Climate Change in APEC

Assessing Risks, Preparing Financial Markets, and Mobilizing Institutional Investors

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Foreword

Many private and public sector leaders agree on the urgent political and business imperative of addressing climate change, and of sustainable development and sustainable investment more broadly. While public resources are important to advance this process, mobilizing private investors is essential to financing climate change mitigation and adaptation and to closing the United Nations Sustainable Development Goals' investment gap. A significant share of global investment capital is concentrated in the hands of a relatively small number of institutional investors and banks. Engagement and alignment of global policymakers with investors around areas of shared interest will be essential to ushering in the new era of climate finance and of sustainable investment and development. Acting jointly, leaders of the global investing community can be highly effective in reshaping markets – by allocating investments to, and creating the enabling environment for, companies and projects that supporttheir shared objectives.

The World Bank Group prepared this report, *Climate Change in APEC: Assessing Risks, Preparing Financial Markets, and Mobilizing Institutional Investors* to inform policymakers, financial sector regulators, and investors from across APEC member economies about the interconnected climate change challenges that they face. This report aims to help these stakeholders better understand the human and economic risks that climate change poses to the region and to provide them with a starting point for discussions about opportunities for action.

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Boxes, Figures, and Tables

Executive Summary

Climate change poses extreme risks to the Asia-Pacific Economic Cooperation (APEC) region. Without increased action from governments, global temperatures are expected to rise by more than 3°C above pre-industrial averages by 2100, with a 20% chance of warming more than 4°C. Today, 70% of global natural disasters happen in the APEC region, the intensity and severity of which are expected to increase with climate change. This is expected to include more days of extreme heat, more frequent droughts, inundated coastal land and more frequent coastal and river flooding – all of which will have significant human and economic costs.

Climate change and related policy responses pose substantial risks to financial systems in APEC member economies and across the world. Given their intergenerational obligations and long-term investment horizons, these risks are particularly troublesome for the many of the world's largest institutional investors that are based in the region. With leadership from regulators including central banks and financial supervisors, financial markets across APEC can mobilize to manage the risks of climate change and to capitalize on related investment opportunities. They can do so most effectively if policymakers similarly mobilize to remove barriers to climate finance (i.e. fossil fuel subsidies) and use carbon pricing and other policy mechanisms to level the investment playing field between fossil fuels and renewable energy.

This report outlines the potential human and economic impacts of climate change on APEC member economies and the benefits to mitigating these impacts. It then outlines the climate-related risks to financial institutions and how financial system regulators can help institutions to manage these risks. It concludes with a discussion of the policy, regulatory and market barriers to scaling-up institutional investors' contributions to climate finance and solutions to each. In doing so, this report aims to capitalize on the unique and exciting opportunity provided by the 2019 APEC Investor Forum for policymakers, financial sector regulators and investors from across APEC member economies to share insights on the interconnected climate change challenges that they face and to provide a starting point for discussions about opportunities for action.

Key considerations outlined in this report are as follows.

Climate change poses great risk to human life and economic progress in APEC member economies. If they act now, APEC member economies can avoid its most severe consequences.

The impacts of unmitigated climate change on APEC member economies will potentially be catastrophic. The expected increase in temperatures could reduce agricultural and labor productivity and cause reductions in output across most sectors of the economy. Increased sea levels are expected to inundate productive coastal land and increase the frequency and severity of coastal floods, and more frequent extreme rainfall could increase the regularity and severity of river floods, causing destruction of capital stock. Without adaptation measures, lower and middle-income economies in the APEC region — including Indonesia, Thailand and Viet Nam — are likely to feel these impacts most severely. Across the APEC region, losses are expected to equal 7.3% of GDP.

Beyond the economic impacts, climate change is expected to bring considerable human costs. The resulting increased number of days with dangerously high heat levels could cause an estimated additional 350,000 deaths per year across the APEC region. Higher temperatures might increase the disease burden, and more frequent and intense coastal and river floods could cause displacement and mortality. In addition, the ongoing combustion of carbon intensive fuels will continue to degrade air quality and cause respiratory disease and premature mortality.

These estimates say nothing of what might happen if increases in global temperatures exceed 3°C or of other potentially costly impacts of climate change. One extra degree of warming, a plausible outcome given current policy, could double the economic losses caused by chronic climate change impacts. There is also a risk of 'tipping-points' in the climate system, whereby small changes in climatic variables have large impacts on others, leading to a "Hothouse Earth" pathway. Further, the scientific evidence base is not yet able to quantify other important and likely economic impacts of climate change, including increased migration and conflict and reduced biodiversity.

The necessary actions to reduce or mitigate these disastrous consequences can be undertaken immediately by APEC member economies. While the problems may seem daunting, other of the recommendations in this report provide a roadmap for APEC member economies to help slow the harmful effects of climate change.

Investing in mitigating climate change (e.g. through carbon taxes) and adapting to its effects would be cheaper for APEC member economies than inaction.

The average economic costs of reducing emissions to limit warming to below 2°C are estimated to be only 2.6% of GDP in 2050 and 3.4% of GDP in 2100 across APEC member economies. This is less than half of the cost of the expected damage caused by the physical impacts of unabated climate change. Strict climate policy could also save lives. Phasing out fossil fuels and reducing related air pollution could reduce deaths by around 500,000 per year by 2050 across the APEC region. Limiting warming to below 2°C by 2100 could help to avoid 380,000 extreme-heat related deaths per year.

Carbon taxation, a key instrument of climate policy, could raise significant government revenue, which could be used to reduce labor or other marginal tax rates. Introducing carbon taxes at a level sufficient to achieve Paris goals is estimated to result in revenues averaging 0.6% of GDP across APEC countries. In addition, carbon taxes can encourage reallocation of resources from the informal to the formal economy, resulting in increases in GDP for countries with large informal sectors.

Enacting strict climate policies could create an additional $470 billion per year in additional energy investment opportunities across APEC.

Implementing strict climate policy in line with the Paris Agreement goals would create an estimated additional $470 billion per year in energy investment opportunities in APEC member economies.[1] This includes investments in energy efficiency, renewable energy generation and energy transmission and distribution infrastructure. Opportunities to invest in climate-resilient infrastructure and other adaptation measure could provide additional investment opportunities and generate benefits equal an estimated four times their costs.

[1] All $ in this report are USD unless otherwise noted.

Further, in order to achieve emissions consistent with the Paris Agreement, low-carbon investment needs to overtake fossil fuel investment by around 2025. Unfortunately, this goal is unlikely to be met, as fossil fuel subsidies have almost doubled since 2015 and very few countries have adopted carbon taxes. Making the shift from fossil fuels towards low-carbon energy as soon as possible could help APEC member economies to effectively mitigate the impacts of climate change while capitalizing on new energy investment opportunities.

Climate risks are financial risks.
Financial regulators in APEC can support financial institutions in managing these risks.

Beyond its expected impact on GDP, climate change poses substantial risks to financial markets across APEC member economies. To effectively manage these risks, financial institutions should treat climate risks as pure financial risks, systematically integrate them into financial risk management frameworks and take organizational steps to treat them with the same importance as other financial risks. These risks include physical risks to supply chains, decreased worker productivity, operations, facilities and damage to capital equipment caused by extreme weather events and rises in sea levels. They also include the transition risks embedded in governments' policy responses to climate change (e.g. new carbon pricing schemes and emission standards) and related changes in financial markets (e.g. shifts in consumer preferences to "green" products and increased competitiveness of low-carbon technology).

Research shows that financial markets do not adequately reflect climate risk. This underpricing of climate risk could have huge implications as the effects of climate change become more severe. Given the substantial interconnectedness of global financial institutions, climate change-related losses could spread to institutions not directly exposed to climate risks and wreak havoc on broader financial systems.

Financial system regulators can play a vital role in ensuring that financial institutions across APEC member economies comprehensively address the risks of climate change. This includes assessing the preparedness of financial institutions to manage climate risks, setting related expectations and providing needed technical support. Treating climate risk as financial risk requires financial institutions to adopt the right quantitative tools to manage this risk and access needed climate risk data.

Green credit markets provide notable opportunities to reduce financial institutions' exposure to climate risks. Policymakers and financial systems can partner to expand these markets.

Financial systems across APEC member economies can continue to expand green credit markets, including markets for green bonds and green loans. Green credit markets are an important component for the financing of low-carbon, climate-resilient investments and provide financial institutions with valuable tools for reducing their exposure to climate risks. Green bonds and green loans fund projects and firms are the most aligned with low-carbon standards and are therefore less exposed than other projects and firms to transition risk. Expanding green credit markets requires a combination of policy leadership and market-based actions that focus on things like harmonizing definitions and guaranteeing market integrity and credibility.

Institutional investors are particularly vulnerable to climate risks and uniquely positioned to address them.

Institutional investors in APEC are responsible for ensuring the present and future solvency of pension, insurance and sovereign wealth funds with more than $42 trillion in assets across the region and representing the equivalent of more than 100% of GDP in some countries. They include more than two-thirds of the largest 100 institutional investors in the world. Risks to their investment portfolios from climate change threaten the retirement and insurance payments and savings of millions of people, substantial portions of the savings of entire nations, and regional economic stability. The long-term horizon of these investors not only makes them particularly vulnerable to climate risk, but it also uniquely positions them to capitalize on things like the $470 billion in new annual investment opportunities that could be generated by enactment of strict climate policy across the region.

Institutional investors in APEC can most effectively address climate risks and capitalize on climate change investment opportunities with adequate support from policymakers, regulators and capital markets.

Enabling and supporting institutional investors to effectively manage the risks of climate change is centrally important to the successful functioning of financial systems in APEC member economies. Despite notable efforts by some, institutional investors across APEC do not appear to managing climate risks in a systematic way or capitalizing on low-carbon investment opportunities, and for good reason: fossil fuel subsidies disincentivize investments in renewable energy; regulatory frameworks do not adequately encourage and support integration of climate risks into long-term investment management; and institutional investors struggle to find climate finance products that align with their risk appetites and return expectations.

A collection of policy, regulatory and market solutions can help support institutional investors' climate risk management and encourage their increased investment in climate solutions. First and foremost, this includes eliminating fossil fuel subsidies and using carbon taxes and other policy mechanisms to level the investment playing field between fossil fuels and renewable energy. It also includes mandating corporate climate-related disclosures aligned with the recommendations from the Task Force on Climate-Related Financial Disclosures and otherwise helping institutional investors build their capacity for climate risk analyses; using innovative blended finance structures to attract institutional investor capital to climate change mitigation and adaptation projects that they might otherwise forgo given associated risks; connecting institutional investors to immediate opportunities to contribute to climate finance available in most asset classes (e.g. green bonds, climate-focused indexes and sustainable Exchange-Traded Funds); developing robust infrastructure pipelines and enhancing local capital markets.

It is primarily within the purview of governments and regulators to enact most of these reforms, but that does not mean that institutional investors must sit on the sidelines and wait for action; rather they can use their size and influence to advocate for requisite policy and regulatory action.

If combined and brought to scale, these recommended solutions provide a remarkable opportunity for policymakers, regulators and institutional investors in APEC member economies to work together to save lives, save money and protect trillions of dollars in pension, insurance and sovereign wealth savings from the risks of climate change – all while capitalizing on the expected $470 billion per year in new energy investment needs.

Chapter 1.

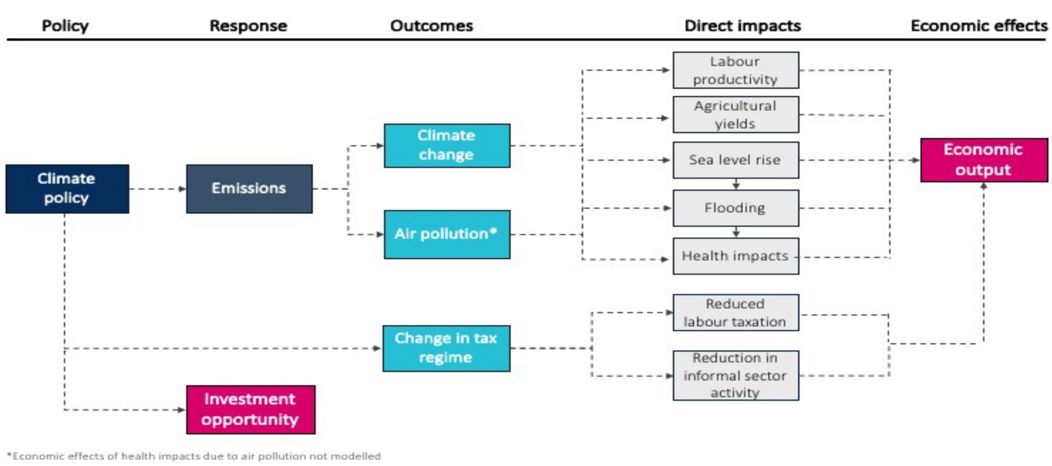
Macro-economic Impacts of Climate Change on APEC Member Economies

Across the globe there is increasing understanding of the need to reduce emissions in order to mitigate the most damaging physical effects of climate change. This increase is partially attributable to urgent calls for action from the scientific community. The Intergovernmental Panel on Climate Change (IPCC)'s recent report, "The Ocean and Cryosphere in a Changing Climate" outlines the projected risks for people and ecosystems from changes to the ocean system caused by anthropogenic climate change. In its earlier "Global Warming of 1.5°C" report, the IPCC highlighted the potential for large differences in climate change impacts caused by small changes in global average temperatures (IPCC, 2018).

Simultaneously, there is a growing understanding of the wide-ranging impacts of climate change on the economy. Researchers including McKibbin et al. (2017), for example, suggest that climate change and climate policy could undermine the ability of policymakers to promote macroeconomic stability by increasing the frequency of supply side shocks from climatic events (e.g. tropical storms or coastal flooding) and by impacting price stability from carbon pricing, complicating monetary policy. Climate change and climate policy could also impact financial stability by increasing the risk to assets from extreme weather events or causing a rapid devaluation of assets.

This chapter estimates the economic and human impacts from climate change for APEC member economies. It does so under a baseline "weak policy" scenario in which climate change is not abated, and under a scenario where policy mitigates climate change, avoids climate related damages, and generates economic and human co-benefits. These estimates draw on the latest scientific evidence and economic literature and use state-of-the art models to assess potential impacts (see Figure 1). Recent evidence suggests that the estimates presented in this report are conservative and might underestimate the negative impacts from climate change (Schewe et al., 2019). Accordingly, there is a non-negligible risk that the impacts of climate change on APEC member economies could be greater than the results presented here. In addition, this report does not quantify the important impacts of climate change on land systems, biodiversity, species loss and extinction.

Figure 1. Modelling framework



Source: Vivid Economics

This chapter also describes how climate policy can be used to achieve the goal of the Paris Agreement to limit global warming to well below 2°C, identifies investment opportunities from the transition to a low-carbon economy and outlines the primary benefits and co-benefits of climate policy. It draws on the models identified above to estimate the physical, human and economic benefits of a reduction in emissions to levels consistent with the Paris Agreement. Appendix A contains additional information about the methods used to produce estimates in this chapter and additional data tables.

Baseline scenario

Future greenhouse gas emissions depend on the interaction between socioeconomic trends, technology and climate policy. Socioeconomic trends (e.g. economic and population growth) impact the demand for energy: higher growth and higher energy demand increase the difficulty of achieving aggressive greenhouse gas reductions; lower growth and rapid technological progress in low carbon technologies make achieving reduction targets relatively easier.

The baseline emissions scenario considered in this report is a “weak policy” scenario with a middle-of-the-road socioeconomic pathway and medium technological progress. Figure 2 below depicts the future trajectory of global carbon emissions under the baseline scenario and the increase in global temperatures expected to result. The baseline emissions scenario is “weak policy” in the sense that it is consistent with continuation of climate policy excluding announced policies under the Paris Agreement’s Nationally Determined Contributions (NDCs).[2] The combination of weak policy, reduced population growth and medium technological progress results in a slowing of the rate of increase of annual emissions and a peak in emissions peaking towards the end of the century.

By the end of the century, climate models suggest that the most likely outcome for global mean temperatures under the baseline emissions scenario is an increase of more than 3°C compared to pre-industrial times. Due to uncertainties regarding the response of the climate to emissions, there is estimated to be a roughly 20% chance that temperatures might exceed 4°C by 2100 given this emissions profile (Schellnhuber et al., 2012). Wagner and Weitzman (2015) calculate a 10% chance of long-term warming exceeding 6°C with a similar emissions profile.

Shared Socioeconomic Pathway

This report draws on a Shared Socioeconomic Pathway (SSP) for projections of socioeconomic trends, including population and economic growth. SSPs are based on narratives about broad socioeconomic and technological trends and are used in analysis supporting the IPCC’s Sixth Assessment Report (due in 2020). The analysis in this report is based on SSP2, a middle of the road scenario described as follows:

> *“The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements*

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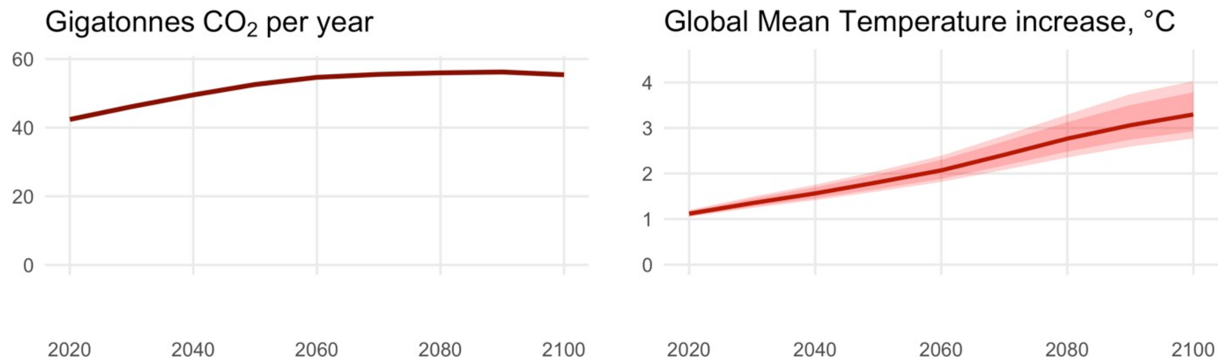
[2] The baseline emissions scenario is defined by as RCP60/SSP2 in the RCP-SSP-SPA framework (van Dingenen et al., 2018). Projected radiative forcing from the AIM/CGE model under the “Continuation of climate policy ambition prior to the announcement of the NDCs, accounting for the effects of the Cancun Pledges” policy scenario and SSP2 assumptions is 6.11 W/m2 in 2100, compared to 6.0 under the RCP 6.0 scenario.

> *and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain."* (Riahi et al., 2017)

All models run in support of this report use population and growth projections consistent with this narrative and displayed in Appendix A.

Figure 2. Global emissions and Expected Global Mean Temperature increase under baseline scenario



Note: Expected Global Mean Temperature increase relative to pre-industrial baseline. Baseline emissions scenario is defined by SSP2/RCP6.0. Lighter shaded area shows 25-75th percentile of probabilistic estimates from the MAGICC climate model. Darker shared area shows 17-83th percentile of probabilistic estimates.
Source: Fricko et al., 2017; Vivid Economics

1.1 Physical impacts of climate change

Increased atmospheric concentration of greenhouse gases will raise global temperatures and cause changes in numerous other climatic variables, including those driving extreme weather events. Currently, 70% of global natural disasters happen in the APEC region, with an estimated $100 billion in related losses annually and significant human costs (Emergency Preparedness Working Group, 2017). The intensity and severity of such natural disasters is expected to increase with climate change, adding to the burden on the APEC region.

The impact of climate change is better understood for some climatic variables than others. Table 1 shows the scientific consensus of climate change impacts on a selection of important weather variables, drawing on evidence from the Intergovernmental Panel on Climate Change (IPCC). While there is scientific consensus about the impacts of climate change on temperatures, sea levels and precipitation, impacts on drought, tropical cyclones and winter windstorms remain less certain.

Table 1. The impact of climate change is better understood for some perils than for others

Impact	Likelihood of further changes by late 21st century	Region
Warmer and/or more frequent hot days	Virtually certain	Over most land areas
Increased incidence and/or magnitude of extreme high sea level	Very likely	Global
Heavy precipitation events, increase in the frequency, intensity, and/or amount of heavy precipitation	Very likely	Over most of the mid-latitude land masses and over wet tropical regions
Increases in intensity and/or duration of drought	Likely	On a global scale
Increase in intense tropical cyclone activity	More likely than not	In the western North Pacific and North Atlantic

Source: IPCC (2013), Table SPM.1

This section draws on outputs from Global Circulation Models (GCMs) to describe the expected physical impacts of climate change on APEC member economies from extreme heat, sea level rise, precipitation and drought. These are important climatic variables that are expected to be impacted by climate change, but other changes in weather and climate can be expected too. In all cases and in line with common practice, results are presented based on the combined predictions of many different GCMs (see Box 1). Different GCMs have different internal representations of the climate and its response to emissions, causing uncertainty in projections of the future climate which increases over time. As such, impacts could be significantly larger or smaller than those presented here.

Box 1. Global Circulation Models

Global Circulation Models are mathematical representations of the climate used by the international scientific community to model future climates. They simulate the climate system through representations of energy transfers, including models of the atmosphere, ocean, land and ice. They can be used to model the climatic impact of greenhouse gas emissions by running simulations of climate under varying emissions trajectories. GCMs vary in their representations of the climate system and as a result produce somewhat diverging simulations for any given emission scenario. It is common practice to report the average of the outputs of multiple GCMs ("an ensemble") to provide a central estimate of climate change impacts. An overview and evaluation of the GCMs used in the IPCC's 6th Assessment Report is provided in Flato et al. (2013).

1.1.1 Average temperatures and number of extreme heat days

Across APEC member economies, an average warming of 2.5°C relative to 1986-2005 is expected by the end of the century under the baseline scenario.[3] Figure 1 and

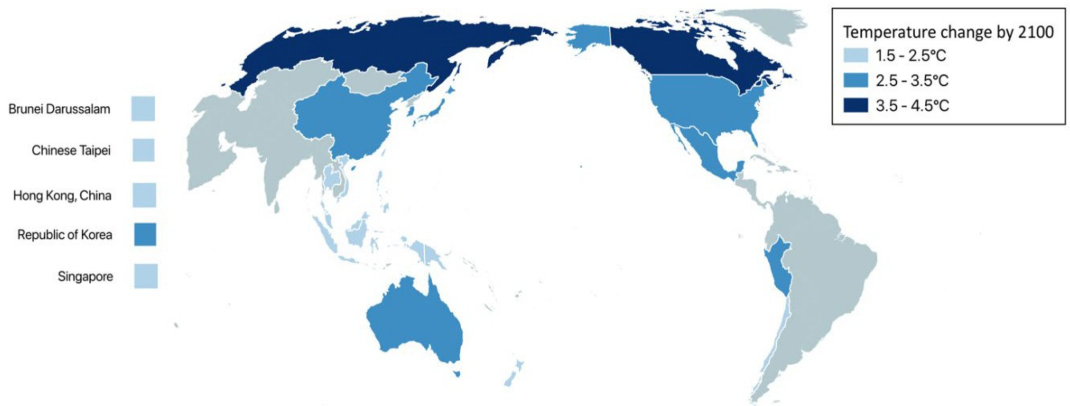
Table **2** depict the expected increase in temperature for each APEC member economy. The changes in annual average surface air temperatures are larger in more northerly countries. By the end of the century, warming of over 4°C is expected in Canada and Russia. This potential for increased warming at higher latitudes has been highlighted by other research, including the IPCC "Global Warming of 1.5°C" report (IPCC, 2018). As a result of increased temperatures, there is expected to be a significant increase in the number of days with dangerous heat (defined as more than 35°C) by 2100. This increase is most severe for equatorial countries with high average temperatures today. In Singapore, the average number of days with dangerous heat per year is projected to increase by 144 days by 2100. Impacts of climate

[3] Globally, average temperatures 1986-2005 are estimated to be 0.61°C above their pre-industrial levels.

change on temperature are less pronounced in 2050, where average temperatures are predicted to rise by 1.3°C, with a more modest increase in the number of days with dangerous heat.

The country-level temperature changes presented here represent the *expected* outcome under the baseline emissions scenario. However, the outcomes could be more extreme. Averaging across APEC member economies, the range of temperature increases is 0.3°C to 2.8°C by 2050 and 0.9°C to 4.9°C by 2100, relative to 1986-2005 levels.

