugman, P. (2014). Four Observations on Secular Stagnation. In C. Teulings & R. Baldwin (Eds.), Secular Stagnation: Facts, causes and Cures. CEPR Press.

L'Orange Seigo, S., Dohle, S., & Siegrist, M. (2014). Public perception of carbon capture and storage (CCS): A review. Renewable and Sustainable Energy Reviews, 38, 848–863. https://doi.org/10.1016/j.rser.2014.07.017

Lampin, L. B. A., Nadaud, F., Grazi, F., & Hourcade, J.-C. (2013). Long-term fuel demand: Not only a matter of fuel price. Energy Policy, 62, 780–787. https://doi.org/10.1016/J.ENPOL.2013.05.021

Launay V. (2016). Pricing partially guaranteed bonds: valuation of bonds benefiting from a World Bank partial guarantee, Financial Solutions Occasional Paper 0001/16, World Bank, Washington DC.

Lawrence, J., & Haasnoot, M. (2017). What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty. Environmental Science & Policy, 68, 47–57. https://doi.org/10.1016/j.envsci.2016.12.003https://doi.org/10.1016/j.envsci.2016.12.003

Lawrence, J., Blackett, P., & Cradock-Henry, N. A. (2020). Cascading climate change impacts and implications. Climate Risk Management, *29*, 100234.

Le Quéré, C., Andrew, R. M., Friedlingstein, P., Sitch, S., Pongratz, J., Manning, A. C., Korsbakken, J. I. Peters, G. P., Canadell, J. G., Jackson, R. B., Boden, T. A., Tans, P. P., Andrews, O. D., Arora, V. K., Bakker, D. C. E., Barbero, L., Becker, M., Betts, R. A., Bopp, L., … Zhu, D. (2018). Global Carbon Budget 2017. Earth System Science Data, 10(1), 405–448. https://doi.org/10.5194/essd-10-405-2018

Leduc, S., & Wilson, D. (2017). Are state governments roadblocks to federal stimulus? Evidence on the flypaper effect of highway grants in the 2009 recovery Act. American Economic Journal: Economic Policy, 9(2), 253–292. https://doi.org/10.1257/pol.20140371

Lee C, Betru A, Horrocks P. (2018) Guaranteeing the Goals: Adapting Public Sector Guarantees to Unlock Blended Financing for the U.N. Sustainable Development Goals Milken Institute and the OECD https://milkeninstitute.org/sites/default/files/reports-pdf/Guaranteeing-the-Goals-FINAL-4.pdf

Lefèvre J., Wills W, Hourcade J.C. (2019). Combining low-carbon economic development and oil exploration in Brazil? An energy–economy assessment Climate policy 18 (10), 1286-1295

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., & Schellnhuber H. J. (2019). Climate tipping points — too risky to bet against. Nature, 575(7784), 592-595. doi:10.1038/d41586-019-03595-0.

Liban, B. du. (2010). Intermediate Circular on Reserve Requirements. Intermediate Circular No. 236. https://doi.org/10.1017/CBO9781107415324.004

Litterman, B. (2020). Managing Climate Risk in the U.S. Financial System, Report of the Climate-Related Subcommittee Market Risk Advisory Committee of the U.S. Commodity Futures Trading Commission, Report number: ISBN: 978-0-578-74841-2

Lucas, R. (1990). Why doesn't Capital Flow from Rich to Poor Countries? American Economic Review. 80 (2): 92–96.

Lucas, R. (1972). Expectations and the Neutrality of Money. Journal of Economic Theory, 4(2): 103–124

Lundsgaarde, E. (2017) : The European Fund for Sustainable Development: changing the game?, Discussion Paper, No. 29/2017, ISBN 978-3-96021-054-2, Deutsches Institut für Entwicklungspolitik (DIE), Bonn

Mach, K.J., Kraan, C.M., Adger, W.N. et al. (2019). Climate as a risk factor for armed conflict. Nature 571, 193–197

Magnan, A. K., Schipper, E. L. F., Burkett, M., Bharwani, S., Burton, I., Eriksen, S., … Ziervogel, G. (2016). Addressing the risk of maladaptation to climate change. Wiley Interdisciplinary Reviews: Climate Change, 7(5), 646–665. https://doi.org/10.1002/wcc.409

Malesky, E. (2017). Dictators, Democrats, and Development in Southeast Asia: Implications for the Rest. Bulletin of Indonesian Economic Studies, 53(3), 363–367. https://doi.org/10.1080/00074918.2017.1433523

Manne, A. Richels R. (1992) Buying Greenhouse Insurance, MIT Press

Mansley, M. (1994). Long term financial risks to the carbon fuel industry from climate change. London.