Figure 1. Country-level temperature change, baseline



Note: Relative to baseline period of 1986-2005, based on average of 16 Global Circulation Models.
Source: World Bank Climate Change Knowledge Portal, Vivid Economics

Table 2. Change in temperature related variables in baseline scenario

Member	Change in annual average temperature		Change in days with dangerous heat	
	2050	2100	2050	2100
Australia	1.4°C	2.6°C	19	37
Brunei Darussalam	1.0°C	1.9°C	15	59
Canada	2.1°C	4.2°C	0	0
Chile	1.1°C	2.0°C	0	0
Chinese Taipei	1.0°C	2.1°C	28	64
Hong Kong, China	1.1°C	2.2°C	5	54
Indonesia	1.0°C	1.9°C	18	77
Japan	1.3°C	2.6°C	0	5
Malaysia	1.1°C	2.0°C	18	67
Mexico	1.4°C	2.6°C	-1	9
New Zealand	0.9°C	1.8°C	0	0
Papua New Guinea	1.1°C	1.9°C	7	35
People's Republic of China	1.6°C	3.1°C	0	5
Peru	1.4°C	2.7°C	11	32
Philippines	0.9°C	1.9°C	41	124
Republic of Korea	1.4°C	2.7°C	0	4
Russia	2.2°C	4.1°C	0	0
Singapore	1.0°C	1.9°C	61	144
Thailand	1.1°C	2.2°C	-25	26
The United States	1.7°C	3.3°C	2	8
Viet Nam	1.1°C	2.1°C	-13	28

Note: Relative to baseline period of 1986-2005, based on average of 16 Global Circulation Models
Source: World Bank Climate Portal, Vivid Economics

1.1.2 Sea level rise, precipitation and drought

Alongside impacts on temperature, climate change is expected to cause higher sea levels, increased intensity of extreme precipitation events and increased likelihood of drought. Rising sea levels are likely to inundate low lying coastal land, rendering it economically unproductive, and increase the chance and severity of coastal flood events, causing economic and human losses. More extreme rainfall is likely to increase the severity of both river and surface water flooding, again causing economic damages and loss to human life. Droughts are likely to reduce agricultural yields and cause stress to the urban water supply.

The impact of these changes on APEC member economies is expected to be significant, with the most severe physical impacts likely to fall disproportionately on APEC members nearest the equator. Sea levels are expected to rise by an average of 56cm across APEC countries over the course of the century, with an increase of as much as 75cm expected around the Philippines. Extreme precipitation is expected to increase in most APEC member economies in both 2050 and 2100, with the largest increases expected in Thailand, Chinese Taipei and Papua New Guinea. The likelihood of severe drought is expected to increase across all APEC member economies in both 2050 and 2100, which would reduce agricultural yields and cause stress to the urban water supply. Notably, by 2100, there is a 45 percentage point increase in the annual probability of severe drought in Chile and Mexico.

1.2 Human impacts of climate change

Significant human damages are expected from unabated climate change. Rising temperatures are likely to increase the number of days with extreme heat, make fatal coastal and river floods more frequent and increase the disease burden. In addition, the continued combustion of carbon intensive fuels is likely to degrade air quality, causing respiratory related disease. Such impacts on human health have consequences for economic output, as described in Section 1.3. In this section, mortality impacts are reported as change in the annual number of deaths, while the impact of disease is quantified through its expected impact on labor productivity.

1.2.1 Air pollution

In addition to the release of greenhouse gases, the combustion of fossil fuels releases pollutants that can become suspended in air and negatively impact human health. The World Health Organisation (WHO) estimates that 91% of the world’s population currently lives in areas where air quality exceeds WHO guidelines, with 4.2 million deaths annually attributable to air pollution globally. This report assesses the impact of pollutants most closely associated with negative human health impacts, particulate matter (PM2.5) and ozone (O_3). Health impacts from particulate matter include ischemic heart disease (IHD), chronic obstructive pulmonary disease (COPD), stroke, lung cancer and acute lower respiratory airway infections. Ozone is linked to increased incidence of respiratory disease.

This report uses the TM5-FASST model to assess the impacts of air pollution on human health.[4] The TM5-FASST model is a global air quality model capable of estimating the impact of air pollution on human health for 56 regions, including for most APEC member economies (van Dingenen et al., 2018). The TM5-FASST model can be used to model the impact of any emissions profile. For this report, pollutant

[4] The TM5-FASST model is only used to estimate human health damages from air pollution. The FASST model is not used to assess the interaction between air pollutants and warming. Likely levels of warming under the baseline and policy scenarios are assessed using GCMs.

emissions consistent with the baseline and emissions reduction scenarios were extracted from Fujimori et al. (2018), which provides spatially explicitly emissions data for 2005-2100 under combinations of SSPs and emissions trajectories. The Fujimori et al. (2018) outputs were processed and used as inputs into the TM5-FASST model. More methodological details are provided in Appendix A.

By mid-century, air pollution could cause 1.8 million deaths per year in the APEC region under the baseline scenario. In relative terms, Russia, the Republic of Korea and China are expected to experience the largest annual number of deaths from air pollution in 2050, experiencing more than 900 deaths per million population per year. Member economy level results expressed in annual deaths per million population can be found in Appendix A. Even under the baseline emissions scenario, the absolute number of deaths from air pollution is expected to decline in the APEC region by 2100. This is largely driven by a decline in population, particularly in China. However, some member economies, such as the United States could experience an increase in the number of annual of deaths from air pollution from 2050 to 2100.

1.2.2 Effects on health due to changes in extreme hot and cold days

Extreme temperatures negatively affect human health and can lead to temperature related-excess mortality. Typically, such impacts arise when temperatures fall below freezing or rise above 35°C. Segments of the population with impaired health are particularly at risk. For example, the elderly and people with cardiovascular or respiratory disease, diabetes or other pre-existing medical conditions are at greater risk from extreme heat exposure than the rest of the population (Huang et al., 2011).

This report draws on the estimates of temperature-related excess mortality from Gasparrini et al. (2017) to estimate the future impacts of extreme hot and cold days on human health. The results assume that member economies do not undertake any adaptation actions to changing temperatures. In practice, some adaptation is likely to occur, such as the purchase of air conditioning or changes to daily routines. For example, Carleton et al. (2018) estimate that increasing incomes could result in a 68% decline in heat related excess mortality globally for the 5-64 age category by 2100.

Changes in the number of extreme hot and cold days could lead to more than 350,000 deaths per year by 2100 compared to today. In 2050, the number of deaths is expected to be slightly lower than today, driven by a reduction in the number of excess cold days. However, the net reduction in deaths from a reduction of excess cold days by 2050 is quickly eclipsed by a substantial increase in the number of deaths from excess heat by 2100. There is considerable regional variation between APEC member economies in both 2050 and 2100. By 2050, Indonesia and Mexico are likely to experience an increase in deaths from days with extreme heat, while there is a net reduction in deaths in China and Japan. This is driven by an increase in the number of days with extreme heat in Indonesia and Mexico and a decline in the number of days with extreme cold in China and Japan. By the end of the century, the number of days with extreme heat increases further from 2050. In Mexico and Indonesia, an extra 100,000 deaths are expected per year by 2100 respectively.

The net impact of temperature-related excess mortality could be larger if modelled declines in excess cold mortality does not occur. The estimates presented above are the combined effect of changes in mortality due to changes in the number of extremely hot and extremely cold days. As temperatures increase, some of the increased mortality from extremely hot days is expected to be offset by a decline in mortality from cold days. However, some recent literature has questioned the link between winter temperatures and excess mortality (Ebi & Mills, 2013). If the reduction in mortality from extreme cold does not materialize, the impacts of climate change on mortality might be substantially larger, particularly in APEC member economies at higher latitudes.

1.2.3 Coastal and river flood mortality

Temperature rise is expected to increase the frequency and intensity of coastal and river flooding, which could cause small increases in mortality. Higher sea levels are likely to increase the frequency and intensity of coastal floods (Hinkel et al., 2014). Warmer temperatures are expected to trap more moisture in the atmosphere leading to more intense rainfall and an increase in the frequency and intensity of river floods (Coffel, Horton, & de Sherbinin, 2018, Dottori et al., 2018). Across the APEC region today, annual average mortality from flooding is estimated at 1,400 deaths a year from river flooding and 900 a year from coastal flooding. Given these relatively low baseline mortality levels, absolute increases in mortality from climate change are likely to be modest.

The health impacts from coastal and river flooding using the DIVA model (Hinkel & Klein, 2009) for coastal floods and estimates from Dottori et al. (2018) for river floods. Under the baseline scenario, it is assumed that no adaptation measures are undertaken. Adaptation measures, such as new or improved sea dikes or levees, can reduce the risk of flooding to people and property. The adoption of better flood warning systems, which could also reduce the risk to people, are also not considered here.

Across the APEC region, increased coastal flooding underline the baseline scenario could cause an additional 5,000 deaths per year by 2100 compared to today. Mortality from river floods in the APEC region is expected to increase modestly by around 300 deaths per year by 2050 and 500 deaths per year by 2100. China is expected to experience the largest absolute increase in mortality from river flooding, with deaths increasing by 130 per year by 2050. By 2100, Viet Nam, Thailand and the Philippines also experience a sizeable increase in mortality from river floods.

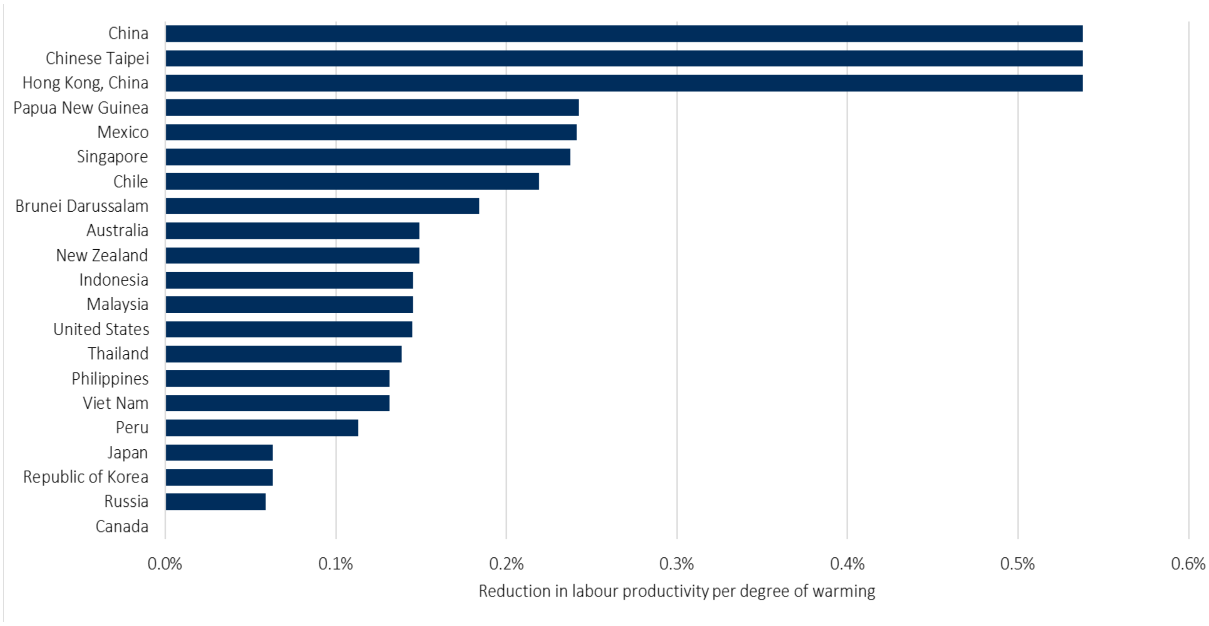
1.2.4 Disease

Rising temperatures are likely to change the incidence of vector borne and hot and cold related diseases, which could negatively impact labor productivity. Rising temperatures could increase the existing range of mosquito borne diseases such as malaria and dengue fever and the prevalence of heat related diseases. If untreated these diseases can increase the disease burden in the population. As well as negative human impacts and increased spending on healthcare, this is likely to generate negative impacts for labor productivity (Levi, Kjellstrom, & Baldasseroni, 2018).

This report uses estimates from Roson and Sartori (2016) to assess the disease related health impacts from climate change. Roson and Sartori (2016) estimate the effect of increases in temperature on labor productivity, assuming a linear damage function without medical advances or changes in behavior to treat or avoid infections. They assess vector borne diseases, including malaria, dengue and schistosomiasis, heat related diseases and diarrhea. However, the research acknowledges that the impact of the changing incidence of disease from climate change is highly uncertain. In the future, new types of medicine and technology could treat or even eliminate the risk of infection, mitigating potential impacts. This section estimates the disease related health impacts in the absence of this possibility.

China, Hong Kong and Chinese Taipei are expected to experience the largest reductions in labor productivity (0.5% per °C of warming) from climate change induced disease. Papua New Guinea, Singapore, Mexico and Chile are likely to experience moderate reductions in labor productivity of around 0.25% per °C of warming while APEC member economies with temperate climates, such as Canada, Japan, Republic of Korea and Russia, are likely to experience much more minor increases 0.06% per °C of warming. Figure 4 depicts the estimates of the impact of climate change induced variation in disease on labor productivity per °C of warming, from Roson and Sartori (2016).

Figure 4. Impact of disease on labor productivity per °C of warming



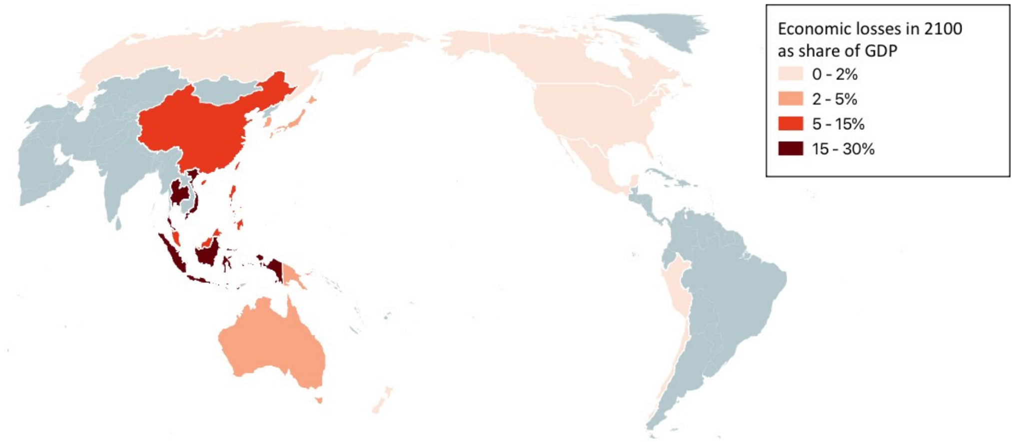
Source: Roson and Sartori (2016)

1.3 Economic impacts of climate change

Climate change is expected to cause global economic damages as higher temperatures reduce productive capacity and increase the risk of damage to land, capital stock and people. Rising temperatures and changing rainfall patterns are expected to reduce agricultural yields, while temperatures reduce labor productivity and increase the level of heat related disease and mortality experienced by workers. Increased sea levels can inundate productive coastal land and increase the damage from coastal floods. More frequent extreme rainfall increases the severity of river floods, which can result in capital destruction. Recent research has suggested the physical impacts of climate change might result in a net global economic impact of 6.6% of GDP by the end of the century (Takakura et al., 2019). Economic impacts will vary across countries depending on current and future temperatures, exposure to extreme weather and economic structures.

The APEC region could experience long-term economic losses equivalent to 7.3% of GDP by 2100 due to the physical impacts of climate change under the baseline scenario. The economic losses are expected to fall most severely on lower middle-income APEC member economies located near the equator. Figure presents the economic losses by member economy by 2100.

Figure 5. Economic losses in 2100 as share of GDP



Source: Vivid Economics

1.3.1 Modelling the economic impacts of climate change

Climate change will cause economic losses both through long-term reductions in productive capacity and through increased losses from more frequent extreme weather events. Increased temperatures directly impact labor and agricultural productivity and the associated sea-level rises can inundate productive coastal land. For this report, the impact of these 'chronic' climate change impacts on economic output are integrated and modelled using GTAP-IAM, an integrated assessment model which permits climate and trade interactions for 37 countries and 60 commodities groups, allowing for forward looking behavior. The model encompasses the climate change impacts described below, with estimates for each APEC member economy drawn from Roson and Sartori (2016). It is one of many models used within the scientific literature to estimate climate change effects on the macroeconomy. The GTAP-IAM model encompasses the climate change impacts described below, with estimates for each APEC member economy drawn from Roson and Sartori (2016).

Higher average temperatures are expected to reduce labor productivity, particularly in the manufacturing and agricultural sectors. There is a documented empirical relationship between local air temperatures and labor productivity (Somanathan et al., 2018). In addition, as discussed in Section 1.2.4, increased temperatures can increase the disease burden, making labor less productive. The economic implications are likely to be largest in member economies with larger agricultural and manufacturing sectors and those with higher baseline temperatures. Acclimatization and air conditioning might go some way to reduce impacts, although the effectiveness of these measures is uncertain (Roson and Sartori, 2016)

Agricultural yields are sensitive to climatic variables including temperature, precipitation patterns and drought. Agricultural production is likely to be negatively impacted in most APEC member-countries as a result of climate change. The expected impact varies across crops and countries, with the expected effect greatest for APEC economies nearest the equator. For example, wheat yields are expected to decline nearly 20% in Malaysia, Viet Nam and the United States. However, these impacts could be larger or smaller depending on the level of adaption by farmers, firms and organizations, the amount of fertilization due to higher CO_2 concentration and level of future water availability (Roson and Sartori, 2016).

Higher average temperatures are virtually certain to cause rising sea levels, which could inundate low-lying coastal lands. The macro-economic model integrates the effects of the reduction in available land due to inundation from sea level rise. The most severe reductions in available land are expected in the territorially small coastal economies of Singapore (7.7% of land lost) and Hong Kong (4.4% of land lost). The impacts could be larger or smaller, with uncertainty in the response of polar ice sheets to climate change (Horton et al., 2018)

In addition to chronic GDP impacts, temperature rise is expected to result in more frequent and severe river and coastal floods, increasing average expected economic losses. Economic losses from coastal flooding are modelled using the DIVA model, a research modelling framework for coastal systems that assesses biophysical and socio-economic consequences of sea-level rise (Hinkel & Klein, 2009). The economic damages from river flooding in terms of GDP are derived from data published in support of Dottori et al (2018). More details on these models are provided in Appendix A.

1.3.2 Economic impacts

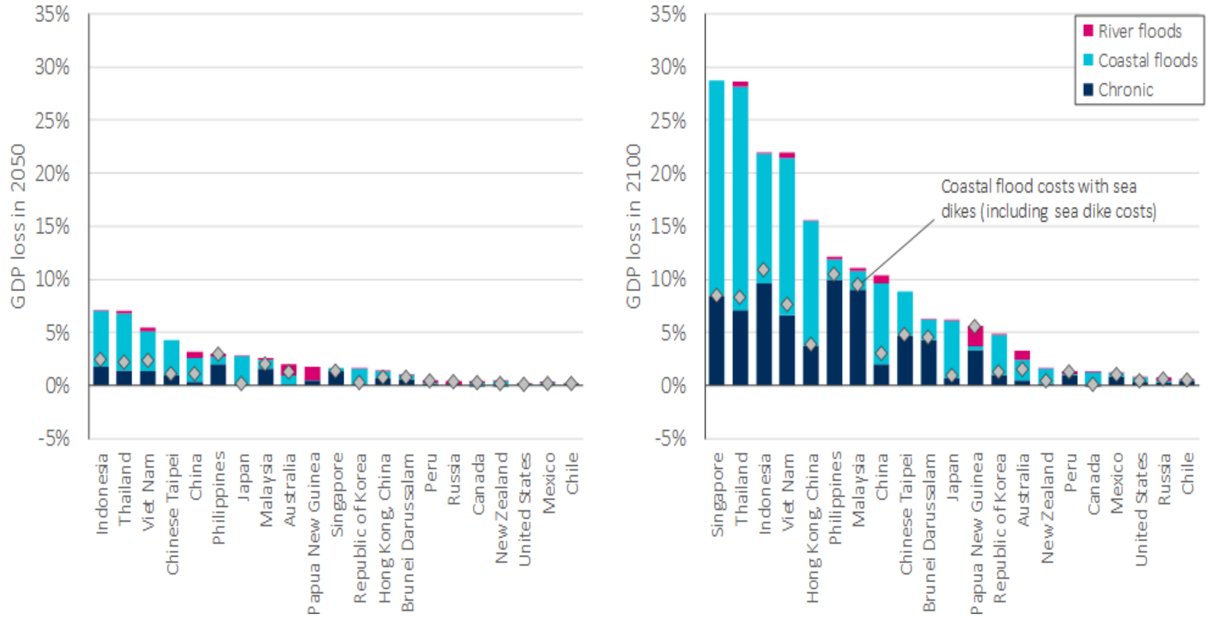
Across APEC, losses of 7.3% of GDP are expected under the baseline scenario by 2100, with developing countries near the equator likely to experience the largest economic losses. Figure shows the combined losses from chronic and acute climate change impacts for each APEC member economy in 2050 and 2100. Singapore, Thailand, Indonesia and Viet Nam could each experience losses of more than 20% of GDP by 2100. Developed member economies located in higher latitudes, including Canada, the United States, Republic of Korea, Australia and New Zealand are expected to see lower losses, of less than 5% of GDP by 2100. However, although many of the countries with the largest losses are developing, there are substantial impacts in the developed economies of Hong Kong and Singapore. There is considerable variation across countries as to the source of losses and relative exposure to impacts of flooding. While coastal flooding in Singapore and Hong Kong could result in losses of more than 15% of GDP, river flooding is likely to cause the larger impacts in Papua New Guinea and Australia, with losses of 2% and 0.8% of GDP by 2100 respectively.

Economic impacts are less pronounced in 2050. Losses in 2050 follow a similar pattern of relative intensity between APEC member economies. However, due to the more modest temperature increases expected by 2050, no member economy experiences losses of more than 7.5% of GDP from the climate change impacts modelled.

Economic impacts could be more severe in certain subnational locations. The results presented above are estimates of average country-level impacts. However, there might be considerable variation in *within* countries, caused by differential exposure to climate change risks. For example, in the United States, the Gulf Coast region is expected to experience a greater increase in sea level rises than the Pacific Northwest (Sweet et al., 2017), which can be expected to lead to more severe coastal flooding impacts. More research is needed to identify how the severity of subnational impacts compare to the estimated impacts at the economy-wide level presented above.

Estimated losses of 7.3% of GDP in the APEC region are consistent with much of the recent modelling literature. For example, Kahn et al. (2019) estimate that a persistent increase of average global temperature of 0.04°C per year would reduce GDP by 7.2% by 2100. Most of the existing climate change-macroeconomy literature estimates the GDP effect of increases in average temperatures to be in the range of a few percentage points of GDP (Kahn et al., 2019).

Figure 6. Economic impacts under baseline scenario

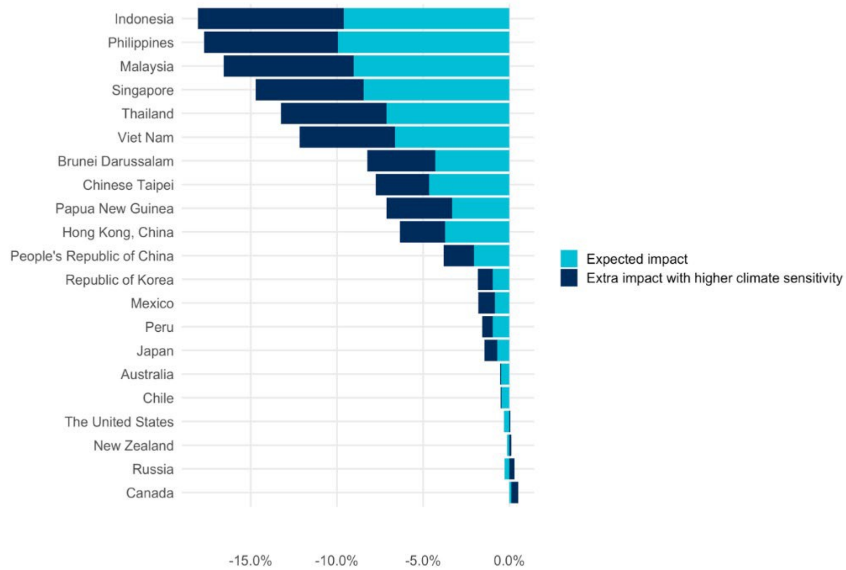


Note: 2050 coastal flood costs with adaptation are unavailable for Papua New Guinea
Source: Vivid Economics

Despite this, there is a risk that the economic impacts of climate change under the baseline scenario could be substantially higher than the macroeconomic impacts presented above. Burke, Hsiang & Miguel (2015) estimate climate change could cause losses of 23% of GDP by 2100 under a worst-case emissions scenario. Figure shows that an extra degree of warming, a plausible outcome of current climate policy, could lead to a doubling of chronic impacts on GDP for most APEC member economies. In addition, there is recent evidence to suggest that the kinds of models used for assessing the impact of climate change on economic outcomes might still underestimate impacts (Schewe et al., 2019). Other studies have suggested the risk of “tipping-points” in the climate system, whereby small changes in climatic variables have large impacts on others, leading to a “Hothouse Earth” pathway (Steffen et al., 2018). For example, small changes in the extent of Artic summer sea ice could amplify warming (Lenton et al., 2008). Because of such concerns, the probability of a disastrous collapse of global welfare due to climate change is seen by many as non-negligible (Weitzman, 2009).

Adaptation measures could substantially reduce negative economic impacts of climate change, particularly from coastal flooding. The DIVA model used for generating estimates of losses from coastal flooding also calculates the costs of building sea dikes to provide an optimal level of protection against coastal flooding. Accounting for construction and maintenance costs, adaptation could limit increased losses from coastal flooding from an average of 5% of GDP in the APEC region to less than 1% of GDP by 2100 for most member economies. Adaptation measures such as air-conditioning or introduction of more temperature-resistant crops could reduce some of the other economic impacts of climate change too.

Figure 7. Extra economic impacts under higher climate sensitivity, 2100



Note: Combined impact of climate change on agricultural productivity, labor productivity and available land
Source: Vivid Economics

1.4 Other impacts of climate change

The results presented above account for the impact of climate change on agricultural productivity, labor productivity and land and capital stock, however, climate change could additionally impact or exacerbate existing stresses in several other fragile human and ecological systems. Given the complexity and potential for non-linearities in these systems, estimates of climate change impacts are uncertain. However, recent literature and historical examples can shed light on direction and scope of possible impacts across.

Lower agricultural yields can be expected to lead to higher food prices, which have historically increased food insecurity and poverty in vulnerable regions. Globally, increased temperatures, more extreme precipitation events and more droughts are expected to negatively impact agricultural yields. These changes could be severe and increase food insecurity and poverty in vulnerable regions. In the past, higher food prices have disproportionately affected lower income segments of the population. For example, it is estimated that the 60% increase in food prices in 2008 pushed 105 million people into poverty in low-income countries (World Bank, 2013). Variability of yields is also expected to increase under climate change, particularly in tropical regions, which could experience in an increase in food insecurity and hunger as crop unexpectedly fail (Challinor et al., 2014).

Climate change could have a significant impact on both internal and between country migration. Hauer et al. (2016) assess the impact of sea-level rise on the potential for movement within the United States, accounting for population growth. The study estimates that increased sea-levels could affect 13.1 million people by 2100, which could lead to a significant internal migration. There are numerous historical examples of environmental degradation in combination with depressed economic activity and extreme weather events leading to large-scale resettling. For example, the 1930s drought in the Great Plains region of the United States, known as the “Dust Bowl,” led to significant migration, with some counties experiencing population declines of 20% (Long & Siu, 2018).

Climate change might also increase social tensions and lead to conflict. Mach et al. (2019) assess the current understanding between climate and conflict. Drawing on the judgements of experts from diverse disciplines, they find consensus that climate has affected conflict within countries in the past and could in the future. Negative economic shocks from climate change may fuel conflict in countries with fragile social and political systems. Volatility in food prices and food shortages, which might increase with climate change, have been found to trigger incidents of conflict (Brück & d’Errico, 2019).

Climate change could increase or perpetuate within and between country inequality. Diffenbaugh & Burke (2019) find that global warming has already likely exacerbated global economic inequality. Lower income groups are typically more exposed to the adverse effects of climate change, more susceptible to the damage caused by climate change and less able to cope and recover from climate change induced damages (Islam and Winkel, 2017).

Changes in climate, growth in human populations and changes in land use are likely to have a severe impact on biodiversity. For example, Newbold (2018) estimates the impact of climate and land-use change on the biodiversity of terrestrial vertebrates. By 2070 around 38% of these species could be lost. The impact of climate change on complex ecosystems is likely to pose additional negative risks to economic activity.

1.5 Mitigating climate change

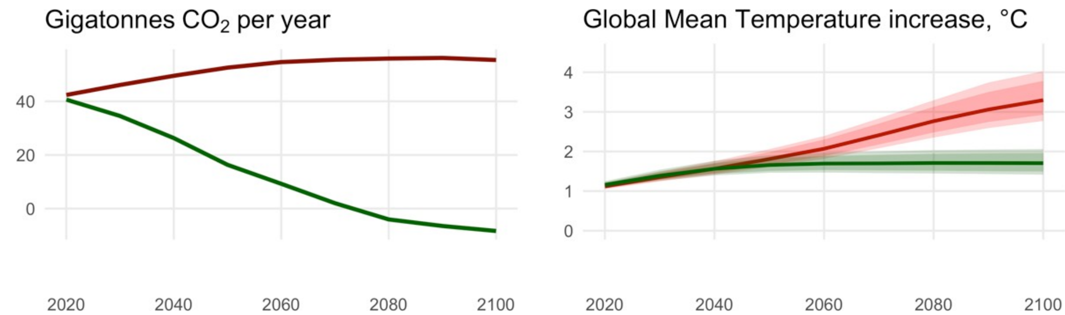
In 2015, signatories to the Paris Agreement agreed to take action to limit global temperature increases to “well below” 2°C and to pursue efforts to limit temperature increases to 1.5 °C relative to pre-industrial temperatures. A wide range of macroeconomic and financial policies are available to help mitigate impacts and achieve this target. These include carbon pricing, as well as fiscal and monetary policy (Krogstrup & Oman, 2019).

Results show that the economic costs of limiting greenhouse gas emissions to levels consistent with the Paris Agreement might be less than the losses expected from unabated climate change. The transition to a low-carbon economy requires a reallocation of resources which can result in economy-wide costs. However, if energy efficiency continues to improve in line with recent trends, the average economic costs of reducing emissions across APEC members are expected to be only 2.6% of GDP in 2050 and 3.4% of GDP in 2100. This is less than the expected damage caused by the physical impacts of unabated climate change. Policy costs are expected to be lowest as a share of GDP in developed economies and highest in energy exporting economies.

1.5.1 Change in global emissions and expected global mean temperature increase

Limiting the increase in global temperatures to well below 2°C requires a sustained reduction in emissions from 2020 to the end of the century. Figure compares a carbon emissions trajectory compatible with the Paris agreement to expected emissions under the baseline scenario. Annual emissions need to reduce rapidly from 2020 and turn negative after 2070, based on the use of Negative Emissions Technologies (NETs). In addition to reducing the quantity of greenhouses gases released into the atmosphere, emissions reduction is associated with a reduction in the emissions of pollutants, including those damaging to human health.

Figure 8. Change in global emissions and expected Global Mean Temperature increase



Note: Global Mean Temperature increases are relative to pre-industrial baseline. Baseline emissions scenario is defined by SSP2/RCP6.0. Emissions reduction scenario is defined by SSP2/RCP2.6. Lighter shaded area shows 25-75th percentile of probabilistic estimates from the MAGICC climate model. Darker shared area shows 17-83th percentile of probabilistic estimates.

Source: Fricko et al., 2017; Vivid Economics

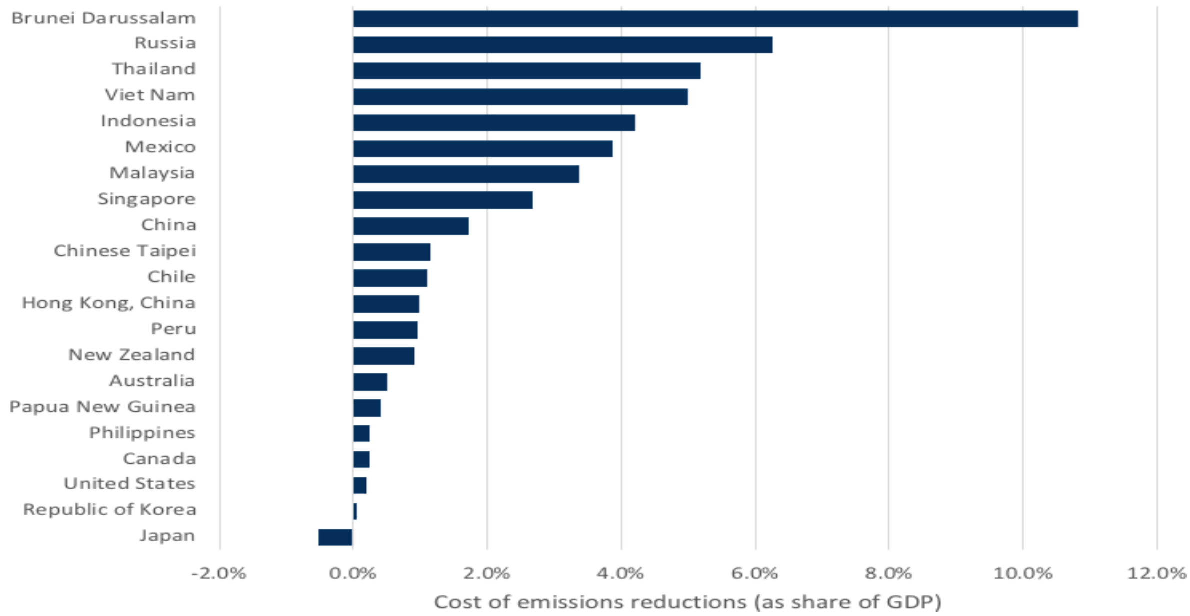
1.5.2 Costs of achieving the Paris Agreement goals

Reducing emissions to a level compatible with the Paris Agreement is expected to cost only an average of 3.4% of GDP across APEC members by 2100. Reducing emissions to this level will have economic and human benefits, which are outlined in Section 1.0. However, using more expensive energy sources also has economic costs. If energy efficiency continues on its current trajectory, the economic costs of achieving emissions reduction are moderate, particularly for developed APEC member economies. Across the region, achieving emissions consistent with the Paris goals in 2050 costs 2.3% of GDP by 2050 (see

Figure for member economy results). This figure does not consider the avoided economic losses caused by higher temperature, which are described in Section 1.0. The costs of achieving the Paris goals are lowest in developed economies, less than 6% of 2050 GDP in equatorial economies, and highest in energy exporting economies. Fossil fuel exporters Brunei and Russia could face policy costs of 11% and 6% of 2050 GDP respectively.

The economic costs of emissions reduction will depend on technological developments and demand-side changes in energy demand. Policy costs will be higher if the current trajectory in energy efficiency does not continue or if population growth is higher than modelled. In line with most Integrated Assessment Models, the modelling assumes the presence of Negative Emissions Technology (NET) later in the century. If NET fails to become economically viable additional costly decarbonization will be required in ‘hard-to-treat” sectors. However, behavioral changes, such as a reduction in meat consumption or travel, could substantially reduce economic costs of emissions reduction (Mundaca, Ürge-Vorsatz, & Wilson, 2019). Costs will also be lower if costs of low carbon technologies, such as zero emissions vehicles and low carbon heat, reduce at a greater rate than expected.

Figure 9. The cost of emissions reduction in 2050 are highest for exporters of fossil fuels



Note: Figure shows cost of emissions reductions as a share of projected 2050 GDP
Source: Vivid Economics

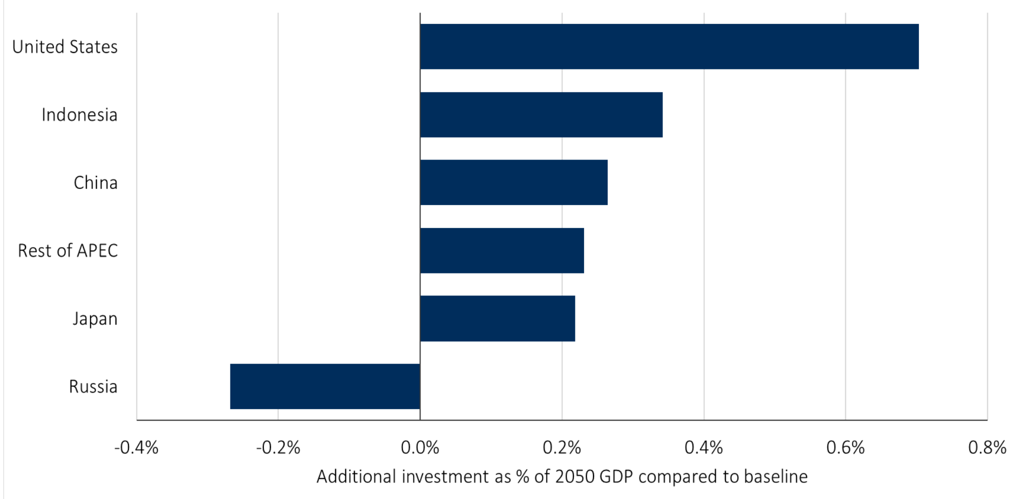
1.5.3 Energy investments needs

By 2050, implementing Paris consistent policies is expected to require an additional $470 billion per year in energy investment in the APEC region compared to baseline.[5] This provides a significant opportunity for investors. As well investment in the generation of renewable electricity and the production of low-carbon fuels, there are also considerable investments required in electricity transmission and distribution and storage. Figure shows the additional annual energy investment needs as a proportion of 2050 GDP that is required in order to meet Paris targets in 2050, based on modelling in McCollum et al. (2018).[6] Total energy investment needs across APEC countries are estimated to be $1.8 trillion per year in 2050, approximately 1.4% of GDP on average. Around 90% of the additional investment is needed in China, the United States, Indonesia and Japan. The United States and China require an addition $220 billion and $160 billion in energy investment per year by 2050 respectively to achieve Paris consistent climate policy. This additional energy investment is driven in part by the need to expand transmission and distribution infrastructure to accommodate the electrification of currently unelectrified end uses. Fossil fuel exporters, such as Russia, could experience a decline in total energy investment needs as investment in hydrocarbon extraction declines.

[5] A discussion of infrastructure investment needs in a range of sectors is provided by Rozenberg and Fay (2019). The estimates presented in this sub-section result from global-level modelling, which is unable to provide a detailed sectoral breakdown of investment requirements.

[6] McCollum et al. (2018) estimates an additional $320 billion in annual energy investment in needed globally between 2015 and 2030 to limit warming to below 2°C. This is comparable to the estimate from the New Climate Economy, which estimates an additional $270 billion in energy investment is needed over this period.

Figure 10. Additional annual investment in the energy system needed per year in 2050 in Paris scenario



Source: Vivid Economics, based on McCollum et al. (2018)

Although reducing emissions requires only a modest increase in total energy investment by 2050, a substantial reallocation of the energy investment portfolio is necessary (McCollum et al., 2018). Globally, it is estimated that low-carbon investments need to overtake fossil investments by around 2025 in order to limit warming to 2°C or 1.5°C (McCollum et al, 2018). By 2050, the share of low carbon investment needs to increase to around 80% of total energy investment. Non-bioenergy renewable investment needs to nearly double, energy efficiency investments need to more than double and electricity system transmission and distribution investments need to increase by almost 50%.

Energy investment needs are uncertain, and the cost of decarbonization will depend on how climate policies are designed. For example, changes in the path of energy efficiency improvements or the cost of low carbon technologies could increase or decrease the quantity of energy investment needed. The estimates presented above estimate energy investment needs for a "middle of the road" scenario of population and economic growth. Increases in either population or economic growth could increase energy demand and energy investment needs. There is also uncertainty in the modelling of future energy investment needs. The estimates shown in Figure above represent the average of six Integrated Assessment Models. Individual models produce varying global estimates of global additional energy investment needs, based on assumptions around the capital cost of low-carbon technologies, energy efficiency improvements and demand management, and the extent to which the transition results in stranded assets. As a result, some models suggest lower investment requirements in the climate change mitigation scenario compared to baseline (Rozenberg and Fay, 2019).

1.5.4 Adaptation investments

In addition to low carbon energy, there is an opportunity to invest in climate-resilient infrastructure to improve adaptation and avoid further losses. The Global Commission on Adaptation estimates that $1 trillion of investment is needed globally between 2020 and 2030 to make infrastructure more climate resilient (Hallegatte et al., 2019). Benefits of such investments are estimated to be four times the costs. The Commission estimates that upgrading infrastructure to be more climate resilient typically only adds around 3% to upfront costs. Yet, climate-resilient infrastructure pays a triple dividend by avoiding losses, reducing risks to existing infrastructure and by safeguarding non-market benefits. For example, investments in mangrove forest preservation and restoration can generate benefits that are 10 times the cost once avoided economic and mortality losses from coastal flooding and non-market benefits associated with fisheries and forestry are considered.

1.6 Mitigating climate change: benefits and co-benefits

Increased ambition of climate policy could mitigate the direct economic losses due to climate change and bring a range of other significant benefits. By 2050, improved air quality resulting from a transition to a low-carbon economy might reduce deaths by around 500,000 per year across the APEC region. By 2100, limiting warming to below 2°C is expected to reduce annual deaths related to extreme temperatures by 380,000 deaths per year. Revenues from carbon taxation are expected to be significant and enable government to reduce labor and other tax rates. Carbon taxation can also encourage the reallocation of economic resources from the informal to the formal sector, increasing government revenues and GDP.

Reducing emissions to levels compatible with the Paris Agreement has both primary benefits (the avoided physical impacts and resulting economic losses) and co-benefits (the secondary impacts of climate policy), outlined in Table 3 and described below.

Table 3. Major co-benefits of climate action

Benefits and co-benefit	Included in analysis
Avoiding economic losses from climate change	X
Avoiding damages to human health from climate change	X
Reduced damages to health by air pollution	X
Increased labor productivity linked to reduced air pollution exposure	-
Increased ecosystem service provisions and enjoyment of environmental amenities	-
Revenue-recycling effect: environmental taxes generate revenues that can be recycled through cuts in pre-existing marginal tax rates	X
Potential for 'green jobs'	-
Agricultural productivity increases from better soil carbon and reduced ground-level ozone	-
Decrease in informal-sector activity and increase in formal sector activity	X
Increased biodiversity	-

Source: Hamilton et al. (2017), Vivid Economics

1.6.1 Avoided physical impacts

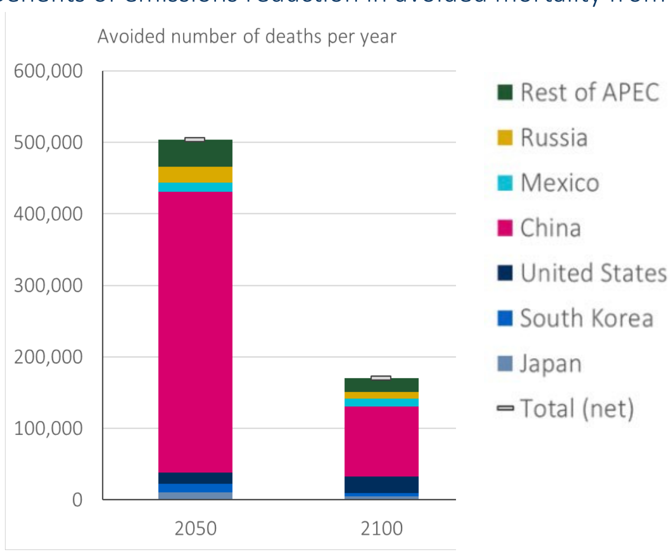
Fulfilling the Paris Agreement is expected to limit physical impacts of climate change, including the number of days with dangerous heat, sea level rise, extreme precipitation events and the likelihood of drought. Differences in climatic conditions between the baseline and the Paris-compatible scenario are much more significant in 2100 compared to 2050. In 2100, limiting global warming to below 2°C could reduce the number of days with extreme heat by 50 or more days in Brunei, Hong Kong, Indonesia, Malaysia, the Philippines, Thailand, Singapore and Viet Nam by 2100. The difference in sea level rise is more modest between the two scenarios, since sea levels react with significant lag to emissions and temperature rise. Limiting global warming to below 2°C can also significantly reduce impacts of global warming on extreme rainfall patterns and drought. For example, limiting climate change is expected to reduce the annual probability of severe drought by 25 percentage points in Chile.

1.6.2 Health benefits

Improvements in air quality resulting from a reduction in emissions could avoid 500,000 deaths per year by 2050 across the APEC region. Figure shows the expected potential benefits from reduced air pollution across member economies in both 2050 and 2100. In absolute terms the benefits are largest in China, where 390,000 deaths are expected to be avoided in 2050. Avoided deaths are lower in 2100, since here technological progress and declining populations are expected to lead to a significant reduction in consumption of polluting energy sources even under the baseline scenario. The findings are consistent with prior studies that have identified reductions in the health damages from air pollution as the largest co-benefit from climate policy (Hamilton, Brahmbhatt, & Liu, 2017). Nonetheless, deaths from air pollution are not expected to be eliminated completely, since some fossil fuel consumption is expected to continue and natural air particulate matter, such as fine dust particles, will remain in the atmosphere.

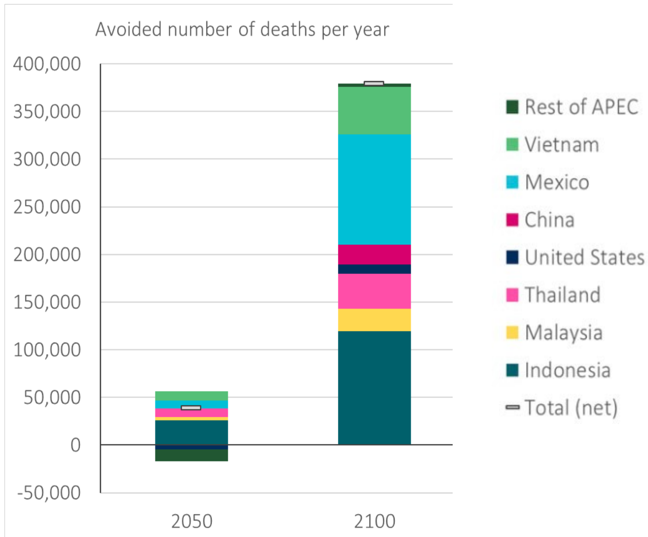
Limiting temperature increases could avoid nearly 400,000 deaths per year caused by extreme temperatures by 2100. Figure presents the benefits from Paris compatible policy and highlights member economies that could experience the greatest potential benefits. Mexico and Indonesia could accrue the largest benefits from Paris-compatible policy. The benefits of action to reduce global warming on deaths from extreme temperatures are significantly greater in 2100 than in 2050. A reduction in the number of extremely cold days is expected in the middle of the century, which reduces some mortality from extreme cold. However, by the end of the century, this positive effect of warming is eclipsed by an expected substantial increase in the number of deaths from excess heat.

Figure 11. Benefits of emissions reduction in avoided mortality from air pollution



Source: Vivid Economics

Figure 12. Avoided mortality from extreme hot and cold days from Paris compatible policy compared to baseline



Source: Vivid Economics

The direct health benefits of avoiding increased coastal and river flooding are modest compared to the human health benefits from reduced air pollution and fewer days of extreme heat. Limiting global temperature increase to less than 2°C might reduce coastal flood mortality by around 2,000 deaths per year across APEC member economies. Additional figures in Appendix A show the direct benefits from Paris compatible policy relative to baseline for the APEC region and the member economies that could benefit most from policy. Across the APEC region, projections suggest that around 700 deaths per year from river flooding might be avoided if climate change is limited.