Material Economics. (2019). Industrial Transformation 2050 Industrial Transformation 2050: Pathways to net-zero emisisons from EU Heavy Industry. Material Economics

Maúre, G., Pinto, I., Ndebele-Murisa, M., Muthige, M., Lennard, C., Nikulin, G., … Meque, A. (2018). The southern African climate under 1.5 °C and 2 °C of global warming as simulated by CORDEX regional climate models. Environmental Research Letters, 13(6), 065002. https://doi.org/10.1088/1748-9326/aab190

Maxwell K., Julius S. Grambsch A, Kosmal A. Larson L, Sonti N. (2018). Built Environment, Urban Systems and Cities, in Impacts, Risks and Adaptation in the United-States: Fourth National Climate Assessment, Volume II, Reimiller D.R., Avery C.W., Easterling, D.R., Kunkel K.E., Lewis K.L.M., Maycock T.K. & Stewart B.C. (eds) Washington D.C. U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH10

Mazzucato M. (2015). The Entrepreneurial State, Public Affairs.

Mbow, C., Rosenzweig, C., Barioni, L., Benton, T., Herrero, M., Krishnapillai, M., … Xu, Y. (2019). Food security. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, ... J. Malley, (Eds.), Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (pp. 437- 550). Geneva: IPCC.

McCollum, D. L., et al. 2018. Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. Nature Energy, 3, 589–599, doi:10.1038/s41560-018-0179-z.

McKibbin, W. J. and Vines, D. (2020). Global Macroeconomic Cooperation in Response to the COVID-19 Pandemic: A Roadmap for the G20 and the IMF. Oxford Review of Economic Policy, volume 36 July 2020, https://ssrn.com/abstract=3651586 or http://dx.doi.org/10.2139/ssrn.3651586

McIntyre-Mills, J. (2014). Extending our horizons: Implications for transdisciplinarity, democracy, governance and ethics. In Systemic ethics and non-anthropocentric stewardship (pp. 87-99). Cham: Springer.

McKibbin, W. J., Morris, A. C., Panton, A. J., & Wilcoxen, P. J. (2017). Climate Change and Monetary Policy: Dealing with Disruption. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3084399

McNamara, K. E., & Buggy, L. (2017). Community-based climate change adaptation: A review of academic literature. Local Environment, 22(4), 443–460. https://doi.org/10.1080/13549839.2016.1216954

McNamara, K. E., & Jackson, G. (2019). Loss and damage: A review of the literature and directions for future research. Wiley Interdisciplinary Reviews: Climate Change, 10(2)

MDB. 2019. Joint report on Multilateral Development Banks' Climate Finance, World Bank Document.

Mercure, J.-F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., … Knobloch, F. (2018). Macroeconomic impact of stranded fossil fuel assets (D6189, trans.). Nature Climate Change, 8(7), 588–593. https://doi.org/10.1038/s41558-018-0182-1

Mian A. R., & Straub L., Sufi A. (2020). The Saving Glut of the Rich, NBER Working Papers 26941, National Bureau of Economic Research, Inc.

Michaelowa, A., Allen, M., & Sha, F. (2018). Policy instruments for limiting global temperature rise to 1.5°C – can humanity rise to the challenge? (D2275, trans.). Climate Policy, 18(3), 275–286. https://doi.org/10.1080/14693062.2018.1426977

Miles, D. (1993). Testing for Short Termism in the UK Stock Market. The Economic Journal, 103(421), 1379. https://doi.org/10.2307/2234472

Mirrlees J. A. (1999) The Theory of Moral Hazard and Unobservable Behaviour The Review of Economic Studies Vol. 66, No. 1, Special Issue: Contracts (Jan., 1999), pp. 3-21

Mirrlees, J. A. (2011). The Theory of Moral Hazard and Unobservable Behaviour: Part I. Welfare, Incentives, and Taxation. https://doi.org/10.1093/acprof:oso/9780198295211.003.0020

Mishra, V., Mukherjee, S., Kumar, R., & Stone, D. A. (2017). Heat wave exposure in India in current, 1.5 °C, and 2.0 °C worlds. Environmental Research Letters, 12(12), 124012. https://doi.org/10.1088/1748-9326/aa9388

Mooij, R. (2000). Environmental Taxation and the Double Dividend. Emerald Group Publishing Ltd.