1.6.3 Revenues from carbon taxation

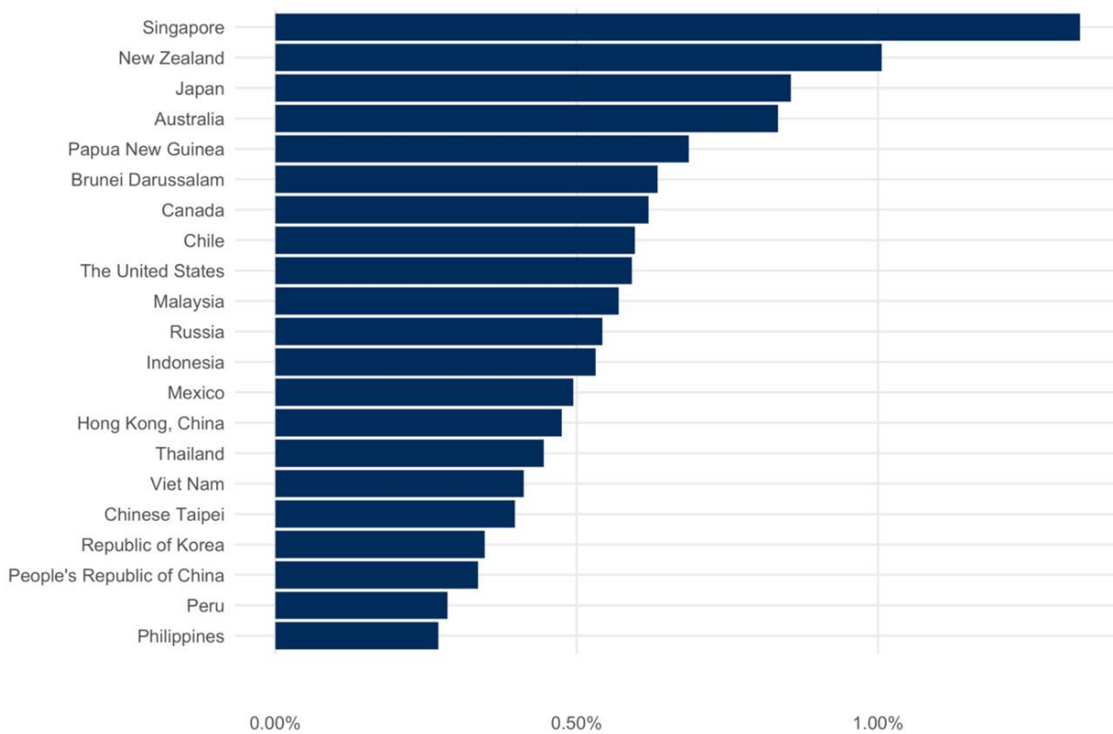
Enacting a carbon tax could result in significant revenues for central governments by 2050. Carbon taxes are a key potential policy instrument to reduce greenhouse gas emissions. Revenues from carbon taxation can be used to reduce labor or other taxes or for climate mitigation, pursuit of other development objectives or debt reduction (World Bank, 2019). Currently, national carbon taxes are implemented in the Canadian, Chilean, Mexican and Singaporean APEC member economies, although at rates below those required to reduce emissions to levels compatible with the Paris agreement (World Bank Carbon Pricing Dashboard). Figure 3 shows projected revenues as a share of 2050 GDP for each member economy if policies to achieve Paris compatible emissions reductions are put in place, based on modelling with GTAP-IAM.[7] Projected revenues from carbon taxes are typically higher in more developed economies due to higher emissions in these countries, though actual revenues depend on the carbon intensity of a specific economy and the cost of available low carbon options. GTAP-IAM includes a stylized

[7] The model solves for the necessary carbon tax rate in order for each member economy to achieve emissions reductions consistent with a below 2°C pathway. Revenues from carbon taxation are therefore endogenous to the model. The model assumes that energy efficiency continues to improve in line with recent trends. If improvements in energy efficiency are slower than assumed, a higher carbon tax will be required in order to achieve the same emissions profile, leading to higher revenues. Emissions trade between countries is not modelled, so the modelled carbon tax varies across member economies. The range of modelled carbon taxes in 2050 is $16 to $174 USD.

carbon price. In practice, the price design of carbon taxes should consider sustainable revenue objectives and equality considerations.

In addition to raising revenue, carbon taxes and other carbon pricing mechanisms can otherwise help increase investment in renewable energy (discussed in chapter 3).

Figure 13. Predicted revenues from carbon tax in 2050 as share of GDP under emissions reduction scenario



Source: Vivid Economics

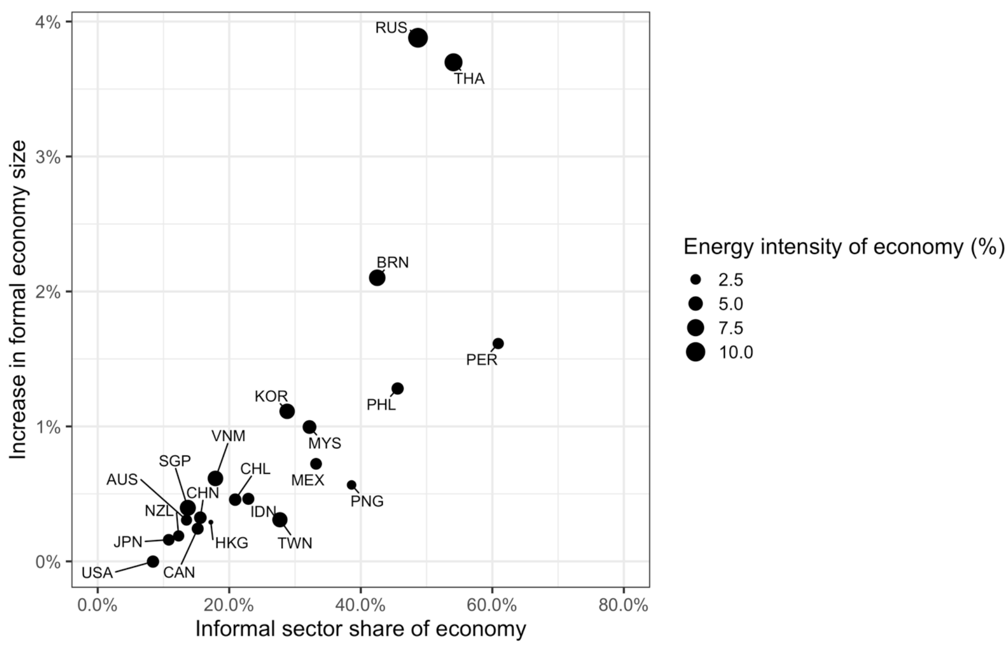
1.6.4 Benefits of carbon taxation in the presence of an informal sector

Carbon taxation can lead to a reallocation of economic activity from the informal to the formal economy, a major benefit of carbon policy for many APEC member economies. Most economic models expect the imposition of a carbon tax to lead to reductions in economic output due to the effective increase in the cost of energy. However, many APEC member economies have large informal sectors, something that these models fail to consider.

Taxing emissions can lead to a reallocation of economic activity from the informal to the formal sector (Bento et al., 2018). There are two channels through which this happens. Firstly, informal firms indirectly pay carbon taxes through purchases of formal energy commodities. Secondly, revenues from a carbon tax enable reduction of labor taxation, making the formal sector relatively more attractive, encouraging a transfer of resources away from the informal sector. Where the informal sector is large enough, imposing a carbon tax can result in an *increase* in the size of the formal economy, since these channels can dominate any negative effect from the imposition of a carbon tax.

Figure shows that imposing a carbon tax might cause increases in formal sector activity in most APEC member economies. These results are based on a model of the impact of carbon pricing in the presence of both informal and formal sectors presented in Bento et al. (2018). The model has been calibrated individually for each APEC member economy using data from the Global Trade Analysis Project. A full model description is provided in Appendix A. The figure shows the implications of the imposition of a carbon tax which reduces emissions by 25% within each APEC member economy. For all countries apart from the USA (which has the smallest informal sector), imposing a tax on emissions within the model causes a positive increase in GDP. Russia and Thailand, which both have large informal economies, see sizeable increases in the formal economy of 4%.

Figure 14. Estimated increase in formal sector economy due to a carbon tax which reduces emissions by 25%



Source: Vivid Economics

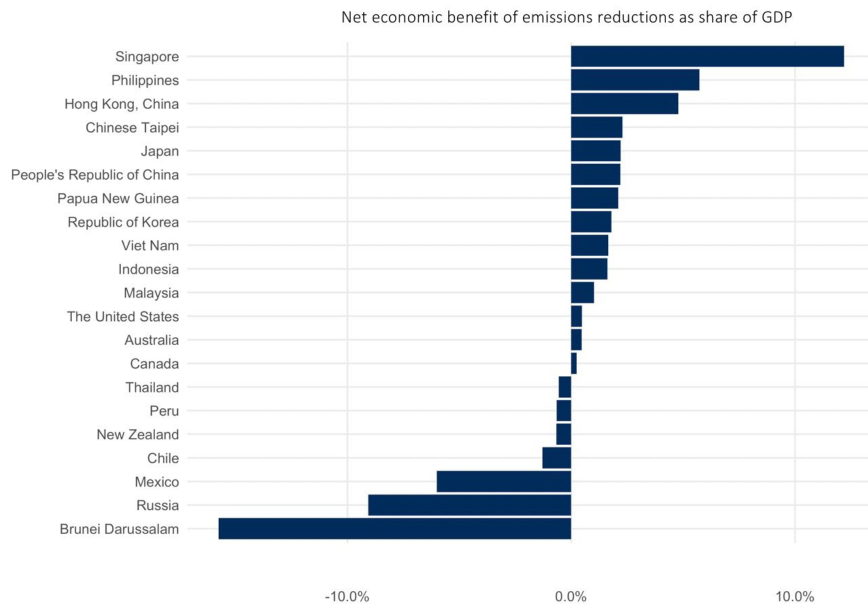
1.6.5 Comparing economic costs and benefits of emissions reduction

The direct economic costs and benefits of emissions reductions are compared assuming global action to reduce emissions. If emissions reductions are not coordinated, a member economy could experience both the costs of emissions reduction and the economic costs associated with higher temperatures described in Section 1.4, though such a member economy will nonetheless likely benefit from the air pollution health co-benefits described above. The cost and benefit comparison examines the economic benefits from avoiding the physical damages described in Section 1.3.2 with the costs described in Section 1.5.2. The comparison does not account for the benefits of carbon taxation in terms of reducing informal sector activity, for reduced mortality from air pollution and the other co-benefits already identified as outside the scope of this analysis in Table 3.

By 2100 the direct economic benefits of mitigating climate change are greater than the costs of emission reductions required to do so in most APEC countries. Achieving Paris-compatible emissions is expected to cost an average of only 3.4% of GDP across APEC member economies, with the costs lowest in developed economies and highest in energy exporting economies. In 2050, the economic costs of emissions reductions are generally larger than the economic losses caused by unabated climate change. However, by 2100, the economic benefits of lower temperatures are larger than the costs of emissions reduction in most APEC member economies. In Singapore, benefits from avoided climate change as a share of GDP are 12 percentage points higher than costs, with economic costs significantly higher than benefits only in Mexico, Russia and Brunei Darussalem.

Figure sets out the results at the member economy level.

Figure 15. In 2100, benefits of lower temperatures are larger than the costs of emissions reduction in most member economies



Note: Chart shows the combined economic costs and benefits (through reduced temperatures) of achieving emissions compatible with Paris goals, with no adaptation. Numbers above zero indicate that the benefits are larger than the costs.

Source: Vivid Economics

1.7 Summary

Climate change poses severe human life and economic consequences for APEC member economies. Temperature increases of more than 3°C over preindustrial levels could generate economic losses equivalent to an average of 7.3% of GDP by 2100, with lower middle-income member economies located near the equator expected to feel these effects most acutely.

Yet there are many estimated benefits for APEC member economies to limiting global warming to well below 2°C in line with the Paris Agreement goals and to limiting the frequency and intensity of days of extreme heat and natural disasters. Beyond reducing deaths across the region by an estimated 500,000 per year by 2050, preventing extreme climate change could also save money. In fact, the costs of transitioning to a low-carbon economy is estimated to be the equivalent of only 2.6% of GDP in 2050 and 3.4% of GDP in 2100, lower than the economic losses associated with maintaining the status quo. Strict climate policy could also generate as much as $470 billion in new energy investment opportunities across the region per year by 2050. Further, carbon taxes could raise revenues by an average of 0.6% of GDP across APEC member economies by 2050.

Chapter 2.
The Impacts of Climate Change on Financial Institutions

Last January, Pacific Gas and Electric Company (PG&E), California's largest utility, filed for bankruptcy, citing liabilities of $30 billion or more from wildfires. The Wall Street Journal dubbed this case "the first climate-change bankruptcy" and warned that this failure will not be the last.[8] Financial regulators, including the Bank of England's Governor Mark Carney, also sounded the alarm and recently predicted that "companies that don't adapt [to climate change]—including companies in the financial system—will go bankrupt without question." But the central banker also expects "great fortunes [to be] made along this path aligned with what society wants."[9]

These two examples illustrate the profound transformation that is taking place in the perception of climate change inside financial institutions and financial regulators. "Climate change is a source of financial risk" is the message conveyed by more than 40 central banks and financial regulators grouped into the Central Banks and Supervisors Network for Greening the Financial System. But as the members of this network and many others underline, the massive amounts of capital and the new financial products required to fund the transition to a low-carbon economy ($470 billion in annual new energy investment needs by 2050 in APEC member economies alone), also constitute an opportunity for financial institutions. Everybody agrees on one conclusion: climate change will profoundly transform global economies and financial institutions must be ready to face the costs that it will generate, as well as seize the business opportunities that it will create.

This chapter describes the financial risks of climate change, discusses the regulatory initiatives that are currently on the table regarding climate financial risk management, and presents the recent developments in green credit markets, of which growth represents an opportunity for financial institutions. It solely focuses on the financial risks stemming from climate change for financial institutions and does not address the issue of the impact of financial institutions' capital allocation decisions on climate change (i.e., their alignment with the transition to a low-carbon economy). Similarly, it describes the measures and policies that can mitigate these risks, without discussing their alignment with the transition. However, measures and policies that aim to reduce financial institutions' exposure to transition risks are generally also aligned with the transition – because the economic activities that are the most exposed to transition risks are, by definition, the ones that are the less aligned with climate goals.

2.1 Climate change as financial risk

"Climate-related risks are a source of financial risk": the opening sentence of the first comprehensive report by the Central Banks and Supervisors Network for Greening the Financial System (NGFS, 2019) is a wake-up call for most investors. The message conveyed by more than 40 central banks and supervisors is crystal clear: climate change and the transition to a low-carbon economy that is necessary to mitigate it will have some consequences for investors' portfolios.

2.1.1 From climate change to climate financial risk

[8] "PG&E: The First Climate-Change Bankruptcy, Probably Not the Last", Wall Street Journal, January 18, 2019.
[9] "BoE's Carney warns of bankruptcy for firms that ignore climate change", Reuters, July 31, 2019.

Climate-related costs impact equity and debt market value through different channels. In short, the market price of a financial asset is equal to the *expected present value of its future payoffs* plus a risk premium. For equity instruments, payoffs are equivalent to the dividends paid by the firm issuing the equity. For debt instruments, they are the interest and the repayment of the principal paid by the borrower. If the issuer of a financial instrument defaults, the payoffs also include the liquidation value of the assets owned by the issuer – for equity instruments – and the value of the assets posted as collateral by the issuer – for debt instruments. The physical costs generated by climate change and the transitions costs induced by a move to a low-carbon economy reduce asset payoffs and the value of the assets owned by the issuer of financial instruments.

Physical costs

Physical costs correspond to the potential economic and financial losses caused by climate-related hazards (as described in chapter 1). They include acute hazards resulting from increased droughts, floods and storms, and chronic hazards resulting from progressive shifts in climate patterns such as increasing temperatures, sea-level rise and changes in precipitation. Each has both direct impacts (e.g., property damage) and indirect impacts (e.g., supply chain disruptions).

Physical costs can reduce revenue from decreased production capacity (e.g., from supply chain interruptions and worker absenteeism) and lower sales (e.g., from demand shocks and transport difficulties) and can increase operating costs (e.g., from the need to source inputs from alternative more expensive suppliers) and increased capital costs (e.g., from damage to facilities). They can also reduce the value of issuers' assets both through direct damages (e.g., to houses and factories during), but also through write-offs of assets situated in high-risk locations.

Transition costs

Transition costs are the costs of economic dislocation and financial losses associated with the process of adjusting toward a low-carbon economy. They come from changes in policy (e.g., carbon prices or emissions caps), technology (e.g., low-carbon technologies becoming more competitive than carbon-intensive ones) and market preferences (e.g., households switching toward greener consumption). All three types of change require that firms adapt their business models to the new economic conditions. Not all sectors and firms will be equally impacted by these costs given things like the availability of low-carbon alternatives to a sector and the preparedness of individual firms.

Transition costs can affect payoffs in several ways, including: research and development expenditures in new and alternative technologies, costs to deploy new practices and processes, reduced demand for carbon-intensive products and services, and increased production costs due to changing input prices (e.g., for energy and water) and output requirements (e.g., for carbon emissions and waste treatment). The transition to a low-carbon economy can also significantly affect the value of equity and debt issuers' assets: re-pricing of stranded fossil fuel assets is a case in point, as is changes in real estate valuation due to stricter energy efficiency standards.[10]

Climate change and market expectations

[10] In the Netherlands, for example, the price difference between low-energy homes and others can be explained by the costs involved in making them more energy-efficient, which is mandatory now under European legislation (see DNBulletin, "Energy efficiency is factored in well in the Dutch housing markets", September 12, 2019).

When payoffs are not known in advance, investors must rely on their forecasts to assess them and value a financial asset. Expectations about future payoffs thus play a pivotal role in determining the market price of financial assets. Expected dividends, expected probabilities of default and expected values of liquidated assets and of collaterals underpin all financial asset prices. In financial markets, asset price movements are thus highly dependent on the evolution of investors' expectations. Their revision can lead to sharp price movements (see Cambridge Institute for Sustainability Leadership, 2015).

There are two situations in which climate-related events can trigger such expectations revisions. First, a change in expectations can result from the occurrence of exogeneous events. A storm, for example, can seriously damage buildings and drastically reduce their value as collateral. In reaction, as investors integrate this new collateral value in their payoff expectations, the price of the debt instruments that are backed by these buildings decreases. The realization of transition risks can have similar effects. The introduction of a carbon tax, for example, will impact the profits of firms using carbon-intensive inputs. Financial analysts will integrate this fact in their payoffs forecasts when it becomes clear that the government is likely to introduce such a policy (i.e., when the government credibly commit to its introduction) and revalue assets accordingly. When the uncertainty about government's commitment to a policy increases and the risk of a policy reversal become large, one can expect more volatility in expectations, and therefore in prices.

Note that the realization of a climate-related risk can trigger significant and rapid change in asset prices because, when such a shock happens, investors revise their expectations for the entire stream of future payoffs. Changes in costs that occur over relatively long periods of time are thus immediately integrated and cumulated in investors' expectations, and thus into market prices.

Second, expectations revisions can also be endogenous. This happens, for example, when financial analysts change their forecasting models or update their parameters to reflect new developments in forecasting techniques (e.g., when better models to forecasts climate-related costs become available). The introduction of new sources of costs into a forecasting model is a case in point for such endogenous expectation revision. This case is particularly relevant for climate-related costs. Indeed, for long, these costs have been ignored or understated by financial analysts. Standard financial forecasting models were simply not integrating them. The situation is changing as the awareness of climate-related costs grows in the society. Models that integrate climate-related costs in asset valuation are now available (see, e.g., Monnin, 2018) and an increasing number of investors are starting to use them. This might lead to a significant revision of investors' expectations.

A key question for the likelihood of expectation revisions is whether climate-related costs are sufficiently reflected in current financial market forecasts. If they are not, then there is a risk that investors significantly revise down their payoffs expectations once they start integrating climate-related costs in their forecast. This could trigger large downward revaluations of asset prices and thus constitute a risk for the financial sector.

Amplification mechanisms on financial markets

Downward price movements triggered by the revision of investors' expectation can then be exacerbated by the structure of financial markets and the way they are functioning. There are several channels by which asset price movements can be amplified on financial markets (herding behavior, speculation, financial frictions, etc.). Considering amplification mechanisms on financial markets is important because even if the direct financial risks posed by climate change might seem manageable at first sight, the asset price revaluations that such mechanisms can trigger are much larger than the initial shock. The last financial crisis illustrates this well: apparently small and insignificant initial losses on the subprime mortgage market generated effects that threaten the stability of the entire financial system.

Network effects are an example of amplifying mechanisms on asset markets. Such effects imply that initial losses due to climate-related events in one sector or for one financial institution can percolate through the entire economy or through the entire financial system. At the economic level, firms are not only affected by the consequences of climate change on their own activities but also by its effects on their supply chains or on their customers. Cahen-Fourot et al. (2019), for example, show that a cap on coal production would strand assets in the mining sector, but also trigger waves of asset stranding in other sectors – like electricity and gas, coke and refined petroleum products, basic metals and transportation – through the input-output structure of the economy. At the financial level, financial institutions that are exposed to climate risky assets will directly be impacted by a decrease in the price of these assets. But financial institutions that are not directly exposed to them might also suffer losses through their exposures to other financial institutions. Battiston et al. (2017), for example, show that the indirect exposure of European banks to climate-policy-relevant sectors is as large as their direct exposure.

2.1.2 The impact of climate change on financial institutions: existing evidence

The bulk of climate-related costs is yet to materialize but some early empirical evidence of their effect on financial assets is already available.

Impact of physical risks on asset prices

There are several studies that show that the occurrence of climate-related hazards – i.e. the materialization of physical risks – significantly impact financial asset returns or the payoffs that underpin them. Kruttli et al. (2019), for example, find that within the 120 trading days after the landfall of hurricanes, the stock returns for firms operating in the disaster region is significantly lower than the returns of other firms in the US. Droughts are another case in point: Hong et al. (2019) show that stock returns in the food industry are significantly lower in countries that experience increasing drying weather conditions than in other countries. Other studies find that physical costs affect firms' profits – i.e., the payoffs of financial assets – and thus potentially their market price. Higher temperatures, for example, negatively impact firms' profits in some specific sectors (Addoum et al., 2019 and Hugon and Law, 2019).

Physical damages from extreme weather events associated with climate change also affect the ability of borrowers to service their debt. Noth and Schüwer (2018), for example, find that, in the U.S., banks operating in regions hit by weather-related disasters observe higher non-performing loans and higher foreclosure ratios than others. This significantly increases the default probabilities of these banks. Klomp (2014) finds similar results for a sample off banks in 160 countries over the period from 1997 to 2010.

Impact of transition risks on asset prices

Evidence on the impact of transition costs are scarce as the transition to a low-carbon economy is yet to happen. However, Bernardini, et al. (2019) provide some insights on how such a transition can impact firms' profits within a specific sector. They study the case of European electric utilities and show that, following the progressive introduction of economic incentives by the European Union to stimulate investment in renewable energy, like a policy shock, the profit of electric utilities companies using non-renewable energy as input fell sharply whereas it stayed constant for companies using renewable energy as input.

There is also evidence that transition costs impact borrowers' financial soundness. The measures taken by Chinese authorities to foster the transition to a low-carbon economy provide a useful case study to highlight the impact of policy-triggered transition risks on debt instruments. Huang et al. (2019), for example, show that after the implementation of the Clean Air Action launched by the Chinese government in 2013, default rates of high-polluting firms rose by around 50%. In the same context, Cui et al. (2018) highlight that Chinese banks with a higher green credit ratio – i.e., banks that are less exposed to loans to polluting firms – experience lower non-performing loans.

Do financial markets adequately reflect the risks of climate change?

The question whether financial markets currently adequately reflect climate risk is important; if they do not, then the likelihood to observe sharp expectation revisions due to climate-related costs is significant. The empirical evidence on this question is not clear-cut, but it provides strong suspicion that financial markets currently underprice climate risks.

Empirically, there are several ways to shed light on the question of whether climate financial risks are already priced-in in current markets. First, in efficient markets, if investors integrate future climate costs in their forecasts, then current information about such costs should not be able to forecast future returns. Several examples show that this is not currently the case. Hong et al. (2019), for example, find that the trend in droughts in a country forecasts the stock returns for companies in the food industry. Kumar et al. (2019) find that firms' sensitivity to temperature anomalies forecast their stock returns. Both studies conclude that this return predictability is consistent with asset prices underreacting to climate change risks.