Mooij, R., & Bovenberg, A. (1994). Environmental levies and distortionary taxation. American Economic Review, 84(4), 1085–1089. https://doi.org/10.2307/2118046

Morita, K., & Matsumoto, K. (2015). Financing Adaptation to Climate Change in Developing Countries. In Handbook of Climate Change Adaptation (pp. 983–1005). https://doi.org/10.1007/978-3-642-38670-1_22

Mulder, B. Y. N., & Tooze, A. (2020). The Coronavirus Oil Shock Is Just Getting Started. Foreignpolicy, 1–15. Retrieved from https://foreignpolicy.com/2020/04/23/the-coronavirus-oil-shock-is-just-getting-started/

Nakhooda, C; Watson, C. (2016). Adaptation finance and the infrastructure agenda. Retrieved from https://www.odi.org/sites/odi.org.uk/files/resource-documents/10489.pdf

Nemet, G. F., Callaghan, M. W., Creutzig, F., Fuss, S., Hartmann, J., Hilaire, J., Lamb, W. F., Minx, J. C., Rogers, S., & Smith, P. (2018). Negative emissions—Part 3: Innovation and upscaling. Environmental Research Letters, 13(6), 063003 https://doi.org/10.1088/1748-9326/aabff4

Net Zero Barometer Report. (2021). https://www.bsigroup.com/en-GB/topics/sustainable-resilience/net-zero/netzerobarometer/

New Climate Economy. (2016). The Sustainable Infrastructure Imperative: Financing the better growth and development. Washington D.C.: New Climate Economy.

NGFS. (2019). A call for action climate change as a source of financial risk. Retrieved from https://www.banque-france.fr/sites/default/files/media/2019/04/17/ngfs_first_comprehensive_report_-_17042019_0.pdf

Nikulin, G., Lennard, C., Dosio, A., Kjellström, E., Chen, Y., Hänsler, A., … Somot, S. (2018). The effects of 1.5 and 2 degrees of global warming on Africa in the CORDEX ensemble. Environmental Research Letters, 13(6), 065003. https://doi.org/10.1088/1748-9326/aab1b1

NOAA. (2019). Global Monitoring Division. Retrieved from https://www.esrl.noaa.gov/gmd/

ODI (2019). Blended finance in the poorest countries, https://odi.org/en/publications/blended-finance-in-the-poorest-countries-the-need-for-a-better-approach/

OECD (2021). Strengthening the Economic Recovery, the Need for Speed OECD economic outlook 2021, https://www.oecd.org/economic-outlook/

OECD (2020) Global economic outlook 2020 OECD, Paris, France

OECD. (2019). Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences. Global Material Resources Outlook to 2060. Paris: OECD Publishing. https://doi.org/10.1787/9789264307452-en

OECD. (2017). Investing in Climate, Investing in Growth. https://doi.org/10.1787/9789264273528-enOECD. https://doi.org/10.1787/9789264273528-en

OECD. (2016a). Projections of Climate Finance Towards the USD 100 Billion Goal: Technical Note.

OECD (2016b). Infrastructure Financing Instruments and Incentives

OECD. (2015). Climate Finance in 2013-14 and the USD 100 billion goal: A Report by the OECD in Collaboration with Climate Policy Initiative (R. D2528, Trans.). Retrieved from Organisation for Economic Co-operation and Development (OECD) website: http://www.oecd.org/env/cc/OECD-CPI-Climate-Finance-Report.pdf

Ouazadd A & Kahn M.E. (2019): Mortage Finance in the Face of Rising Climate Risk. NBER Working Paper N°26322 Cambridge M.A. National Bureau of Economic Research https://www.nber.org/papers/w26322

Pablo-Romero, M. del P., Sánchez-Braza, A., Salvador-Ponce, J., & Sánchez-Labrador, N. (2017). An overview of feed-in tariffs, premiums and tenders to promote electricity from biogas in the EU-28 (D2589, Trans.). Renewable and Sustainable Energy Reviews, 73, 1366–1379. https://doi.org/10.1016/j.rser.2017.01.132

Paillard S., Tréyer S., Dorin B. (Ed.). (2014). Agrimonde - Scenarios and Challenges for Feeding the World in 2050. New York, London, Springer, 250 p.