Second, if analysts correctly understand the impact of climate events on asset payoffs, they should revise their payoff forecasts once such an event occurs. Addoum et al. (2019) find no evidence that analysts adjust their earnings forecasts after firms have experienced an extreme temperature event that affects their profits. This suggests that analysts do not fully integrate the impact of climate change in their expectations. Griffin et al. (2015) provide a counterexample of analysts' forecasts revision after receiving news on transition risks: they find that stock markets reacted after the publication of a 2009 paper in *Nature*, which concluded that only a fraction of the world's existing oil, gas, and coal reserves could be emitted if global warming by 2050 were not to exceed 2 °C above pre-industrial levels. This result hints that investors revised their payoff forecast downward after becoming aware of possible stranded assets in the oil and gas sector. The small magnitude of the reaction contrasts however with the predictions of some analysts and commentators of a substantial decline in the shareholder value of fossil fuel companies from a carbon bubble. This small reaction could be explained by the current lack of political consensus around climate policies and thus the low probability that such policies will be implemented soon.

Third, if investors price-in climate risks, then assets exposed to these risks should trade with a premium. Bansal et al. (2016) and Balvers et al. (2017) finds that stocks that are more exposed to temperature shock – i.e., to physical risks – entail a significant risk premium. In contrast, Görgen et al. (2019) find that stocks that are more exposed to transition risk deliver lower returns than others, which is inconsistent with a risk premium. Evidence that green bonds (bonds that are less likely to be exposed to transition risks), trade at higher price or lower yield than non-green bonds with similar characteristics (evidence of a "green bond premium"), is mixed for corporate bonds.[11] Finally, Delis et al. (2019) and Huang et al. (2019)

[11] Gianfrate and Peri (2019) estimate the green bond premium to 20 bp over a period from 2013 to 2017 for European corporate issuers. Nanayakkara and Colombage (2019) highlight a green bond premium of 63 bp on corporate green bonds over the period 2016 to 2017 in a sample of 25 countries. In contrast, Zerbib (2019) and Hachenberg and Schiereck (2018) find that the

find evidence that banks charge a risk premium for loans that are exposed to transition risks. However, the economic significance of this risk premium is rather small and is very unlikely to match the potential losses from transition costs. This premium may also reflect reputational risks rather than transition risks.

2.1.3 Climate change and financial institutions: what lies ahead?

Several studies provide an assessment of the impact of future physical and transition costs on asset prices. Campiglio, Monnin and von Jagow (2019) review them. Among all available methodologies, they argue that stress-tests are more able to give an accurate picture of the climate risks that investors face in the short and medium term. According to their review, Vermeulen et al. (2019) give the most sophisticated estimation of transition risks currently available. These authors show that, in the case of a transition triggered by both a policy and a technological shock, the portfolios held by Dutch insurers and pension funds, which include equities, bonds and loan instruments, could lose up to 10% of their value within five years. The Cambridge Institute for Sustainability Leadership (2015) gives similar figures but estimate that a 10% loss in diversified asset portfolio could happen within one year if investors integrate future transition costs in their expectations. The same authors also estimated the impact of physical costs on asset prices in the case of a no-transition scenario. In such a case, a diversified portfolio – i.e., a portfolio mixing equity and debt instruments – could lose up to 40% of its value within 18 months after investors adequately reflect future physical costs in their expectations.

Note that these studies do not assume any second-round, amplification effects on financial markets after the initial losses. Battiston et al. (2017) explore this hypothesis. They find that such second-round effects could more than double the impact of the initial shock due to cross-exposures between financial institutions.

The results presented above, together with others, can then be used to inform the definition of" climate stress tests" that investors can use to assess the impact of climate risk on their portfolios. They can also help financial regulators in establishing the stress test scenario that they could ask financial institutions to run.

2.2 Financial regulators' responses to climate risks

Financial regulators (e.g., governments, insurance industry and pension fund regulators and corporate governance entities) are widely acknowledging that climate change is a source of financial risk (see NGFS, 2019). This also represents a challenge for their supervision and regulation activities (see Campiglio et al., 2018) and pressure is increasing on them to integrate climate financial risk in financial supervision and regulation (see Tooze, 2019). Some of them are beginning to act by seeking to evaluate the climate risk management practices of financial institutions and to check whether they are adequate responses to the financial challenges associated with climate change. The work done by regulators to manage climate risk importantly enables successful integration of climate risk into institutional investors' investment analyses, which is discussed in chapter 3.

2.2.1 The NGFS recommendations

The NGFS is a network of central banks and financial regulators, which aims to accelerate their work on climate and environmental risks. It was funded in 2017 and currently counts more than 45 members from countries on all continents. The countries represent over half of the global GDP, 45% of the global

green bond premium is small and only marginal for corporate bonds. Finally, Tang and Zhang (2019) do not find any consistently significant green premium in a sample of 28 countries.

greenhouse gas emissions and, more importantly, supervise two thirds of the global systematically important banks and insurers. APEC economies are represented in the NGFS by the Reserve Bank of Australia, the Bank of Canada, the Japan Financial Services Agency, the Bank Negara Malaysia, the Reserve Bank of New Zealand, the Monetary Authority of Singapore, the Bank of Thailand, the Hong Kong Monetary Authority, the People's Bank of China, the Banco de México and the Comisión Nacional Bancaria y de Valores (Mexico).

After some initial stock-taking background work, the NGFS recognizes that "there is a strong risk that climate-related financial risks are not fully reflected in asset valuation" and that "there is a need for collective leadership and globally coordinated action" (NGFS 2019, p. 4). Against this background, the NGFS published six recommendations for central banks, financial supervisors, policymakers and financial institutions to enhance their role in the greening of the financial system and the managing of environment and climate-related risks. These recommendations, described below, are primarily aimed at central banks and supervisors, but they can also directly or indirectly be relevant for financial institutions (discussed in chapter 3).[12]

Integrating climate risk into macro and micro-supervision

The NGFS recommends to its members to better integrate climate risk into financial stability monitoring – i.e., into macro-supervision – and into micro-supervision.

Macro-supervision. Concretely, for macro-supervision, the recommendations aim at a better understanding of the climate risk channels to financial risk and a better size of its impacts on the stability of the financial system. The NGFS emphasizes the need to proceed to quantitative assessments of climate financial risks. To do that, the various NGFS subgroups will work on developing a consistent and comparable set of data-driven climate scenarios. Such a set aims at enhancing the comparability of different analyses. Further work is also expected to translate these economic scenarios into financial risk parameters for financial stability analysis. The work done by the Dutch central bank is a good example of how to carry out such an analysis (see Schotten et al., 2016; Regelink et al., 2017' and Vermeulen et al., 2018 and 2019). The Bank of England also announced that it will conduct a climate stress test for selected financial institutions in 2021, to help mainstream climate risk management (Bank of England, 2019), and World Bank Group and International Monetary Fund are developing a climate stress test model for incorporation in Financial Sector Assessment Programs.

The work of the NGFS on defining climate scenarios and sizing their impact on financial stability is important for financial institutions for at least two reasons: first, the scenarios defined by regulators, as well as the models to translate them into financial costs, are likely to become the standards for the financial industry when it comes to climate financial risk analysis. Regulators might choose the option to ask financial institutions to run the stress tests that they have defined and aggregate the results to gain insight on their impacts on the broader financial system. In that case, financial institutions would need to adapt their internal stress methodologies to make them compatible with financial regulators' requirements. Second, the results of these stress test will determine the response of financial regulators in terms of macro-prudential regulation. If climate risk is deemed relevant by them, then they could choose to introduce new macro-prudential measures, such as additional capital buffers.

[12] Note that in this section, we are not discussing the NGFS recommendations on the management of the portfolio of central banks.

Micro-supervision. The NGFS recommends to its members to actively engage with firms to insure that, first, climate-related risks are understood and discussed at board level, considered in risk management and investment decisions and embedded into firms' strategy. This recommendation is like the recommendation of the Financial Sustainability Board's Task Force on Climate-Related Risk Disclosures (TCFD) regarding climate-related risk and governance issues (TCFD 2017, p. 19). Second, this engagement with firms must ensure that climate financial risks are clearly identified, analyzed, managed and reported at the firm level. Supervisors are also recommended to set supervisory expectations to provide guidance to financial firms. Such measures will compel laggard financial firms to revise and adapt their organization at the board level and the risk management level to comply with regulatory requirements.

In addition, the NGFS leaves the door open to the implementation of mitigating measures by financial regulators, when needed. It suggests mitigating measures like, for example, applying capital measures in Pillar 2 for firms that do not meet the supervisory expectations or with concentrated exposure, or, based on risk assessments, integrating climate risk into Pillar 1 capital requirements. Such measure would significantly impact the funding costs of financial firms.

Bridging the data gaps

The NGFS recommends to its members that appropriate public authorities share data that are relevant to the assessment of climate financial risks, and whenever possible, make them publicly available. Public data repositories would also help financial firms in assessing their own financial risks. Chinese firms, for example, welcomed the creation of public database on climate costs by Chinese authorities and used them extensively in the development of their own climate risk assessment systems.

Achieving robust and internationally consistent climate-related disclosure

The NGFS supports the initiatives aiming at creating an internationally accepted disclosure framework and emphasizes the importance of the TCFD as a basis for this framework. For supervisors, the benefits of such a framework is to facilitate the surveillance of the financial system across various jurisdictions, to enhance market discipline, to allow policy to quickly identify environmentally sustainable opportunities and to harmonize the level playing field across jurisdictions. Several important NGFS representatives have spoken in favor of making disclosure, within the TCFD framework, mandatory for firms. The support of the NGFS, and of its members, for disclosure requirements obviously increase the pressure on firms to implement such frameworks.

Supporting the development of a taxonomy of economic activities

The NGFS encourages policymakers to develop a taxonomy of economic activities to identify, first, those activities that contribute to the transition to a low-carbon economy and second, those that are exposed to climate risk. According to the NGFS, a taxonomy would facilitate the identification, assessment and management of climate financial risk and mobilize capital for low-carbon investments. On the one hand, such a taxonomy is an opportunity for financial firms, as it would help them manage climate risk, but also identify economic activities that constitute opportunities for the development of their business. On the other hand, a taxonomy is also a key element for the implementation of new regulatory measures to mitigate climate risks.

China has already implemented such a taxonomy and the European Union (EU) is currently developing its own version. The aim of the EU taxonomy, which is likely to become the reference point for others, is to provide practical guidance for policy makers, industry and investors on how best to support and invest in economic activities that contribute to achieving a climate neutral economy. Experts have already identified low-carbon activities but also transition activities in order to compile the most comprehensive classification system for sustainable activities to date (EU Technical Expert Group on Sustainable Finance, 2019). The proposal by the EU Commission awaits agreement by other co-legislators.

2.2.2 The Bank of England: a leading example in developed economies

The Bank of England, through the Prudential Regulation Authority (PRA), is the regulator of the UK financial sector. The PRA supervises and regulates banks, building societies, credit unions, insurers and other financial institutions. Under the leadership of its governor Mark Carney, the Bank of England can be considered as a pioneer in analyzing the impacts of climate change on financial institutions and their consequences for financial regulators.

Initial initiatives by the PRA regarding climate financial risks

The sheer size of the insurance sector in the UK and the clear link between climate-related hazards and insurance sector's profitability was a key trigger for the PRA to start analyzing the links between climate financial risks and the financial sector (Carney, 2015). The PRA thus focused its initial analyses on the insurance sector by conducting a survey of insurer's practices related to climate risks (PRA, 2015). The lessons learned with the analysis of the insurance sector led the PRA to extend its focus on the banking sector (PRA, 2018). One of the main conclusions of the study on the UK banking sector is that only 10% of UK banks are having a strategic approach to manage climate financial risks, whereas 60% have a responsive approach and 30% a responsible approach (see Figure 16). In a strategic approach, banks are (a) deepening their understanding of climate risk by leveraging enhanced disclosure and scenario analysis, (b) agreeing on a board level, firm-wide strategic response to climate risk and (c) integrating climate risk factors into present day risk management. The PRA consider that only the strategic approach corresponds to an adequate response from banks to climate risk challenges.

Figure 16. UK banks approach to climate financial risk

Source: PRA (2018)

PRA expectations for financial institutions regarding climate financial risks

After these initial stock takings for the insurance and banking sector, the PRA published its expectations for insurances and banks regarding how they should manage the financial risks from climate change (PRA, 2019a). PRA's expectations concern four domains: governance, risk management, scenario analysis and disclosure. The PRA expected financial institutions to:

- Embed the consideration of the financial risks from climate change in their governance arrangements, which means, for example, that financial firms' boards must understand and assess the financial risks from climate change that affect the firm and be able to address and oversee these risks within the firm's overall business strategy and risk appetite. The PRA expects to see evidence of how the firm monitors and manages the financial risks from climate change.
- Incorporate the financial risks from climate change into existing financial risk management practice, which means, for example, that financial firms must identify, measure, monitor, manage, and report on their exposure to climate financial risks. Again, firms should be able to evidence this in their written risk management policies, management information, and board risk reports.
- Use (long-term) scenario analysis to inform strategy setting and risk assessment and identification, which means, for example, that financial firms should use climate scenarios to understand the impact of the financial risks from climate change on their solvency, liquidity and, for insurers, their ability to pay policyholders.
- Develop an approach to disclosure on the financial risks from climate change, which means, for example, that financial firms should disclose how climate-related financial risks are integrated into governance and risk management processes, including the process by which a firm assesses whether these risks are considered material.

2.2.3 Chinese financial regulators: a comprehensive agenda

Chinese financial authorities are also pioneering in terms of regulatory measures taken to ensure that financial institutions integrate climate risk in their risk management (see Box 2). The various policy measures implemented by Chinese regulators to incentivize financial institutions to proceed to this integration must be considered in the more global Chinese context: first, environmental issues have been at the top of Chinese authorities' concerns since the beginning of the century and they triggered a deliberate effort from the government to implement a broad range of policy measures. Financial regulation measures are only one part of this agenda. Second, several governmental are involved in the implementation of these measures, which requires a consequent coordination between them. This coordination is only possible with a constant and declared support from the government.

Chinese authorities implemented a series of measures over time to incentivize financial institutions to integrate climate risk in their risk management framework. As mentioned above, the implementation of these measures followed three guiding principles: the progressivity of the measures in terms of stringency, the coordination between the governmental bodies, and the complementarity of measures in the sense that the introduction of new regulation and standards was usually accompanied with new tools or databases available to financial institutions to help them adapt to the new regulatory requirements. The following examples illustrate this complementarity:

- The *Green Credit Policy* in 2007 prohibits banks form lending to firms blacklisted by the Ministry of Environmental Protection (MEP) for environmental violations but is also provides recommendations on how to include environment and social (E&S) risk assessment in their loan origination processes and starts the collection information on environmental violations.
- The *Green Credit Guidelines* in 2012 requires E&S risk ratings to identify high E&S risk clients, but it also provides operational guidance on E&S risk management and starts collecting key performance indicators for green loans.

- The *Green Credit Statistics System* in 2013 provides a standardized definition of green loans, based on consensus within industries and develop tools for banks to calculate environmental benefits of loans. It also tracks data on loans with compliance issues on environment and lists technologies to be phase out.
- The *Green Credit Key Performance Indicators* in 2014 provides a list of quantitative and qualitative key performance indicators that banks can use but also requires them to report on E&S risks twice a year.

The measures taken by Chinese authorities is perceived as very positive by Chinese banks (see Frisari and Monnin, 2019). Banks underline that:

1. The different authorities *provided useful data* to integrate climate risk in banks' risk management framework' methodologies. Data on major factories and utilities assets in heavy industries as well as data on compliance, emissions, regulation limits, air pollution and water pollution that the MEP shared with banks were particularly useful for Chinese banks. Official and freely available data are key for small financial institutions with limited resources to develop their own inhouse methodology.

2. The guidance given by authorities was very useful for banks to have a *clear view of the governmental environmental policies* ahead. Guidelines helped banks better understanding what governmental authorities will consider as green finance, as well as developing the methodologies to responds to authorities' expectations. Governmental measures also convinced banks' top management about the resoluteness of the government in implementing environmental policies and about the pace at which it will do so. This led top-management to put environmental credit risk on top of their agenda, particularly because it convinced them that environmental regulation will have material financial consequences for their loan operations.

3. The feedback loops between authorities and banks were also important to progressively develop and implement methodologies. The ICBC, for example, started to develop its methodology after Ma Jun, Chief economist of the PBoC Research Bureau at the time, suggested that they could set an example for the rest of the banking sector. This methodology was then used by authorities as a starting point for discussions on which tools could be used for banks' reporting.

Box 2: Chinese financial authorities

Until recently, the Chinese financial regulatory system has been fragmented. Before 2017, the People's Bank of China (PBoC) and three commissions had been responsible for the regulation of financial markets and of financial institutions, with equal power. (1) The China Securities Regulatory Commission (CSRC) supervised the issuance, listing, trading, custody and settlements of stocks, bonds (incl. green bonds), and other securities; it monitored market behaviors, investigated activities and penalized conduct in violation of the relevant securities and futures laws and regulations. (2) The China Banking Regulatory Commission (CBRC) conducted regulation and supervision over all banking institutions and their business activities in China; it promoted the safety and soundness of the banking industry, improved its competitiveness and used prudential supervision to protect the interests of depositors and consumers and to boost market confidence. (3) The China Banking and Insurance Regulatory Commission (CBIRC) formulated policies and rules concerning commercial insurances.

Over the years, banks and financial institutions increasingly took advantage of the discoordination and evaded regulations. In 2017, the government established the Financial Stability and Development Committee (FSDC) oversee the coordination of the financial regulatory bodies. The FSDC is mandated to break potential deadlocks between the financial regulators and to exert greater authority over local governments to ensure an overall consistency in financial policymaking. Operated by PBoC, FSDC is expected to gain a considerable expansion of its mandate. The fusion of the CBRC and the CIRC into the China Banking and Insurance Regulatory Commission (CBIRC) in April 2018 constitutes a step to create a more coherent regulatory system that closes on regulatory loopholes.

In addition, The Ministry of Ecology and Environment (MEE), established in 2018, also plays a significant role for financial institutions when it comes to environmental issues. The MEE embodies a considerable expansion of regulatory power and its mandate covers regulatory functions previously exercised by seven separate ministries. These include formulating and enforcing national environmental policy and conducting environmental impact assessment in areas of climate change; air, water, and soil pollution; ecological and marine conservation; nuclear safety and radiation safety, and environmental protection among project execution. The MEE is mandated to require and evaluate environmental information disclosure from corporate enterprises and public institutions.

Chinese authorities also cooperate with experts, think tanks, and regulatory institutions at home and overseas. In 2015, they created the Green Finance Task Force (GFTF). The GFTF has proposed a preliminary framework and 14 specific recommendations for building China's green finance system. Considered as a step-by-step roadmap, the GFTF recommendations covered issues including green banks, green bonds, green insurance, green IPOs, green credit rating, environmental liabilities of banks, green information disclosure, a green database and a green investor network. The recommendations also gave clear instructions to task assignment between regulatory agencies. Since then, most recommendations of the GFTF have been implemented, promoting a clearer division of task among the regulatory agencies and interdepartmental cooperation.

Source: Frisari and Monnin (2019)

2.2.4 Options currently discussed by financial regulators

The road followed by the Bank of England and Chinese authorities to incentivize financial institutions to integrate climate risk in their risk management framework is likely to be adopted by other financial regulators. Other options are also discussed and sometimes implemented in other jurisdictions. Three of them are likely to receive greater attention from financial regulators soon: the integration of climate risk in capital requirements; the introduction of preferential refinancing rates by central banks for banks that lend to environmentally sustainable economic activities; and the implementation of maximum or minimum credit quotas to high-carbon and low-carbon sectors.

Climate financial risk and capital requirements

There is currently an active discussion about the integration of climate financial risk consideration into the capital regulation framework for financial institutions defined in the Basel agreement. In this framework, financial institutions must match a proportion of their assets, including loans, with some capital. The proportion of asset to be backed by capital is a function of assets' risk. As climate risk is a financial risk, it should also be considered in the assessment of the financial risk determining capital requirements (Alexander and Fisher, 2018). In practice, however, the methodologies used to compute capital requirements do not formally integrate climate risk. This might change once regulators legally ask financial institutions to assess their exposure to climate financial risk.

Some propositions go one step further than reflecting climate risk in capital requirements and suggest introducing a so-called green supporting factor (GSF) in capital requirements (European Banking Federation, 2017). Such a GSF implies that financial institutions would have to match their loans to green activities with less capital than for other loans. The supporters of this proposition argue that lower capital requirements would result in lower funding costs for commercial banks and thus encourage lending to green economic activities. Opponents highlight that a GSF would reduce banks' capitalization and thus fragilize them (see Matikainen, 2017 and Ford, 2018). They propose a brown penalizing factor (BPF) – i.e., higher capital requirements for high-carbon loans – which would increase the funding costs for banks associated with environmentally unsustainable loans and thus discourage the funding of high-carbon economic activities. They further emphasize that a BPF would increase banks' capitalization and thus foster their financial soundness.

The possibility of differentiated capital requirement is currently discussed in the European Union. The banking associations have intensively lobbied for the adoption of a GSF. Central banks and regulators consider that a GSF goes against the stability of the financial sector and prefer a BPF that would align environmental and financial stability goals (see Villeroy de Galhau, 2018 and Dankert et al., 2018).

Preferential refinancing rates

To incentivize commercial banks to lend to specific sectors, central banks can use different refinancing rates. For example, banks extending credit to low carbon investment could get preferential rates when they seek refinancing at the central banks. Another possibility for central banks is to adjust the rate at which they discount bills posted by commercial banks in exchange of liquidity. In such a case, financial institutions could be compensated partially, fully or even overcompensated for lending to low-carbon economic activities.

Some central banks have already implemented such schemes. The Bangladesh Bank, the central bank of Bangladesh, for example, has introduced preferential refinancing rates for the green sector in 2009. The People's Bank of China has also introduced a mechanism that incentivize green lending in its refinancing rate policy. In China, the interest rate that commercial banks get on central bank reserves is a function of a score – the so-called Macro Prudential Assessment (MPA) score. The higher the MPA score, the higher the interest rate they get. The MPA score depends on several dimension of banks' activities such as, their capital adequacy ratios, their liquidity conditions, the quality of their assets, their competitiveness behavior, etc. (Zheng 2018). The amount of green loans that a bank provides positively impacts its MPA score. The People's Bank of China also introduced a scheme that allow commercial banks to pledge green bonds as collateral at preferable conditions in exchange of central bank's liquidity.

Credit quotas

Financial regulators can steer credit allocation in the economy with credit guidance (see Bezemer et al., 2018). Setting minimum and maximum credit quotas to specific economic sector is one way to implement such credit guidance. Minimum credit quotas (or floors) are set by financial regulators or by central banks and require commercial banks to allocate a minimum percentage of their loan portfolio to a specified sector, area or cause. Priority sector lending programmes have a long history in developing and emerging economies (see, e.g., World Bank 1993). In contrast, maximum credit quotas (or ceilings) are used to limit commercial bank lending to specific sectors. Credit ceilings can be used to limit the exposure of financial institutions to climate-sensitive sectors of firms. Currently, such ceilings are commonly used in advanced economies to suppress credit to certain sectors (in particular, the real estate sector) following the 2008 financial crisis.

Credit quotas can be used to steer credit toward low-carbon activities and away from carbon-intensive ones (Dikau and Ryan-Collins, 2017 and Dikau and Volz, 2019). Two examples of implemented credit quotas for green activities are found in Bangladesh and India. Bangladesh Bank, the central bank of Bangladesh, has introduced minimum credit quotas to green sectors (5%) in 2016. The Reserve Bank of India (RBI) requires that 40% of commercial bank lending flows to priority sectors. In 2012, the RBI include some off-grid renewable energy solutions into the list of priority sectors. In 2015, The RBI extended the list again to other renewable energy projects.

Note however, that the use of credit quotas is not always well perceived in economic circles. Mainstream economists and central bankers consider this practice as distortionary and sub-optimal and thus do not recommend its usage. In practice, credit quotas are regularly implemented, in particular in developing countries.

2.3 Green credit markets: an opportunity for financial institutions

The massive amounts of capital, $470 billion per year in new energy investment APEC member economies by 2050 alone, and the new financial products that will be needed to fund the transition to a low-carbon economy constitutes an opportunity for financial institutions. Banks can expand their credit activities to provide loans to environmentally sustainable projects and financial institutions in general can benefit from growing prospects in activities related to the issuance, the intermediation and the management of environmentally sustainable financial assets.

2.3.1 The rapid growth of green credit markets

Green credit instruments are specific types of environmentally sustainable credit instruments. They constitute the most visible part of sustainable credit but not its entirety: some credit instruments are environmentally sustainable but are not labelled “green,” either because their issuer did not want to go through the labelling process or because they use alternative sustainable labels. In the sustainable bonds market, we can distinguish between green bonds, sustainability bonds, SDG bonds, blue bonds, forest bonds, etc. Green bonds represented about 75% of the issuances of sustainable bonds in 2018.[13]

Green bonds: the state of the market

[13] Unless stated otherwise, the source for all green bonds figures is Climate Bond Initiative (2019).

Green bonds issuances have been constantly increasing over the last five years, reaching $168 billion in 2018 (see Figure 17), which represents about 3% of global bond issuances. The top two issuers are the U.S. ($34 billion) and China ($31 billion). The green bond market is growing in other APEC economies, too; this notably includes countries in south east Asia (see Figure 18), reflecting the very recent opening of these countries to green bond markets. Europe is the fastest growing region in terms of issuances. Note that if the pace of the green bond issuances slowed in 2018, other types of sustainable bonds continue to grow steadily.

Figure 17. Issuances of green bonds worldwide

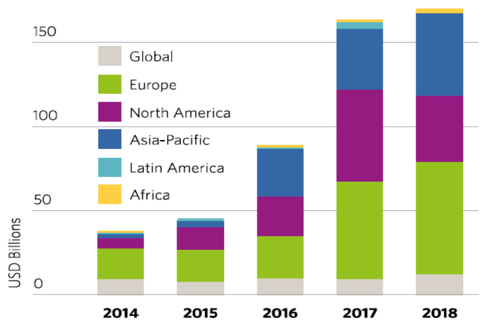
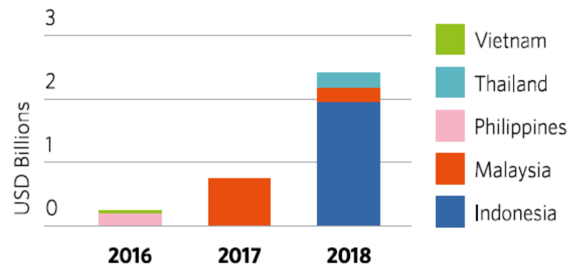


Figure 18. Issuances of green bonds in South East Asia

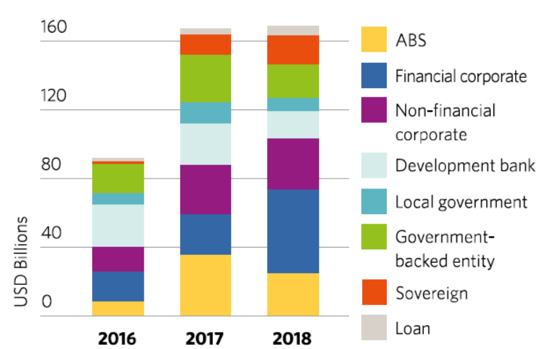


Source: Climate Bonds Initiative (2019)

Development banks and government-backed entities have been traditionally the largest issuers of green bonds. However, in 2018, financial institutions became the largest issuers worldwide, more than doubling their issuance compared to the precedent year (see Figure 19). Commercial banks were the most active of all financial institutions. Property banks and real estate investment trusts were also very much active in 2018.

About 40% of the green bonds issuance by financial institutions are stemming from Chinese banks. The Industrial Bank (China) is the second largest global issuer. However, the role of financial institutions in the green bond market is not restricted to issuing bonds. Financial institutions play a key role as structuring agents and underwriters, actively supporting other issuers in coming to market. They also fulfill an important function as green asset managers. The rise of different types of green bonds is also an opportunity for financial institutions. Until now, senior unsecured bonds have been the most common types of green bonds, with about 60% of the green bonds market, but other forms of bonds, such as asset-backed securities, mortgage-backed securities and covered bonds are emerging. Such new bonds require the expertise of financial institutions in their conception, structure and launch on financial markets.

Figure 19. Issuances of green bonds by types of institutions



Source: Climate Bond Initiative (2019)

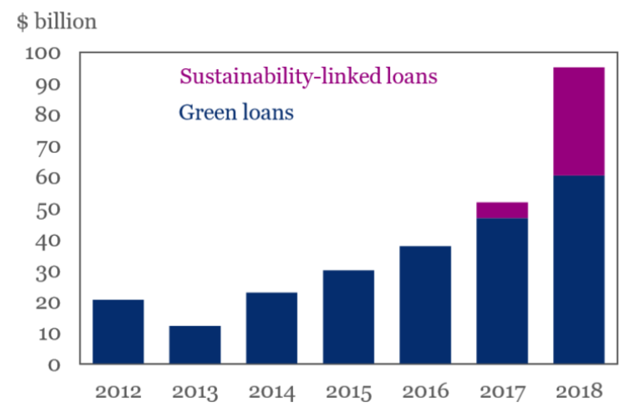
The prospects for green bonds market growth are also promising. Currently, green bonds trade at a premium – i.e., with higher price and lower yield than other bonds (see Gianfrate and Peri, 2019; Nanayakkara and Colombage, 2019; and Zerbib, 2019). This premium means that firms issuing green bonds get funding at a lower price than when they issue traditional bonds. Cheaper funding is an incentive for firms to continue issuing green bonds. Furthermore, several analysts argue that the premium for green bonds reflects a lack of supply of such assets (see, e.g, Pielichata, 2019and S&P Global, 2018). Currently the demand for green bonds seems to be larger than its supply. This excess demand is also a positive condition for a sustained growth of green bond market.

Green loans: a growing niche

Green loans markets are not as developed as green bonds markets. Green loans are important, however, for banks because they involve the core business—i.e., providing loans to their clients. Like green bonds, green loans have been growing steadily over the last six years (see Figure 20). Global green loan issuance amounted to some $60 billion in 2018, up over 30% from 2017. The U.S., the U.K., Spain, and India are the largest issuers of green loans, accounting for over 40% of global issuance. In 2018, outstanding green loans amounted to $278 billion, which represents less than 1% of total bank loans worldwide. This figure, however, is likely to underestimate the real amount of environmentally sustainable loans because it only includes loans that are officially labeled as green—not all loans to environmentally sustainable activities.

Green loans constitute an opportunity for financial firms. First, as described below, green loans could be a useful tool for financial institutions to manage their risk exposure: evidence in China shows that green loans have lower non-performing ratios than other types of loans. Second, green loans can be used by newcomer banks as an entry point to develop their business. China Industrial Bank, for example, used this strategy to distinguish itself from more established Chinese banks (see Frisari and Monnin 2019).

Figure 20. Issuance of green loans worldwide



Source: Institute of International Finance (2019)

The green loan market is likely to develop at a fast pace in the next years because several significant international initiatives regarding green loans have been adopted recently. In March 2018, the Loan Market Association, together with the Asia Pacific Loan Market Association and with the support of International Capital Market Association, launched the Green Loans Principles. These principles create a high-level framework of market standards and guidelines for environmentally sustainable loans. They define how funds should be used, the process of evaluation and selection of projects, how funds should be managed and the reporting standards. In September 2019, 130 banks from 49 countries launched the Principles for Responsible Banking. With these principles, banks commit to strategically align their business with the goals of the Paris Agreement on Climate Change and scale up their contribution to achieving the goals.

2.3.2 Green credit and financial risks

Environmentally sustainable credit instruments are useful not only in financing the transition to a low-carbon economy. They could also be valuable tools for financial institutions to reduce their exposure to climate risks.

In a nutshell, green credit instruments, whether bonds or loans, fund projects and firms that are the most aligned with low-carbon standards. They are thus less exposed than other projects and firms to transition risk. Indeed, transition risk stems from the costs of economic dislocation and financial losses associated with the process of adjusting toward a low-carbon economy. As projects and firms funded by green credit are already adjusted to low-carbon standards, they will not suffer substantial losses when the transition materializes, whether through a policy change, a technology change or a change in consumer preferences. Such projects and firms are clearly more likely to be among the winners of the transition.

Because financial institutions engaging in green credit activities face fewer transition risks, they are likely to experience lower non-performing loans and less defaults on bonds in the future than institutions that finance non-sustainable activities. Some empirical evidence of such effects is already available in China. Chinese authorities have started early to implement political, regulatory and financial measures to foster the transition to a sustainable economy. These actions already impact the performance of credit instruments. Based on a five-year dataset of 24 Chinese banks, Cui et al. (2018) find that a higher green loan ratio in a bank's portfolio reduces the non-performing loan ratio of the bank. Guan at al. (2017) find similar results with an approach that takes the opposite angle: they measure the carbon intensity of the loans for 16 Chinese commercial banks during the period from 2007 to 2014. This measure gives a sense of the "brownness" – instead of the "greenness" for Cui et al. – of a bank's loan portfolio. They show that the higher the carbon intensity of a bank's loan portfolio, the higher its non-performing loans ratio. Huang et al. (2019) provide additional evidence of the impact of a transition triggered by a policy shock on credit instrument performance. They find that after the implementation of the Clean Air Action launched by the Chinese government in 2013, default rates of high-polluting firms rose by around 50%, which is indirect evidence of the higher resilience to transition shocks of environmentally sustainable firms, and thus to the credit instruments linked to them.

These examples show that, through their lower exposure to transition shock, green credit instruments can be effective tools for financial institutions to manage their credit risk.

2.3.3 Fostering the development of green credit markets

Green credit markets are an important component for the financing of low-carbon, climate-resilient investments. Developing these markets, however, requires the involvement and the collaboration of several public and private institutions.

The Sustainable Banking Network recommendations

The SBN is a network of financial regulators and banking associations that have an interest in policies, guidelines and related initiatives to support the financial sector to adopt environmental and social risk management and green lending. The SBN currently has 48 members, mostly from emerging economies: 28 are regulators and 20 are banking associations. Last year, the SBN published a review of best practices to create green bonds markets, with a focus on emerging economies (SBN, 2018).

Case studies analyzed by the SBN show that developing green bond markets requires a combination of policy leadership and market-based actions. Initiatives taken by local financial institutions are one driver of local green bond market development. Two components seem to be particularly important to ensure the sound development of a local green bond market: 1) harmonized definitions and 2) guarantees of market integrity and credibility. Policymakers can significantly contribute in these two ways by issuing clear guidelines, developed in collaboration with private stakeholders.

Harmonized definitions of green bonds and loans should be based on international standards to ensure that local definitions are compatible with investors' needs. The Green Bond Principles and the Climate Bond Standards are reference points in this context. Public authorities should also make sure that their local definitions are aligned on national climate and infrastructure targets. Aligning national definitions with international good standards is also a way to leapfrog and accelerate local green bond market development.

Market integrity and credibility are also essential for successful green bond markets. National authorities, in coordination private institutions, should therefore include tools for the quality of green bonds. For instance, they could ask for external reviews from experienced and credible entities to limit the risk of "greenwashing" and insure investors of the green credentials of bonds. Applying good international practices in this domain is one way to provide this credibility.

Lessons from China's green credit market

China's green bond market is an example of a fast-developing credit market. It can serve as a template for the implementation of other national green bond markets. The case offers several useful lessons for policymakers in other countries—despite the specific context of China, where all authorities are involved in implementing measures to drive economic actors to make the transition to a low-carbon economy.

In China, measures taken by financial authorities and others played a key role in the rapid development of the green bond market. Describing the full set of measures taken by Chinese authorities is beyond the scope of the chapter (see Frisari and Monnin, 2019, for a more complete analysis), but it is important to note that all the measures focused on two goals: first, decreasing the cost of issuing green bonds and, second, increasing green bond market integrity and credibility.

To decrease the issuance cost of green bonds, Chinese authorities issued several guidelines providing clear mandatory criteria for the use and management of proceeds of green bonds as well as the identification of eligible projects. Such guidelines were expected to dispel misconceptions regarding the costs and the complexities of green debt issuance. The setting of clear standards for green bonds also aimed to reduce transaction costs by providing a clear and easy-to-adopt framework for banks willing to issue green bonds. In addition, authorities implemented different subsidy schemes for green bonds, including the opening of the central bank's collateral framework to green bonds of lower quality, which increase their value on financial markets. Finally, the different "fast-track" procedures implemented for the issuance of green bonds are also contributing in reducing their issuance costs.

To increase the integrity and credibility of the green bond market, Chinese policymakers issued guidelines to ensure the quality of external verification. Several verification agencies were created. National guidance was also essential in setting high standards of transparency. The expansion of the central bank's collateral framework to green bonds also contributed to consolidate their attractiveness for financial investors. Finally, multiple green bond indexes such as the Shanghai Stock Exchange Green Bond Index were implemented to provide investors with performance benchmarks as well as new targets for green investments, which strengthen the trading of green bonds. Chinese authorities also aligned their guidelines with international standards to gain credibility for international investors.

2.4 Summary

Climate change risks are financial risks. The risks of climate change are converted into risks for financial institutions through the increased physical and transactions costs of climate change, the uncertainty climate change injects into the market, and the amplification effects climate change has on the interconnected financial system. Current evidence suggests that financial markets are currently underpricing climate risks.

To mitigate these risks, financial regulators are evaluating the climate risk management practices of financial institutions and providing recommendations. These recommendations include things like data sharing, climate-related disclosure, and identifying which economic activities could help transition to a low-carbon economy and/or which are most exposed to climate risk. The Bank of England and Chinese financial authorities provide useful models in this area.

Green credit markets represent an opportunity for financial institutions to fund the transition to a low-carbon economy and to reduce their transition risks. These markets include things like green bonds, green loans, and sustainability bonds.

Chapter 3.
Mobilizing Institutional Investors in APEC to Address Climate Change

Climate change is a first-of-its-kind challenge for institutional investors in APEC member economies. It poses unique and uncertain risks to their investment portfolios. These institutional investors are responsible for ensuring the present and future solvency of more than $42 trillion in pension, insurance, and sovereign wealth assets across the region (*representing the equivalent of more than 100% of GDP in some countries*) (Table 4). They include some of the largest institutional investors in the world (Box 3).

The size of these investment portfolios provides institutional investors in APEC member economies a unique opportunity to influence broader climate-related market behaviors. Their long-term investment horizons uniquely position them to capitalize on the $470 billion in new annual energy investment opportunities in APEC that could result from adoption of strict mitigation policies (to say nothing of additional opportunities to invest in climate-resilient infrastructure and other adaptation measures).

But institutional investors can comprehensively address climate risks and scale up their contributions to climate finance only if policymakers create the requisite enabling environment, regulators provide needed support, and capital markets provide them with investment-grade climate finance products and tools. Addressing climate risks and scaling up investments in climate finance not only serves institutional investors' financial interests, but it will also positively influence broader market activity and help to fortify regional economies.

Box 3. Institutional investors in APEC that are among the 25 largest in the world (millions USD 2016)

Size rank	Organization	Economy	AUM
1	Government Pension Investment Fund, Japan	Japan	$1,443,554
3	China Investment Corporation	China	$900,000
5	National Pension	Korea	$582,938
7	Federal Retirement Thrift	U.S.	$531,489
10	Hong Kong Monetary Authority Investment Portfolio	Hong Kong	$456,600
11	SAFE Investment Company	China	$441,000
12	GIC Private Limited	Singapore	$359,000
13	National Social Security	China	$341,361
14	California Public Employees	U.S.	$336,684
16	Canada Pension	Canada	$283,454
17	Central Provident Fund	Singapore	$269,133
19	Temasek Holdings	Singapore	$230,310
21	California State Teachers	U.S.	$216,193
23	Mercer	U.S.	$211,971
24	Local Government Officials	Japan	$209,880
25	New York State Common	U.S.	$201,263

Source: Thinking Ahead Institute, Willis Towers Watson (2018); reports AUM as of December 31, 2017; March 31, 2018; or August 31, 2018

This chapter outlines ongoing efforts made by institutional investors in APEC to manage climate risks and contribute to climate finance. It then focuses on how these investors—with support from policymakers, regulators, and capital markets—can develop and improve their climate risk analyses and can increase their contributions to climate mitigation and adaptation. It concludes with a profile of Chile, an APEC member economy that has combined various regulatory, policy, and market solutions to help investors to manage climate risks while creating a renewable energy market that might be attractive to institutional investors.

Table 4. Pension fund and insurance corporation assets in select APEC member economies, 2018 (millions)

	Insurance corporations		Pension funds		Insurance corporations + pension funds	
	$	% GDP	$	% GDP	$	% GDP
Canada	$694,704	41%	$1,438,549	84%	$2,133,253	125%
Chile	$55,933	19%	$193,110	65%	$249,043	84%
Japan	$4,399,809	89%	$1,400,143	28%	$5,799,952	117%
Korea, Republic of	$1,115,647	69%	$191,041	12%	$1,306,688	81%
New Zealand	–	–	$54,409	27%	–	–
Russia	$38,107	2%	$58,518	4%	$96,625	6%
United States	$9,977,329	49%	$22,412,974	109%	$32,390,303	158%

Source: OECD (2019)

3.1 Trends in institutional investors' contributions to climate finance in APEC

Investors—including institutional investors and those in APEC member economies—are increasingly acknowledging that climate change poses serious risks to their securities and portfolios and are adopting sustainable investing approaches to help them to manage those risks. Available data indicates, however, that few institutional investors in APEC (or elsewhere) are allocating assets to climate finance, such as mitigation activities (e.g., renewable energy investments) or adaptation activities (e.g., climate-resilient infrastructure).

3.1.1 Existing efforts to manage climate risks

Membership in industry groups that promote ESG integration

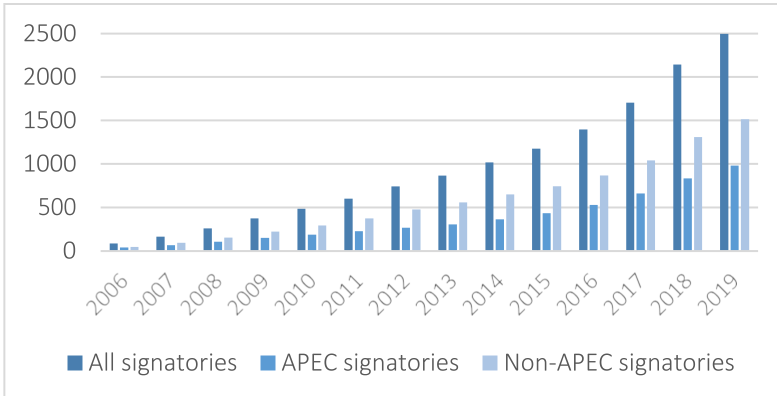
Each year, a growing number of investors sign on to the Principles for Responsible Investment (PRI), an internationally recognized network that guides investors in managing Environmental, Social, and Governance (ESG) risks to their investments to protect and enhance returns. Among PRI's central objectives is guiding investors in tracking and addressing risks related to their exposure to fossil fuels and, most recently, to the "Inevitable Policy Response" to climate change (i.e., the impending policy response to climate change that will generate substantial transition risks for companies, financial markets, and economies).

The number of PRI signatories grew exponentially in its first thirteen years, from just 88 in 2006, to 1,399 in 2016, to nearly 2,500 today (Figure 21). More than two-thirds of these investors are from APEC, including 166 institutional investors and 695 of the asset managers that analyze securities and construct portfolios (Figures 22a and 22b). As of 2019, PRI's board includes the chief investment officer of Japan's Government Pension Investment Fund (GPIF), the largest asset owner in the world; and the chair of the board of the California State Teachers' Retirement System (CalSTRS), the 9th largest institutional investor in APEC and 14th largest in the world ($216 billion AUM).

Support for climate-related financial disclosures

Increasing numbers of institutional and other investors are also supporting the Financial Sustainability Board's (SASB's) Task Force for Climate-Related Financial Disclosures (TCFD), which develops climate-related financial risk disclosures for corporations to use in reporting to their investors. Support for TCFD grew more than 50% between late-2018 and mid-2019, from 513 to 833 organizations (TCFD, 2019b). At least 129 asset owners formally and publicly support TCFD, including at least 45 from APEC and some of APEC's largest and most influential institutional investors: GPIF; Canada Pension Plan Investment Board; Ontario Teachers' Pension Plan; California Public Employees' Retirement System (CalPERS); New York State Common Retirement Fund; and AustralianSuper (TCFD, 2019b).

Figure 21. Growth in total PRI signatories over time, from APEC member economies and elsewhere



Source: Principles for Responsible Investment (2019)

Figure 22a. APEC member economies with 100+ PRI signatories, by type of signatory

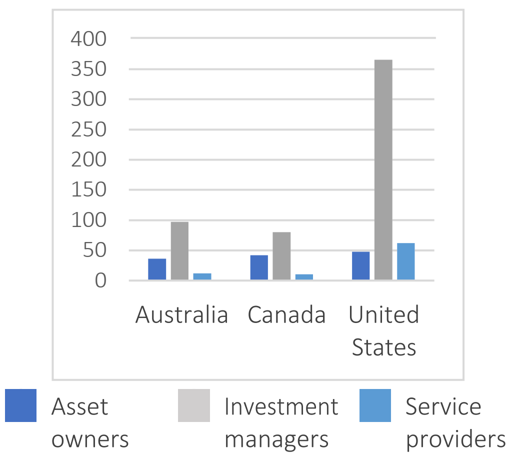
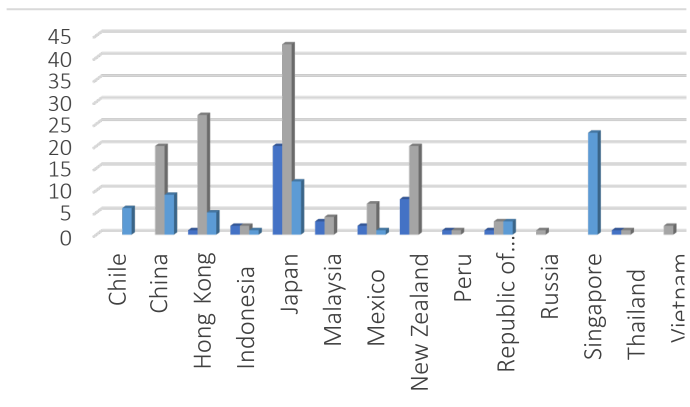


Figure 22b. All other APEC member economies with PRI signatories, by type of signatory



Source: Principles for Responsible Investment (2019)

Sustainable investing

Many institutional investors are not only acknowledging the environmental risks to their investments or supporting related industry groups. They are also increasingly acting on these and other ESG concerns and adopting sustainable investing approaches. These investors are proactively avoiding investments with poor ESG performance or that disregard widely accepted ESG norms and standards, emphasizing investments with positive ESG practices or that solve ESG challenges or engaging with funds and companies to encourage ESG improvements and risk mitigation (Burckart and Ziegler, 2019).

As of 2018, more than one-third of professionally managed assets worldwide were invested using sustainable approaches ($30.7 trillion), 75% ($23 trillion) of which were owned by institutional investors. Sustainably invested assets in four major markets in APEC (Australia/New Zealand, Canada, Japan, United States) totaled $16.6 trillion in 2018, an increase of nearly 54% since 2016 and more than 120% since 2014 (GSIA, 2019). In all, four of these markets, sustainable investment grew both absolutely and relative to total assets under management (AUM) (Table 5). Sustainable investment grew especially fast in Japan, where sustainably invested assets increased by more than 300% percent between 2016 and 2018. There are also indications that enthusiasm for sustainable investment might be on the rise in other APEC markets (e.g., Latin America) (GSIA, 2019).