Peake, S., & Ekins, P. (2017). Exploring the financial and investment implications of the Paris Agreement. Climate Policy, 17(7), 832–852. https://doi.org/10.1080/14693062.2016.1258633

Pearce D. (1991) The Role of Carbon Taxes in Adjusting to Global Warming *The Economic Journal*, Volume 101, Issue 407, 1 July 1991, Pages 938–948, https://doi.org/10.2307/2233865

Peltzman, S. 1992. Voters as Fiscal Conservatives, Quarterly Journal of Economics 107: 325- 345

Perfecto I., Vandermeer J., (2010). "The agroecological matrix as alternative to the land-sparing/agriculture intensification model", Proceedings of the National Academy of Sciences of the United States of America, 107:13, pp. 5786-91

Plantinga, A. & Scholtens, B. (2016). "The financial impact of divestment from fossil fuels," Research Report 16005-EEF, University of Groningen, Research Institute SOM (Systems, Organisations and Management).

Pottier A., E. Espagne, B. Perrissin Fabert & P. Dumas, (2015) The Comparative Impact of Integrated Assessment Models' Structures on Optimal Mitigation Policies, Environmental Modeling & Assessment volume 20, pages 453–473

Quinet, (2019) La valeur de l'action pour le climat Une valeur tutélaire du carbone pour évaluer les investissements et les politiques publiques', Rapport de la commission Quinet, France Stratégie.

Realmonte, G., Drouet, L., Gambhir, A., Glynn, J., Hawkes, A., Köberle, A. C., & Tavoni, M. (2019). An inter-model assessment of the role of direct air capture in deep mitigation pathways. Nature communications, 10(1), 1-12. https://doi.org/10.1038/s41467-019-10842-5

REN21. (2017). Renewables 2017: Global status report. Retrieved from https://www.ren21.net/wp-content/uploads/2019/05/GSR2017_Full-Report_English.pdf

Revi, A., Satterthwaite, D. E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B. R., Pelling, M., … others. (2014). Urban areas. In Working Group II: Impacts, Adaptation and Vulnerability (pp. 535–612). Cambridge, UK & New York, USA: Intergovernmental Panel for Climate Change.

Ritzenhofen, I., & Spinler, S. (2016). Optimal design of feed-in-tariffs to stimulate renewable energy investments under regulatory uncertainty – A real options analysis (D2847, Trans.). Energy Economics, 53, 76–89. https://doi.org/10.1016/j.eneco.2014.12.008

Rochedo, P. R., Soares-Filho, B., Schaeffer, R., Viola, E., Szklo, A., Lucena, A. F., ... & Rathmann, R. (2018). The threat of political bargaining to climate mitigation in Brazil. Nature Climate Change, 8(8), 695-698. https://doi.org/10.1038/s41558-018-0213-y

Rodríguez-Alloza, A. M., Heihsel, M., Fry, J., Gallego, J., Geschke, A., Wood, R., & Lenzen, M. (2019). Consequences of long-term infrastructure decisions—the case of self-healing roads and their CO2 emissions. Environmental Research Letters, 14(11), 114040. https://doi.org/10.1088/1748-9326/ab424a

Roe, M. J., 1994. *Strong Managers, Weak Owners: the Political Roots of American Corporate Finance*. Princeton: Princeton University Press

Rogelj, J, Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., … Vilariño, M. (2018). Mitigation pathways compatible with 1.5°C in the context of sustainable development. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla … T. Waterfield (Eds.), Global

Warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, , sustainable development, and efforts to eradicate poverty (pp. 93-174). Geneva: IPCC.

Rogelj, J., & Den Elzen, M. (2019a). The emissions gap. In The Emissions Gap Report 2019 (pp. 21–25). Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/30797/EGR2019.pdf

Rogelj, J., D. Huppmann, V. Krey, K. Riahi, L. Clarke, M. Gidden, Z. Nicholls, M. Meinshausen. (2019b). A new scenario logic for the Paris Agreement long-term temperature goal. Nature, 573, 357–363, doi:10.1038/s41586-019-1541-4. http://www.nature.com/articles/s41586-019-1541-4.

Roques, F. A., D. M. Newbery, W. J. Nuttall. 2008*. Fuel mix diversification incentives in liberalized electricity markets: A Mean--Variance Portfolio theory approach*. Energy Economics, 30, 1831–1849, doi:10.1016/j.eneco.2007.11.008.