Table 5. Sustainably invested AUM in four major markets in APEC, 2014-2018 (billions)

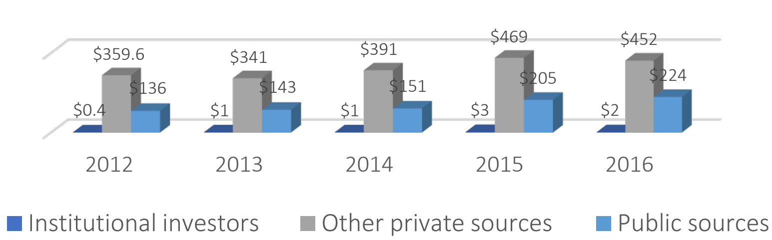
	2014		2016		2018	
	AUM	Market share	AUM	Market share	AUM	Market share
Australia / New Zealand	$148	16.6%	$516	50.6%	$734	63.2%
Canada	$729	31.3%	$1,086	37.8%	$1,699	50.6%
Japan	$7	—	$474	3.4%	$2,180	18.3%
United States	$6,572	17.9%	$8,723	21.6%	$11,995	25.7%
Total	*$7,456*		*$10,799*		*$16,608*	

Sources: GSIA (2017); GSIA (2019)

3.1.2 Contributions to climate finance

Despite increasingly acknowledging and acting on the risks that climate change poses to their investments, few institutional investors in APEC member economies or elsewhere are contributing to climate finance in substantial ways. Available data suggest that few institutional investors are investing in things like renewable energy or in fortifying infrastructure to adapt to extreme weather events and other adverse consequences related to climate change. In 2016, institutional investors worldwide contributed just $2 billion of their more than $42 trillion in AUM to climate finance (CPI, 2018). This represents a near quadrupling of institutional investors' contributions to climate finance between 2012 and 2014 but equals just 1% of all private sector climate finance and less than 1% of total climate finance in 2016 (Figure 23).

Figure 23. Contributions to global climate finance over time, by source (billions)



Sources: CPI (2018). CPI (2016); CPI (2013a)

Climate finance data collection and analysis challenges make it difficult to provide details about which institutional investors (and other private sector actors) are contributing to climate finance or other information about their activities. This is particularly true of data on finance for adaptation and energy efficiency upgrades.[14] Nonetheless, available data do provide a sense of the broader universe of climate finance within which institutional investors operate. Appendix A includes a series of tables that detail what these data indicate about the *who*, *how much*, *how so*, *for what* and *to where* of climate finance between 2012 and 2016 (the most recent year for which data are available). Notable high-level trends apparent in these tables include (CPI, 2013a; CPI, 2016; CPI, 2018):

- With exceptions in specific years, *climate finance has been steadily increasing over time* (from $359 billion in 2012 to $455 billion in 2016). Some of this documented growth is likely due to increased data availability, but it is also due to increased investment by national, bilateral, and multilateral development finance institutions (DFIs). *Despite this growth, annual climate finance is still nowhere near the levels needed to achieve the Paris Agreement goals*.
- Driven by steady investment from project developers, *the private sector consistently provides more than half of all climate finance*, but public investment has been increasing over time, absolutely and relatively, and was nearly half of climate finance in 2016 (again, due to increased contributions from DFIs). Households have also emerged as key contributors to private climate finance (contributing 20% of private climate finance in 2016).
- *Climate finance mostly targets mitigation* (e.g., renewable energy), which totaled $472 billion in 2016. New investments in clean energy sources surpassed those for fossil fuels for the first time ever in 2016. Investment in sustainable transport grew more than 500% between 2013 and 2016, thanks in part to increases in electric vehicle purchases in China and Europe.
- *Most climate finance is sourced and spent domestically*. East Asia and the Pacific consistently receives the highest percentage of climate finance, from both domestic and international sources.
- Market-rate debt and balance sheet financing (debt, equity) are consistently the most commonly used climate finance instruments.

[14] Climate finance data contain notable gaps and inconsistencies. Data on private climate finance for both adaptation and mitigation is difficult to obtain and incomplete. It is particularly challenging to collect data on private climate finance for adaptation and energy efficiency, which private entities are not typically required to report. There are no clear standardized definitions for what constitute energy efficiency upgrades or adaptation measures or which of such activities align with low carbon and climate resilient pathways. Further, such data are difficult to disentangle from information about broader project financing and can be burdensome for private entities to report.

Although comprehensive granular data on individual institutional investors' contributions to climate finance are not available, some individual investors detail their climate finance activities in publicly-available reports. This includes New Zealand Superannuation Fund (NZ Super Fund), New Zealand's sovereign wealth fund with approximately NZ$43 billion in AUM. In 2016, NZ Super Fund announced its Climate Strategy, a plan to manage the risks that climate change poses to its investments and to increase its contributions to climate finance (Box 4).

Box 4. NZ Super Fund's Climate Strategy – a plan for managing climate risks and increasing contributions to climate finance

In 2016, NZ Super Fund launched its *Climate Strategy*, a four-pronged plan for addressing the material risks that climate change poses to its investments.

1. Reduce exposure to companies most at risk from climate change policy due to their emissions or fossil fuel reserves, with an initial focus on its passive global equity portfolio, and then shifting to its actively managed holdings. As of 2018, the Fund had reduced its carbon intensity by 18.7% and its potential emissions from reserves by 32.1%.
2. Analyze climate change risks as part of investment decision-making, which has thus far included developing a framework for integrating climate considerations into asset valuations and will include scenario-modeling in the future. The framework establishes methods for examining technology, resource availability, policy, demand and supply, and liability.
3. Engage with holdings companies, asset managers, and policymakers. NZ Super Fund requires all external managers to complete an ESG due diligence questionnaire and follow related voting guidelines. It is a founding member of the One Planet Sovereign Wealth Fund working group, an international collaboration that encourages integration of climate change considerations into investment decisions.
4. Search for opportunities to invest in climate change mitigation and adaptation. Since 2016, NZ Super Fund has made a series of new direct investments in climate change mitigation companies and projects, including investments in:

Longroad Energy Holdings
($25.3 million initial
with $100 million potential)
Renewable energy development and operating vehicle (Boston, MA)

LanzaTech
($87million)
Converts carbon waste into high-value fuels and chemical (Skokie, IL)

Sources: NZ Super Fund (2017); NZ Super Fund (2018); Whinerary and O'Conner (2019)

3.2 Increasing institutional investors' contributions to climate finance in APEC

The growing adoption of sustainable investing approaches that aim to manage climate change risk by institutional investors in APEC member economies is important and promising to be sure. But these investors need support if they are to comprehensively manage these risks and contribute to climate finance at the levels needed to help to achieve the Paris Agreement goals and to hedge climate change's worst health and financial consequences.

Systemic structural change is necessary for institutional investors in APEC to comprehensively manage the long-term risks of climate change and, importantly, to unlock the massive climate financing potential embedded in their more than $42 trillion in assets. This involves meaningfully confronting well-known policy barriers (i.e., fossil fuel subsidies); ensuring that regulatory frameworks support corporate climate-related risk disclosures and commensurate analysis, management, and reporting by institutional investors; and leveraging proven blended finance structures, connecting institutional investors with other investment-grade products that provide immediate opportunities to contribute to climate finance, and developing local capital markets (Table 6).

No one solution provides *the silver bullet* to scaling up institutional investors' contributions to climate finance in APEC member economies. But when combined and brought to scale, these efforts will not only enable institutional investors to better protect the long-term solvency of their assets, but they will also provide a substantial opportunity to harness their long-term investment horizons, size and influence to change broader market behaviors and fortify regional economies.

Table 6. Summary of barriers to scaling-up institutional investors' contributions to climate finance, and possible solutions

Barriers	Solutions
Policy	
Policies that disincentive investment in climate change mitigation (i.e., fossil fuel subsidies).	Policies and other public sectors tools that level the playing field between renewable energy and fossil fuels, including carbon pricing, feed-in-tariffs and renewable energy auctions.
Regulatory	
Regulatory frameworks that encourage short-termism, discourage long-termism and are otherwise inadequate.	• Clarification that climate risk analysis does not conflict with fiduciary duty. • Mandatory corporate climate risk disclosures. • Standards and guidance that support treatment of climate risks as financial risks and long-term climate-related analysis, management and reporting.
Market	
Lack of adequate climate-related investment products.	• Innovative blended finance structures that reduce risk and uncertainty for institutional investors. • Connection to immediate opportunities to contribute to climate finance or otherwise leverage existing investments across asset classes (e.g., fixed income, green bonds); public equities (active ownership to reduce emissions); real estate (energy efficiency upgrades); real assets and infrastructure (e.g., sustainable forestry to combat deforestation);, and other investment tools (e.g., sustainable Exchange-Traded Funds, climate-focused indexes and sustainable stock exchanges). • Local capital market development.

3.2.1 Policy, regulatory, and market barriers

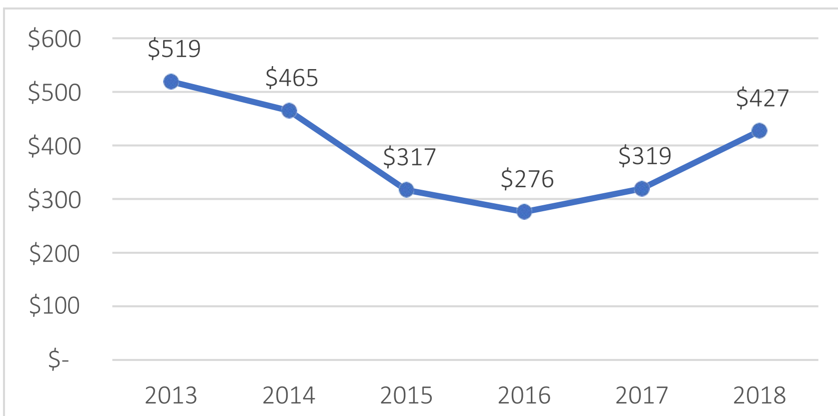
Governments, financial system regulators, and institutional investors in APEC need to confront the market failures and structural barriers that are preventing comprehensive climate risk-management and the scaling-up of institutional investors' contributions to climate finance. This requires tackling the public policies that lock in global dependence on fossil fuels and disincentivize institutional investment in renewable energy; addressing perceived conflicts between fiduciary duty and climate risk-management; fixing the regulatory frameworks that can encourage investors to pursue short-term gains at the expense of long-term considerations; and confronting the lack of climate-focused financial products that align with institutional investors' risk and return preferences.

Public policies that disincentivize investment in climate change mitigation

Fossil-fuel subsidies are a major barrier to scaling up institutional investors' contributions to climate finance in APEC member economies. These subsidies—which take numerous forms (e.g., direct cash transfers, tax exemptions and rebates, price controls)—keep the price of oil, gas and coal artificially low and consumers' dependence on them high. This decreases the competitiveness of key climate mitigation industries (e.g., renewable energy) and makes investments in them unattractive (UNFCCC, 2017).

After steadily declining between 2013 and 2016, total global fossil-fuel subsidies increased in 2017 to a cost of $320 billion and again in 2018 to more than $400 billion (Figure 24). When the estimated costs of environmental degradation and the resultant greenhouse-gas emissions from fossil fuel consumption encouraged by the subsidies are included, the true ("post-tax") cost of the subsidies could be at least $5.7 trillion and 6.5% of GDP in 2017, economists from the International Monetary Fund have estimated (Coady et al., 2019).

Figure 24. Value of fossil fuel subsidies over time, worldwide (billions)



Source: IEA and OECD (2019)

Some of the countries with the largest fossil-fuel subsidies are in APEC (Table 7). Subsidies in China, Russia, and Indonesia are among the costliest in the world—with China consistently ranking in the top three subsidizers between 2016 and 2018 (alongside Saudi Arabia and Iran) and Russia and Indonesia consistently rounding out the top five (IEA, 2019b). Fossil-fuel subsidies in other APEC member economies are also high relative to the rest of the world. The U.S. Congressional Budget Office, for example, estimates that federal fossil-fuel tax preferences cost $4.6 billion in the U.S. in 2016 (Dina, 2017). Total fossil-fuel subsidies in Canada cost in the trillions of dollars and exceed those for education, job training and healthcare combined. In 2018, Canada ranked last among G7 economies in "ending support for oil and gas production" (Whitley et al., 2018).

Attempts to increase investment in renewable energy in APEC member economies, including those that focus on encouraging investment by institutional investors, will be futile so long as fossil-fuel subsidies persist.

Table 7. Value of fossil fuel subsidies over time, in select APEC member economies and worldwide (millions USD)

	2013	2014	2015	2016	2017	2018
China	$29,385	$25,848	$20,267	$43,734	$40,047	$44,440
Indonesia	$33,599	$37,807	$18,302	$18,278	$18,836	$31,344
Korea	$172	$155	$167	$163	$128	$83
Malaysia	$8,012	$4,963	$343	$1,553	$2,085	$2,296
Mexico	$14,474	$7,857	$6,810	$10,832	$11,749	$13,657
Russia	$32,632	$33,539	$34,472	$33,368	$21,250	$37,231
Thailand	$2,937	$2,015	$957	$551	$864	$1,272
Viet Nam	$1,793	$1,116	$79	$107	$471	$612
World	*$518,764*	*$465,430*	*$317,456*	*$276,356*	*$318,751*	*$426,660*

Note: Canada and the United States – two of APEC's largest economies – are not included in the IEA's analyses of fossil fuel subsidies, but other sources indicate that they cost in the trillions of dollars in Canada in 2016 (see *G7 fossil fuel subsidy scorecard* (2018)) and $4.6 billion in the United States in 2018 (see CBO testimony to Congress 2017).

Source: IEA (2019b)

Regulatory frameworks that discourage institutional investors' contributions to climate finance

The existence and specifics of institutional investors' fiduciary obligations vary by APEC member economy (Table 8), but broadly speaking, such regulations require that institutional investors manage assets prudently, loyally, and with impartiality, place their clients' interests above their own, and act in good faith in the interests of their clients (including current and future retirees), among other things (CIEL, 2016; UNEP FI et al., 2017). In the absence of regulatory guidance to the contrary, institutional investors in some APEC member economies are unclear about whether integrating climate-related considerations into their investment decisions conflicts with this duty (Lewis et al., 2016). In short, these investors contend that their central fiduciary obligation is to maximize returns on their investments, which prohibits them from considering long-term risks like those posed by climate change.

Some of the attempts by governments and regulators in APEC member economies to indicate that climate risk (and other social and governance considerations) is material to investment returns—and therefore aligned with fiduciary duty—have been vague or confusing. In 2016, The U.S. Department of Labor (DOL), for example, noted that investments that focus on benefits beyond financial returns align with fiduciary duty. But in 2018, it issued a follow-up memo stating that financial performance is paramount to fiduciary duty while environmental and social impact is a secondary obligation. Institutional investors in the U.S.—pension funds in particular—remain uncertain about whether U.S. Labor Department thinks that ESG issues are material to investment returns and therefore a prudent investment consideration (Manganaro, 2018).

Table 8. Fiduciary obligations in select APEC member economies

Australia	• Superannuation funds, life insurance statutory funds and managed investment schemes must exercise reasonable care and diligence; act in good faith in the best interests the fund; and not use their position to gain an advantage for themselves or the fund. • Some funds are subject to additional legal requirements including to act honestly, properly invest funds, tact in the best interests of the beneficiaries and to exercise a prescribed standard of care, skill and diligence and to give priority to beneficiaries where there is a conflict of interest. All the above largely also applies to trustees.
Hong Kong	Trustees of collective investment schemes established as trusts and of mandatory provident funds should be loyal (e.g., to avoid conflicts of interest and related-party transactions) and prudent (e.g., to monitor fund managers, to conduct due diligence). Trustees are expected to be" fit and proper" persons and are expected to invest as a prudent person would.
Korea, Republic of	Pension funds must be profitable, support financial stability, act in the public interest, maintain liquidity and operate in a transparent manner. All private sector funds and other financial actors must act in good faith, not harm investors' interests while advancing their own or a third party's interest and manage conflicts of interest.
Malaysia	Trusts and trustees, agency relationships and directors of companies and statutory corporations are subject to fiduciary duties. These include the duties of loyalty (e.g., to avoid conflicts between their duties and personal interests) and prudence (e.g., to exercise care and skill in discharging their functions).
Singapore	Fiduciary duty is not a legally defined term, but securities legislation requires that investors avoid conflicts of interest, protect clients' interests and to act in good faith.
United States	Investors have a duty to be loyal and prudent and to diversify investments.

Sources: UNEP FI et al. (2017); UNEP FI (n.d.)

Moreover, despite their long-term investment horizons and mandates, institutional investors in some APEC member economies devote much of their attention to issues related to short-term accounting (e.g., the U.S. and Canada) (Barton and Wiseman, 2014). This short-termism can impede investors (and the corporations that they invest in) from fully pursuing opportunities to create long-term value, essentially focusing on today's beneficiaries at the expense of tomorrow's (PRI and UNGC, n.d.). In other countries and regions, regulations otherwise get in the way of institutional investors' efforts to integrate long-term value considerations into their analyses (e.g., investment restrictions in Viet Nam, short-term competition measures for pension systems in Latin America). Specific market dynamics and regulatory and legal requirements in different APEC member economies propagate short-termism or otherwise inhibit long-term investment in different ways, but commonly include:[15]

- Competitive near-term pressure to retain beneficiaries and prevent them from switching from one pension fund to another;
- Uncertainty regarding whether beneficiaries might elect for early withdrawal;
- Restrictions on portfolio diversification, investible asset classes, and allowable risk;
- CEO remuneration structures that tie compensation to stock price;
- Selecting asset managers based on short-term performance; and
- Requirements that investors report (and in some cases guarantee minimums) based on relative returns benchmarked to industry averages.

[15] See Bhidé, 2010; Davis et al., 2016; IRI, n.d.; Kay, 2015; Morales et al., 2017; OECD, 2018; SwissRe, 2018; and UNGC 2019 for more on the information presented in this bulleted list.

Each of these requirements or objectives can reduce incentives for investors and corporations to pursue activities and investments related to mitigating and adapting to climate change. They can cause them to forgo opportunities to invest in climate- and other sustainability-related research, development, and growth. They can also discourage investments in sectors and technologies that might involve absorbing near-term risks or up-front costs and attractive returns over a long-term horizon (e.g., renewable energy, resilient infrastructure, energy efficiency).

Finally, the lack of comprehensive regulatory support and standards related to climate-related disclosure, data, analysis, and management is also a roadblock to increasing institutional investors' contributions to climate finance in APEC member economies. Among the responsibilities of financial system regulators is helping investors to identify and manage risk and regulating, standardizing and establishing guidelines for associated activities. Although regulators are increasingly providing guidance related to sustainable investment, many of these efforts do not specifically or sufficiently help investors contend with the physical and transitional risks of climate change or help them assess and manage their impacts on the climate (see Castelli Salman, 2019).

The Securities and Exchange Commission (SEC) in the United States, for example, does not uniformly mandate that companies disclose climate-risk information. Rather, it only requires that companies do so when they believe that climate risk is material to their stock price valuation (Williams and Fisch, 2018; Meagher, 2019; SEC, 2019). Those investors that identify and manage security-, fund-, or portfolio-level climate risks, do so voluntarily and without consistent data or standards and are commonly must rely on unregulated third-party sustainability data providers. Their resulting assessments entail any number of issues, including (Burckart and Ziegler, 2019):

- Some agencies collect data directly from companies or investors, others collect it from public reports;
- Data from disparate sources is inconsistent and not comparable;
- Data from certain geographies (i.e., emerging markets) and sectors, and from privately held companies (versus publicly listed) is sparse;
- Different investors and data agencies use different terminology for the same issue;
- Ratings agencies and individual investors use bespoke analytic methods and ratings schemes;
- Voluntarily disclosed data is subject to various biases;
- Most climate risk analyses focus solely on carbon emissions and ignore other material risks (e.g., physical risks to existing assets) or the impacts of investors' behaviors on climate change;
- Analyses tend to use historical data and ignore forward-looking and opportunity-focused considerations; and
- Climate risk findings are sometimes bundled together with other environmental, social and governance (ESG) information and difficult to disentangle.

Moreover, the lack of environmental risk management standards enables widespread "greenwashing": asset managers and other investors can manipulate environmental data, analysis, and terminology to make misleading claims about their environmental impact (Watson, 2016). Reputable ratings agencies—including The Bloomberg Terminal and Morningstar, for example—both score companies' environmental performance for investors but in different ways (Burckart and Ziegler, 2019). Bloomberg analyzes 120 self-reported indicators and ascribes absolute and relative ESG performance and disclosure scores between 1 and 100 to 9,500 publicly listed companies. Morningstar combines ESG data from

Sustainalytics data and other sources to assign "globe ratings" between one and five to 20,000 mutual funds and ETFs. The existence of such rating schemes is encouraging, but without requisite oversight and guidance to ensure data availability and analysis quality, investors do not have the tools to collectively manage climate change risks in a consequential way.

Lack of adequate climate finance investment products

Many institutional investors in APEC and elsewhere cite a dearth of attractive, investible climate finance products as another reason for their lack of contributions to mitigation and adaptation activities (i.e., available products do not align with their risk appetites and return expectations or are not large enough to meet their requirements). One quarter of respondents to a recent survey of asset owners in the U.S., for example, reported that they do not purchase "sustainable" investing products, including those that consider climate-change risks, because they do not understand the selection processes for the underlying investments and because they believe that the products do not perform well (Lewis et al., 2016). This sentiment is likely due, at least in part, to the perceived poor financial performance of the very first "socially responsible" investment funds in the 1980s and 1990s, combined with the failures of many early clean-tech investments between 2005 and 2010 (Lewis et al., 2016).

3.2.2 Policy solutions

Combined with the elimination of fossil-fuel subsidies, several public policy approaches can help to create a policy framework in APEC that encourages institutional investors to re-allocate their assets away from fossil fuels and toward renewable energy and other climate change mitigation and adaptation solutions. It is primarily within the purview of governments to enact necessary policy reforms discussed above, but that does not mean that institutional investors must sit on the sidelines and wait for reforms. Rather they can *and should* use their size and influence to proactively advocate for requisite government action (see Box 8 on page 61).

Public policies and tools that level the playing field between renewable energy and fossil fuels

Carbon pricing schemes are policy mechanisms that aim to discourage fossil-fuel consumption. In doing so, they boost incentives for renewable energy consumption. They also encourage investment in increasing the supply of renewable energy, and, ultimately decrease carbon emissions. Economists praise carbon pricing for its simplicity, cost-effectiveness, and flexibility (see CLC, 2019). The most common carbon-pricing schemes include *emission trading systems (ETSs)* ("cap-and-trade") and *carbon taxes* on fuels or products generating greenhouse gas emissions.

To be maximally effective, carbon prices should equal between $40 and $80 per ton of CO_2 by 2020 and between $50 and $100 per ton of CO_2 by 2030 (as to the single digit prices under some existing programs, as shown in Table 9) and be *implemented alongside complementary mitigation policies* (CPLC, 2017). None of the carbon pricing schemes in APEC member economies are priced accordingly (Table 9).

Table 9. Carbon pricing mechanisms in APEC member economies

Country	National	Subnational	Initiative	ETS	Carbon Tax	GHG emissions covered [$MtCO_2e$]	% of global GHG emissions covered	Price
Australia	✓		Australia ERF Safeguard Mechanism	✓		380.84	0.70%	N/A
Canada	✓		Canada federal fuel charge		✓	179.73	0.33%	$15.13
	✓		Canada federal OBPS	✓		82.09	0.15%	N/A
		✓	Alberta CCIR	✓		124.80	0.23%	$22.70
		✓	BC carbon tax		✓	42.70	0.08%	$30.26
		✓	BC GGIRCA	✓		0.00	0.00%	N/A
		✓	Newfoundland and Labrador carbon tax		✓	4.51	0.01%	$15.13
		✓	Newfoundland and Labrador PSS	✓		4.26	0.01%	N/A
		✓	Nova Scotia CaT	✓		15.20	0.03%	N/A
		✓	Prince Edward Island carbon tax		✓	0.92	0.00%	$15.13
		✓	Quebec CaT	✓		68.85	0.13%	$17.67
		✓	Saskatchewan OBPS	✓		8.64	0.02%	N/A
Chile	✓		Chile carbon tax		✓	46.67	0.09%	$5.00
China		✓	Beijing pilot ETS	✓		84.65	0.16%	$12.16
		✓	Chongqing pilot ETS	✓		97.24	0.18%	$1.67
		✓	Fujian pilot ETS	✓		200.00	0.37%	$2.37
		✓	Guangdong pilot ETS	✓		366.30	0.67%	$3.33
		✓	Hubei pilot ETS	✓		162.09	0.30%	$5.62
		✓	Shanghai pilot ETS	✓		169.69	0.31%	$5.81
		✓	Shenzhen pilot ETS	✓		61.20	0.11%	$4.65
		✓	Tianjin pilot ETS	✓		118.25	0.22%	$1.96
	✓		China national ETS *(scheduled for 2020)*	✓		3231.90	5.94%	N/A
Japan	✓		Japan carbon tax		✓	999.43	1.84%	$2.66
		✓	Saitama ETS	✓		7.91	0.01%	N/A
		✓	Tokyo CaT	✓		13.92	0.03%	$5.95
Korea, Republic of	✓		Korea ETS	✓		468.29	0.86%	N/A
Mexico	✓		Mexico carbon tax		✓	307.33	0.56%	Rate 1: $3.00 Rate 2: $0.37
New Zealand	✓		New Zealand ETS	✓		39.85	0.07%	$15.63
Singapore	✓		Singapore carbon tax		✓	42.02	0.08%	$3.63
USA		✓	California CaT	✓		377.69	0.69%	$17.67
		✓	Massachusetts ETS	✓		14.27	0.03%	N/A
		✓	RGGI	✓		103.14	0.19%	$5.07
		✓	Washington CAR	✓		57.81	0.11%	N/A
		✓	Virginia ETS *(scheduled for 2020)*	✓		36.93	0.07%	N/A

Notes: Additional carbon pricing schemes are under consideration in Canada, Chile, Indonesia, Japan, Mexico, Thailand, the United States and Viet Nam. Prices are not necessarily comparable between carbon pricing initiatives because of differences in the number of sectors covered and allocation methods applied, specific exemptions, and different compensation methods. Due to the dynamic approach to continuously improve data quality and fluctuating exchange rates, data of different years may not always be comparable.