Roy, J., Tschakert, P., Waisman, H., Halim, S., Antwi-Agyei, P., Dasgupta, P., … Rodriguez, A. (2018). Sustainable development, poverty eradication and reducing inequalities. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla … T. Waterfield (Eds.), Global Warming of 1.5 °C. An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (pp. 445-538). Geneva: IPCC.

Rozenberg, J., & Fay, M. (2019). Beyond the gap: How countries can afford the infrastructure they need while protecting the planet. The World Bank.

Ryan-Collins J. (2019). Beyond Voluntary disclosure: why a 'market-shaping' approach to financial regulation is needed to meet the challenge of climate change, SUERF Policy Note, Issue n°61 march 2019, SUERF, The European Money and Finance Forum

Sartor, O., & Bataille, C. (2019). Decarbonising basic materials in Europe: How carbon contracts-for-difference could help bring breakthrough technologies to market. IDDRI. Retrieved From https://www.iddri.org/en/publications-and-events/study/decarbonising-basic-materials-europe

Sato, M., Neuhoff, K., Graichen, V., Schumacher, K., & Matthes, F. (2015). Sectors Under Scrutiny: Evaluation of Indicators to Assess the Risk of Carbon Leakage in the UK and Germany. Environmental and Resource Economics, 60(1), 99–124. https://doi.org/10.1007/s10640-014-9759-y

Schiff H & Ditrich H. (2017) Lasting Impact: the Need for Responsible Exist, Global Impact Investing Report, USAID, http://www.pva-advisory.com/wp-content/uploads/2018/01/GIIN_Responsible-Exits_2018.pdf

Schmidt T.S. (2014). Low-carbon investment risks and de-risking, Nature Climate Change, 4 (4) 237-239

Schoenmaker, D; Tilburg, R. (2016). Financial risks and opportunities in the time of climate change (p. 8). p. 8. Retrieved from http://bruegel.org/wp-content/uploads/2016/04/pb-2016_02.pdf

Schwab, K. (2019). The Global Competitiveness Report. Retrieved from http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf

SDSN. (2013). The urban opportunity: Enabling transformative and sustainable development. Retrieved from http://unsdsn.org/resources/publications/the-urban-opportunity-enabling-transformative-and-sustainable-development/

Shan, Y. Ou, J. et al. (2020). Impacts of Covid-19 and fiscal stimuli on global emissions and the Paris Agreement. Nature Climate Change, 11, 200–206(2021) https://doi.org/10.1038/s41558-020-00977-5

Shine, T; Campillo, G. (2016). The Role of Development Finance in Climate Action Post-2015. https://doi.org/10.1787/18a859bf-en

Shishlov I; & Bellassen V. 2012 Lessons from 10 years of the CDM, Climate Report n° 37, CDC, https://www.researchgate.net/publication/281012769_10_lessons_from_10_years_of_the_CDM

Shukla, P. R. et al. 2015. Pathways to Deep Decarbonization in India. SDSN-IDDRI.

Simpson, N. P., and Coauthors, 2021: A framework for complex climate change risk assessment. *One Earth*, 489–501, doi:10.1016/j.oneear.2021.03.005.

Singh, C., Ford, James., Ley, D., Bazaz, A., & Revi, A. (2020). Assessing the feasibility of adaptation options: methodological advancements and directions for climate adaptation research and practice. Climatic Change 162, 255-277. https://doi.org/10.1007/s10584-020-02762-x

Sirkis, A., Charles, J., Dipak, H., Rogério, D., Kevin, S., Baptiste, G., … Fabert, B. P. (2015). Moving the trillions: a debate on positive pricing of mitigation actions. In Centro Brasil no Clima Ed./CIRED, Nogent-sur-Marne. Retrieved from http://www2.centre-cired.fr/IMG/pdf/moving%7B_%7Din%7B_%7Dthe%7B_%7Dtrillions.pdf

Sorrell, S. (2009), 'The rebound effect: definition and estimation', in L. Hunt and J. Evans (eds) International Handbook of the Economics of Energy, Edward Elgar, Cheltenham

Sovacool, B. K., Linnér, B.-O., & Goodsite, M. E. (2015). The political economy of climate adaptation. Nature Climate Change, 5(7), 616–618. https://doi.org/10.1038/nclimate2665https://doi.org/10.1038/nclimate2665

Sovacool, B. K., Linnér, B.-O., & Klein, R. J. T. (2017). Climate change adaptation and the Least Developed Countries Fund (LDCF): Qualitative insights from policy implementation in the Asia-Pacific. Climatic Change, 140(2), 209–226. https://doi.org/10.1007/s10584-016-1839-2

Stephens, E. C., Jones, A. D., & Parsons, D. (2018). Agricultural systems research and global food security in the 21st century: An overview and roadmap for future opportunities. Agricultural Systems, 163, 1–6. https://doi.org/10.1016/j.agsy.2017.01.011

Stern, N. (2006). The Economics of Climate Change. The Stern Review. Cambridge University Press.

Stewart M. G, Deng X. (2015) Climate Impact Risks and Climate Adaptation Engineering for Built Infrastructure; ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, ISSN (online): 2376-7642

Stiglitz, J. E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G., La Rovere E., Winkler, H. (2017). Report of the High-Level Commission on Carbon Prices. https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices

Stiglitz, J., & Weiss, A. (1981). Credit Rationing in Markets with Imperfect Information. *The American Economic Review, 71*(3), 393-410. Retrieved May 24, 2021, from http://www.jstor.org/stable/1802787

Strefler, J., Amann, T., Bauer, N., Kriegler, E., & Hartmann, J. (2018). Potential and costs of carbon dioxide removal by enhanced weathering of rocks. Environmental Research Letters, 13(3), 034010. https://doi.org/10.1088/1748-9326/aaa9c4https://doi.org/10.1088/1748-9326/aaa9c4

Strobl E. (2019) The Impact of Typhoons on Economic Activity in the Philippines: Evidence from Nightlight Intensity ADB working papers series No. 589 | July 2019

Studart, R., & Gallagher, K. (2015). Guaranteeing Finance for Sustainable Infrastructure: A Proposal. In Moving the trillions a debate on positive pricing of mitigation actions (pp. 92–113). Retrieved from https://hal.archives-ouvertes.fr/hal-01692638/document

Summers, L. H. (2016). The Age of Secular Stagnation: What It Is and What to Do About It (D3286, trans.). Foreign Affairs, 95, 2. https://doi.org/https://www.foreignaffairs.com/articles/united-states/2016-02-15/age-secular-stagnation

Summers, L. H., L. Rachel. 2019. On falling neutral real rates, fiscal policy and the risk of secular stagnation. Brookings Papers on Economic Activity BPEA Conference Drafts, March 7-8.

Sustainability Accounting Standard Board (2016). Climate Risk-Technical Bulletin

Svartzman, R., Dron, D., & Espagne, E. (2019). From ecological macroeconomics to a theory of endogenous money for a finite planet. Ecological Economics, 162, 108–120. https://doi.org/10.1016/j.ecolecon.2019.04.018

Taskforce on Climate Financial Disclosures (2019). Status Report. https://www.fsb-tcfd.org/publications/tcfd-2019-status-report/

Taskforce on Climate Financial Disclosures (2017). TCFD Report. https://assets.bbhub.io/company/sites/60/2020/10/FINAL-2017-TCFD-Report-11052018.pdf

Task Force on Voluntary Carbon Markets (2021). Report.pdf (iif.com)

Tiftik E., K. Mahmood 2020 Global Debt Monitor Attack of the Debt Tsunami November 18, 2020, Institute of International Finance, https://file-us.clickdimensions.com/iifcom-ai7nn/files/globaldebtmonitor_nov2020_v1.pdf

Timilsina G.R., C. de Gouvello, M. Thioye, F.B. Dayo. 2010. Clean Development Mechanism Potential and Challenges in Sub-Saharan Africa, Mitigation and Adaptation Strategies for Global Change, 15, Issue 1, pp 93-111.

Tschakert, P., Ellis, N. R., Anderson, C., Kelly, A., & Obeng, J. (2019). One thousand ways to experience loss: A systematic analysis of climate-related intangible harm from around the world. Global Environmental Change, 55, 58–72. https://doi.org/10.1016/j.gloenvcha.2018.11.006

UNDESA. (2018). 2018 Revision of world urbanization prospects. UNDESA. Retrieved from https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

UNDP (2021). SDG Impact Standards for Bonds Issuers.

UNEP (2021) Are we building back better? Evidence from 2020 and pathways to inclusive green recovery spending.

UNEP-Inquiry. (2018). Aligning climate finance to the effective implementation of NDCs and to LTSs. In Input document for the G20 Climate Sustainability Working Group. Retrieved from http://unepinquiry.org/wp-content/uploads/2018/10/Aligning_Climate_Finance_to_the_effective_implementation_of_NDCs_and_to_LTSs.pdf

UNEP. (2018). The Adaptation Gap Report 2018. Nairobi: UNEP.

UNFCCC. (1992). United Nations Framework Convention on Climate Change. https://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC. (2011). Decision 1/CP16, The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention. FCCC/CP/2010/7/Add.1

UNFCCC. 2015. Decision 1/CP.21 Adoption of the Paris Agreement. FCCC/CP/2015/10/Add.1.

United Kingdom Committee on Climate Change. (2019). Net zero-technical report. London: Committee on Climate Change. Retrieved from https://www.theccc.org.uk/publication/net-zero-technical-report/

United Nations. (2015). Paris agreement. Retrieved from https://unfccc.int/sites/default/files/english_paris_agreement.pdf

United Nations (2021). Financing for Sustainable Development Report, IATF

United Nations (2020). Financing for Sustainable Development Report, IATF

United Nations (2019). Financing for Sustainable Development Report, IATF

United Nations and United Arab Emirates. (2020). Future possibilités report. https://www.un.org/sites/un2.un.org/files/20200720_un75_uae_futurepossibilitiesreport.pdf

Unruh, G. C. (2002). Escaping carbon lock-in. Energy Policy, 30(4), 317–325. https://doi.org/10.1016/S0301-4215(01)00098-2

UNU-WIDER (2020). Estimates of the impact of COVID-19 on global poverty :https://www.wider.unu.edu/sites/default/files/Publications/Working-paper/PDF/wp2020-43.pdf

UNWTO 2020 International Tourism and Covid 19, https://www.unwto.org/international-tourism-and-covid-19

Upton, G. B., & Snyder, B. F. (2017). Funding Renewable Energy: An Analysis of Renewable Portfolio Standards (D3467, Trans.). Energy Economics, 66(0), 205–216. https://doi.org/10.1016/j.eneco.2017.06.003

Ürge-Vorsatz, D., Rosenzweig, C., Dawson, R. J., Sanchez Rodriguez, R., Bai, X., Barau, A. S., … Dhakal, S. (2018). Locking in positive climate responses in cities. Nature Climate Change, 8(3), 174–177. https://doi.org/10.1038/s41558-018-0100-6

USAID: (2017) Agency Financial Report: Helping People Progress Beyond Assistance, USAID, Washington D.C. https://www.usaid.gov/results-and-data/progress-data/agency-financial-report/fy-2017

van Vuuren, D. P., Stehfest, E., Gernaat, D. E. H. J., van den Berg, M., Bijl, D. L., de Boer, H. S., … van Sluisveld, M. A. E. (2018). Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies. Nature Climate Change, 8(5), 391–397. https://doi.org/10.1038/s41558-018-0119-8

Vogl, V., Åhman, M., & Nilsson, L. J. (2018). Assessment of hydrogen direct reduction for fossil-free steelmaking. Journal of Cleaner Production, 203, 736–745. https://doi.org/10.1016/j.jclepro.2018.08.279

Voltz U. 2017. On the Role of Central Banks in Enhancing Green Finance. Geneva: UN Environment Inquiry into the Design of a Sustainable Financial System. https://unepinquiry.org/wp-content/uploads/2017/02/On_the_Role_of_Central_Banks_in_Enhancing_Green_Finance.pdf

Waisman, H.-D., Guivarch, C., & Lecocq, F. (2013). The transportation sector and low-carbon growth pathways: modelling urban, infrastructure, and spatial determinants of mobility. Climate Policy, 13(sup01), 106–129. https://doi.org/10.1080/14693062.2012.735916

Waisman, H., Bataille, C., Winkler, H., Jotzo, F., Shukla, P., Colombier, M., … Trollip, H. (2019). A pathway design framework for national low greenhouse gas emission development strategies. Nature Climate Change, 9(4), 261–268. https://doi.org/10.1038/s41558-019-0442-8

Ward, J. S., Fankhauser, C., Hepburn, H. J., & Rajan, R. (2009). Catalysing low-carbon growth in developing economies: Public Finance Mechanisms to scale up private sector investment in climate solution. Retrieved from http://www.unepfi.org/fileadmin/documents/catalysing_lowcarbon_growth.pdf

Watson C., Schalatek L. (2020) The Global Climate Finance Architecture, Heinric Böll Stiftung, February 2020, Washington D.C., https://climatefundsupdate.org/wp-content/uploads/2020/03/CFF2-2019-ENG-DIGITAL.pdf

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Boykoff, M., … Montgomery, H. (2019). The 2019 report of The Lancet Countdown on health and climate change: Ensuring that the health of a child born today is not defined by a changing climate. The Lancet, 394(10211), 1836–1878. https://doi.org/10.1016/S0140-6736(19)32596-6

WBGU. (2019). Towards our common digital future. Berlin: WBGU.

Weidmann J., Bundesbank Chief: How central banks should address climate change? Financial Times, November 19, 2020, https://www.ft.com/content/ed270eb2-e5f9-4a2a-8987-41df4eb67418

Weitzman, M. L. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. Review of Environmental Economics and Policy, 5(2), 275–292. https://doi.org/10.1093/reep/rer006

Weitzman, M. L. (2014). Fat Tails and the Social Cost of Carbon. The American Economic Review 104 (5): 544–46.

Werners, S. E., Pfenninger, S., van Slobbe, E., Haasnoot, M., Kwakkel, J. H., & Swart, R. J. (2013). Thresholds, tipping and turning points for sustainability under climate change. Current Opinion in Environmental Sustainability, 5(3–4), 334–340. https://doi.org/10.1016/j.cosust.2013.06.005https://doi.org/10.1016/j.cosust.2013.06.005

Werners, S. E., R. M. Wise, J. R. A. Butler, E. Totin, and K. Vincent, 2021: Adaptation pathways: A review of approaches and a learning framework. *Environ. Sci. Policy*, **116**, 266–275, doi:10.1016/j.envsci.2020.11.003. https://doi.org/10.1016/j.envsci.2020.11.003.

Wesseling, J. H., Lechtenböhmer, S., Åhman, M., Nilsson, L. J., Worrell, E., & Coenen, L. (2017). The transition of energy intensive processing industries towards deep decarbonization: Characteristics and implications for future research. Renewable and Sustainable Energy Reviews, 79, 1303–1313. https://doi.org/10.1016/j.rser.2017.05.156

Westcott, S. (2019). 2019 Proxy Season Preview. Retrieved from https://corpgov.law.harvard.edu/2019/04/15/2019-proxy-season-preview-2/

Wezel A., Bellon S., Dore T., Francis C., Vallod D., David C. (2009). Agroecology as a science, a movement and a practice. A review. Agronomy for Sustainable Development, vol. 29, n° 4, pp. 503-515.

Whitney, A, Grbusic T., Meisel J, Bodnar P., 2020. State of Green Banks 2020, RMI, London.

Wilder AM, M., & Curnow, P. (2012). Superannuation trustees and climate change report. Retrieved from http://www.climateinstitute.org.au/verve/_resources/BakerandMcKenzie_SuperannuationTrusteesandClimateChangeReport_October2012.pdf

Winpenny, J. 2005. Guaranteeing Development? The Impact of Financial Guarantees, OECD, Paris.

Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Van Garderen, E. R. M. A., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change, 28, 325–336. https://doi.org/10.1016/j.gloenvcha.2013.12.002

World Bank, Ecofys, and Vivid Economics. (2016). State and Trends of Carbon Pricing 2016. World Bank, Washington DC: World Bank.

World Bank (2020a): Global Economic Prospects 2020

World Bank. (2020b). World Development Report 2020: Trading for Development in the Age of Global Value Chains. https://doi.org/10.1596/978-1-4648-1457-0 Economic Prospects 2020

World Bank (2021): Global Economic Prospects 2021

World Bank. (2019a). 2018 joint report on multilateral development banks climate finance. Retrieved from https://doi.org/10.18235/0001736

World Bank. (2019b). Doing business 2019: Training for reform. Washington DC: World Bank.

World Food Programme. (2020). Global Update on COVID-19: November 2020

WTO 2020 Trade set to plunge as COVID-19 pandemic upends global economy

Wyns, T., Khandekar, G., Axelson, M., Sartor, O., & Neuhoff, K. (2019). Industrial transformation 2050: Towards an industrial strategy for a climate neutral Europe. Retrieved from https://www.ies.be/node/5074.

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