Source: WBG (2019a)

Given that most carbon pricing schemes are not yet priced adequately to galvanize private investment in renewable energy in APEC, many countries are turning to innovative project procurement methods to get renewable energy projects off the ground. This primarily includes feed-in tariffs (FITs) and renewable energy auctions—widely-used, effective, public policy tools for encouraging private investment in renewable energy, with more direct impact than through carbon pricing. Through both FITs and auctions, governments offer long-term (e.g., 20 years) power purchase agreements (PPAs) to renewable energy project developers to supply energy at a set price. The long-term nature and price stability of FITs and auctions provide security for project developers, especially those for newer or emerging renewable energy technologies and for smaller projects, and guaranteed returns over a specified period (IRENA, 2017; Milanés-Montero et al., 2018; WBG, 2019b). This, in turn, attracts private investors—including long-term institutional investors – to renewable energy projects that would not otherwise align with their risk appetites and return profiles.

FITs are more popular than auctions, but auctions are quickly gaining popularity worldwide and developing a promising track record, including driving the costs of solar PV and wind power to record lows in numerous countries (IRENA, 2019; REN 21, 2019). China, for example, has completed two renewable energy auctions for solar power generation since 2016, the most recent of which approved nearly 4,000 projects to install 22.78 gigawatts for an average price of $0.048. China will also begin using auctions for onshore wind power generation in 2020 (Bellini and Hall, 2019). As of 2018, 111 countries, states, or provinces had FITs (REN 21, 2019). These included Vietnam, which recently released plans to continue and expand its successful FIT program that was set to expire in 2019 (Box 5).

Box 5. Plans to expand Viet Nam's successful FIT

Launched in 2017, Vietnam's FIT ($0.0935/kWh) has helped to connect 82 solar power plants to power grids and to generate 4.46GW of solar power—making solar power the source of more than 8% of electrity inVietnam. Another 13 plants that generate a total of 630 MW of energy are scheduled to be connected to the grid by the end of 2019 thanks to the FIT. Vietnam's Ministry of Industry and Trade recently released draft plans to continue the FIT through 2021. This second iteration of the FIT contains notable changes that reflect lessons learned from the first tariff and Vietnam's evolving energy needs. Namely, it includes a range for the tariff, $0.0667/kWh to $0.1087/kWh, that varies based on geographic region and technology used. Tariffs would be higher in areas with lower solar irradiance (i.e., less sunlight) and lower in those with higher irradiance (i.e., more sunlight) and would vary based on project type (floating, ground-mounted, rooftop, or contain an integrated storage system). PPAs would last for 20 years.

Sources: Baker Mackenzie (2019); GlobalData Entry (2019)

3.2.3 Regulatory solutions

Among institutional investors' most effective tools for managing climate risks is data to inform their climate-related long-term investment decisions and behaviors. Financial regulators across APEC member economies (e.g., governments, insurance industry and pension fund regulators and corporate governance entities) can *and should* play a substantial role in helping institutional investors to collect, analyze, and use information about long-term climate-related considerations. This includes clarifying their fiduciary duty vis-à-vis climate risk, and ensuring that they have the information, tools, and guidance required to effectively and comprehensively assess climate financial risks (physical and transition), avoid investments that jeopardize their long-term goals and obligations, and pursue those in their long-term interest. As with the policy solutions discussed above, institutional investors should proactively encourage swift regulatory action along each of these dimensions (see Box 8 on page 61).

Clarifying that consideration of climate risk does not conflict with fiduciary duty

Government and other regulatory entities in APEC member economies responsible for establishing fiduciary duty rules and regulations should clarify that fiduciary rules, codes and guidance to establish that climate-related considerations (alongside other social and governance factors) do not conflict with fiduciary duty. When feasible, they should also specify that fiduciary duty in fact requires that institutional evaluate ESG considerations, including establishing that ESG considerations are material to risk and return and explaining that fiduciary duty requires institutional investors and their asset managers to assess long-term ESG factors and to vote and engage with holdings accordingly (UNEP FI et al., 2017).

Mandating corporate climate risk disclosures

Although the efforts of some institutional investors in APEC to require that their holdings disclose carbon emissions and other climate-related information to them have helped increase corporate climate risk disclosures (e.g., GPIF and NZ Super), corporate disclosures overall remain low. Further, disclosures vary by industry and sector and few of the companies that disclose climate risk information do so in accordance with recommendations from the internationally recognized TCFD recommendations. That is, while these corporations provide investors with information, much of it is not useful for the purpose of making decisions (TCFD, 2019a).

Corporate governance regulators in APEC member economies might therefore establish requisite TCFD-aligned laws, mandates and guidelines for comprehensive and effective climate risk disclosure. This means requiring that all corporations across all industries and sectors report climate-related information in their public financial disclosures, including information about: (a) governance around climate-related risks and opportunities; (b) the potential impacts of material climate-related issues on the company (business, strategy, financial planning); (c) how the corporation identifies, assesses, and manages climate-related risk; and (d) climate-related metrics and targets (TCFD, 2017). Disclosures should outline both physical risks (acute, chronic) and transition risks (policy and legal, technological, market, reputational) and an assessment of their potential financial impacts. The Sustainability Accounting and Standards Board (SASB) provides a suite of tools for identifying material risks for 77 major industry sectors (SASB, 2019).

Corporate reporting should include long-term metrics for integration into examinations of the long-term performance and health of companies. These metrics vary by industry sector but might include things like climate-related research and development plans and energy intensity of production over time (Barton and Wiseman, 2014).

Encouraging and supporting effective management of climate risks

As is outlined in chapter 2, all financial institutions—including institutional investors—should treat climate risks as pure financial risks. Beyond encouraging the practice, regulators should provide institutional investors with the technical and capacity-building support and guidelines necessary to ensure that they adopt best practices for doing so. These best practices include:

- Ensuring support from the governing board. Effective integration of climate risks into investment analyses requires making decisions about things like business objectives regarding climate risk management, climate risk reporting, and the definitions climate-related exposure limits. Governing boards play an important role in supporting investors' integration of climate risk, making these decisions, and setting commensurate expectations.
- Appropriately assigning ownership of climate risk. Climate risk analysis should not be the responsibility of a separate specialist unit. Rather, institutional investors should integrate it across the risk management units that manage all other sources of financial risks (i.e., credit and asset management units) and might: (a) develop a team specialized in climate risk within the firm, (b) disseminate climate risk specialists across all teams within the firm and (c) train all employees on climate risk management.
- Selecting appropriate risk metrics. The development of climate risk metrics is still a work in progress, however, several options already exist that an institutional investor can leverage to integrate meaningful climate-risk measures in its risk management (see, for example, UNEP Finance Initiative's comprehensive overview of available methodologies). Investors should be attuned to five core methodological issues when developing climate financial risk metrics (Box6).
- Choosing the right climate stress test scenarios. Most methodologies for assessing climate financial risk metrics rely on stress tests that consider the effect of a scenario in terms of financial cost and likelihood. When choosing stress-test scenarios, investors should consider: (a) the extent and speed of the transition to a low-carbon economy and the roots of the physical and transition risks; (b) those risks mostly like to impact their assets in different sectors (e.g., hazards most likely to occur in their operating area, the transition risks that have major consequences for the output of the model); (c) the second-round amplifying effects of climate risks; and (d) the impact of sudden shifts in investors' expectations about climate risk on financial markets and asset prices.

Although they are not institutional investors, Chinese banks are early movers in integrating climate risk in their risk management framework. They and the regulators who support them provide a valuable model for doing so for the entire financial system (see Box 7).

Box 6. Chinese banks and regulators: a model for climate risk management

The effects of economic activity on the environment has become a major concern in China and has led the Chinese government to enact measures such as fines on polluters and financial regulators to prioritize things like environmental risk management. Two of China's largest banks — Industrial Commercial Bank of China (ICBC)) and China Industrial Bank (CIB) — have subsequently integrated environmental risks into their risk-management frameworks, in ways aligned with the best practices described in this section and with support from financial regulators.

Governing boards. ICBC's governing board supported environmental risk integration after realizing that such risks had material implications for borrowers' ability to repay their loans (negatively impacted by environmental litigation) and the costs associated with switching from carbon-intensive to low-carbon technologies. They also forecasted that pressure on borrowers to take environmental measures and included environmental risks in their credit risk assessments. CIB's board was motivated by a desire to be considered a leader in the assessment of environmental credit risk that could give them a competitive edge.

Preparation. CIB emphasized the need to ensure that personnel had requisite specialized environmental risk assessment management expertise before engaging in the market. Both banks underlined the importance of internal support and that it is important to ensure that changes such as change in leadership do not disrupt early efforts around research, innovation and monitoring. They also emphasized the importance of cooperation and coordination with governmental authorities regarding future policy developments that might impact definitions, classifications, standards, guidelines and requirements.

Risk-assessment methodologies. ICBC developed environmental stress tests, the development of which highlight three steps in designing an adequate methodology: (a) group industries with similar environmental policy measures, operational and market conditions, production technologies and resource depletions and apply specific stress tests to them; (b) focus on high-polluting and high-depleting industries to implement stress test to achieve the biggest impact on decreasing pollution and resource depletion and to isolate industries that are likely to be the most impacted by transitions costs; and (c) define scenarios according to the specific conditions of the industry under scrutiny (e.g., location, production costs, specific environmental laws). CIB uses the monitoring system developed by the Ministry of Ecology and Environment to assess firms' environmental risks.

Support from regulators. Chinese authorities indicated their desire for banks to rapidly start integration environmental risks. Related incentivization measures reflected three core three principles: (a) *progressivity in measures*—they implemented their framework progressively through "opinions," the more formal "guidelines", and then "requirements"; (b) *coordination between governmental bodies*—they replaced a fragmented framework with a coherent with that requires coordination between the different governmental bodies; and (c) *complementary of measures*—they provided tools and data alongside the new regulations that helped banks adapt to the new standards.

Source: Frisari and Monnin (2019)

Encourage long-term climate-related analysis, management, and reporting

Institutional investors have near- and long-term beneficiary obligations. As described above, despite their long-term investment horizons, institutional investors in APEC member economies must devote much of their attention to short-term considerations (for various reasons, described above), sometimes at the expense of managing of long-term considerations like climate change. Doing so can lead them to invest in things like carbon-intense assets and to forgo investments in renewable energy companies, thus generating unintended consequences like environmental degradation (FCLT, 2018). The answer is not for institutional investors to ignore their short-term obligations. Instead, regulators (e.g., pension fund and insurance industry regulators) should encourage and help institutional investors achieve the right balance between making money for today's beneficiaries and creating value for tomorrow's—by integrating long-term considerations like climate change into their investment management processes (Barton and Wiseman, 2014).

Notable institutional investors and regulatory entities in APEC have started to embrace and otherwise endorse long-term value creation. Singapore's sovereign wealth fund (GIC Private Ltd.), for example, publicly reports on a 20-year horizon for value creation. GIC provides an example of how consideration of longer-term risks and rewards can usefully inform asset allocation (Barton and Wiseman, 2014). As of 2014 (and since the mid-2000s), GIC has invested up to one-third of its assets in public and private companies in emerging markets in Asia and indicated plans to tolerate short-term underperformance of these investments given their long-term growth potential (Barton and Wiseman, 2014). In 2018, Japan's Financial Services Agency (FSA) and the Tokyo Stock Exchange revised the Japanese Corporate Governance Code to, among other things, encourage corporations and institutional investors to consider mid- and long-term sustainable value creation (Tokyo Stock Exchange, 2018).

However notable GIC's long-term horizon and Japan's integration of long-term value creation into its corporate governance code, neither takes the important step of explicitly connecting climate-related considerations with long-term investment management. To date, France is the only country to legally mandate that financial system participants examine and report on long-term climate-related risk (PRI, n.d.). Article 173 of France's Energy Transition Law requires that corporations, institutional investors, and other financial system participants measure and report on the physical and transition risks of climate change physical and transition risk. It also requires that they report on efforts to set and meet low-carbon targets. The law does not prescribe specific analysis and reporting methods but does require that entities justify the methods used. November 2016, the European Union directed all EU-based pension funds to assess climate change risk (Guarascio 2016).

The CEO of Singapore's GIC and representatives from other of APEC's institutional investors sit on the board of directors for Focusing on Capital for the Long Term (FCLTGlobal), which develops and disseminates investor-driven recommendations for long-term value creation and reporting. This includes tools for predicting the long-term success of corporations, communicating with board members and other stakeholders about the value of long-term planning, navigating long-term investment in the public markets, and managing risks across multiple time horizons.

It is primarily within the purview of governments and regulators to enact the various necessary policy and regulatory reforms discussed above, but that does not mean that institutional investors must sit on the sidelines in this area (Box 8).

Box 7. Institutional investors using their influence to advocate for policy and regulatory reform

Institutional investors can influence policy and regulatory action that increases their ability to contend with climate change risks and contribute to climate change solutions, individually and through investor-led coalitions. In fact, there are various examples from the past 20 plus years of institutional investors using their collective influence to force environmental or social change, including helping to end apartheid in South Africa.

In September 2019, a group of 477 institutional investors with more than $34 trillion in assets under management signed the *Global Investor Statement to Governments on Climate Change*. In it, they implored world leaders to take necessary action to achieve the Paris Agreement Goals; urged them to adopt requisite policy and regulatory reforms that mirror many of those outlined in this chapter; and offered to partner with governments to make it all happen. Among their requests are:

- Aligning public policies with the Paris Agreement goals;
- Incorporating Paris-aligned climate scenarios into policy frameworks and energy transition pathways;
- Phasing out fossil fuel subsidies;
- Phasing out thermal coal power;
- Putting a meaningful price on carbon; and
- Committing to improving climate-related financial disclosures in line with TCFD's recommendations.

The signatories asked that these and other recommendations be undertaken with "the utmost urgency," noting that they are "vital" to achieving the Paris Agreement goals and maintaining investor confidence and highlighting an "ambition gap" between the Agreement goals and full implementation of existing Intended Nationally Determined Contributions.

Sources: The Investor Agenda: Accelerating Action for a Low-Carbon World (2019); US SIF Foundation (2016)

3.2.4 Market solutions

Innovative blended finance structures that reduce risk and uncertainty for institutional investors

Blended finance is a promising approach for attracting institutional investors to climate finance in APEC member economies. Some climate-related sectors, subsectors and technologies have matured to a point where they provide investment-grade opportunities at deal sizes and risk levels appropriate for institutional investors (e.g., photovoltaic solar and wind power companies, renewable energy storage and technology and low emissions vehicles) (WEF, 2016). But the majority of climate change mitigation and adaptation projects are still too "early stage," immature or small for institutional investors to invest in. This is particularly true of infrastructure projects in developing countries, for which there is a limited track record of private investment (IFC, 2018).

Using blended finance structures, public and philanthropic entities agree to absorb many of the risks and uncertainties associated with investing in climate change mitigation and adaptation projects. In doing so, they galvanize private investment in climate finance projects that institutional and other private investors might otherwise decline given existing market conditions—that is, risks and uncertainties associated with investing in new or immature technologies or in developing countries and emerging markets (Blended Finance Taskforce, 2018).

Blended finance structures commonly include (Brown and Jacobs, 2011; Convergence, 2018):

- *Concessional capital* through which the public or philanthropic entity assumes the highest risk for the same or lower rate of return.
- *Loan guarantees and insurance* through which public financial institutions protect investors against default by underwriting project loans, transferring risk (e.g., political or regulatory) from the lender to the guarantor.
- *Technical assistance funds and design stage grants* that assist projects in reaching bankability and financial close.

They might also include: s*ubordinated financing* that gives private investors the first claim on the distribution of profit at a higher priority than payments to public institutions; *foreign exchange liquidity facilities* from which project developers can access funds to repay lenders in the event of local currency devaluation; and *pledge funds* that enable investors to make defined contributions to a fund over time *but only invest in the specific projects that they want to invest in* (CPI, 2013b).

Each of these structures provide frameworks through which public and philanthropic entities can mitigate these risks for institutional investors and offer them a new opportunity for portfolio diversification (Blended Finance Taskforce, 2018). Climate Investor One and the Sarulla geothermal project (one of the largest geothermal projects in the world) in Indonesia (an APEC member economy) provide useful examples of how public entities are raising and using blended finance to invest in climate change mitigation and adaptation (Box 9).

National, bilateral and multilateral development finance institutions (DFIs) not only directly provide nearly half of all climate finance, but they are also adept at mobilizing blended concessional finance—concessional finance from donors or third parties (e.g., governments or foundations) alongside their own finance or other commercial finance—to catalyze co-investment from private and other public sources (DFI Working Group, 2018). In 2017, DFIs leveraged approximately $1.2 billion in concessional funds and about $3.9 billion of their own funds to mobilize more than $3.3 billion in private sector finance for sustainable development projects and for projects in developing countries (DFI Working Group, 2018).

DFIs are particularly effective at brokering partnerships between international institutional investors, policymakers and domestic investors to raise blended finance for climate change projects. Such partnerships provide structured mechanisms to address information asymmetry and home bias that international institutional investors typically encounter when investing in developing markets. They also enable DFIs to support international investors in participating in long-term investments in developing markets through things like direct co-investment in infrastructure projects and investment in local infrastructure funds.

This is true, for example, of the partnership between the World Bank Group and the National Association of Securities Professionals (NASP) that has mobilized $800 million through South Africa's private equity industry for infrastructure projects across Africa. NASP provides a useful example of how DFI's develop peer-to-peer networks between international and domestic institutional investors and establish blended finance vehicles to advance things like climate change adaptation. In partnerships like this one, DFIs provide valuable technical inputs on policy and regulatory reforms, local markets development including minimum threshold of financial sector development, and asset pipelines, that help inform the investment focus. They also leverage their convening power, which enables structured policy dialogues, peer-to-peer relationships with domestic investors, and wide market participation.

For every dollar that they invested in climate change mitigation and adaptation from 2016 through 2018, for example, six multilateral DFIs jointly raised between $1.38 and $1.58 in co-investments—$0.87 in other public finance and $0.62 in private finance, on average (WRI, 2019) (see Figure 25).

Institutional investors have been slower to embrace blended finance than other private sector investors, but recent market activity indicates that this might be changing. For example, Allianz (the world's largest insurance company) committed $110 million to the Emerging Africa Infrastructure Fund in 2018 (Convergence, 2018). Such efforts benefit from the recent publication of blended-finance principles by organizations like the World Bank Group's International Finance Corporation, which put forth standards related to ensuring that the blending of funds achieves several goals—that it fills a gap in the market, attracts private investment with the minimum required concessionality, is in pursuit of both sustainability and commercial viability, addresses market failures and distortions, and promotes adherence to high governance, transparency, and other standards (IFC, n.d.). Attracting institutional investors to blended finance for climate change mitigation and adaptation will also require scaling up the size of related investment vehicles from the millions to the billions (Convergence, 2018).

Box 8. Raising and using blended finance for climate change mitigation and adaptation in action – Climate Investor One and the Sarulla geothermal project (Indonesia)

Raising capital: Climate Investor One. Launched in 2015 by the Netherlands Development Finance Company (FMO) in partnership with Phoenix InfraWorks, Climate Investor One raises and blends capital for renewable energy projects in low and lower middle-income countries. It includes three stages (tiers) of investment, each that uses a different blended finance approach to provide capital for a different project phase with its own level of risk and expected returns and that raise capital for the entirety of a project's lifecycle.

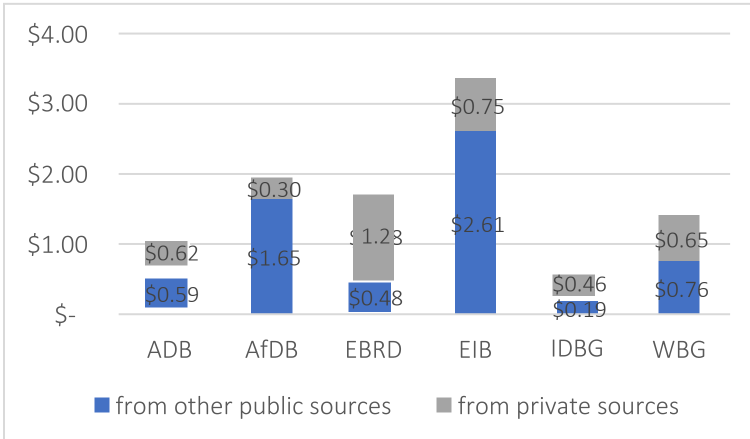
<table>
<tr><th rowspan="2">Tiers</th><th rowspan="2">Blended finance structure</th><th colspan="2">Direct investment</th><th rowspan="2">Expected returns</th></tr>
<tr><th>Concessional + public</th><th>Private</th></tr>
<tr><td>Tier 1 (20%)</td><td>First loss</td><td rowspan="3">$175 million</td><td rowspan="3">$300 million ($225 million guaranteed)</td><td>2% (inflation)</td></tr>
<tr><td>Tier 2 (40%)</td><td>Subordinated equity</td><td>20%</td></tr>
<tr><td>Tier 3 (40%)</td><td>Senior fixed income</td><td>8%</td></tr>
</table>

As of June 2019, the fund had raised $850 million which it plans to use to invest in projects that will deliver an estimated 1,700MW of additional capacity, generating approximately 5,100GWh of electricity per annum and reduce greenhouse gas (GHG) emissions by 1.9 million per ton of CO_2 per year.

Financing projects: the Sarulla geothermal project. Using a political risk guarantee provided by the Japan Bank for International Cooperation and a 20-year Business Viability Guarantee from the Government of Indonesia, the Asian Development Bank led an effort to secure $350 million in blended capital to launch the Sarulla geothermal project. One of the largest geothermal projects in the world, the Sarulla project was fully operational as of 2018 and supplying 330MW of geothermal energy.

Sources: Asian Development Bank (ADB) (n.d.); Blended Finance Task Force (2018); Convergence (2018); Richter (2018); The Lab (2019)

Figure 25. Co-financing mobilized for every $1 spent by multilateral DFIs for climate change mitigation and adaptation, 2016-2018



Source: WRI (2019).

Other climate investment products and strategies

The market for investment-grade climate-related investment products is small and still developing, but various products, tools and other options provide institutional investors with immediate, high-quality opportunities to contribute to mitigation and adaptation solutions. Further, some climate-related sectors, sub-sectors and technologies once deemed too new, immature or small for institutional investment (i.e., risky) have matured and provide opportunities for larger deals in bankable- and operational-stage projects (WEF, 2016).

There are potentially profitable investment opportunities or strategies in most asset classes through which institutional investors can support energy efficiency projects and energy efficient companies, influence climate change mitigation efforts outside of investing in renewable energy and promote sustainable cities and public transportation. They include, for example:

- *Fixed income investments* like green bonds, the market for which has grown tremendously since the first bond was issued in 2007 – in terms of popularity, capital raised, deal size, market confidence, among other things. As described in chapter 2, today's $168 billion green-bond market largely aligns with internationally-recognized standards and principles (e.g., the Green Bond Principles and the Climate Bond Standard); has 625 issuers (including financial institutions, commercial banks, asset managers, and pension funds); and has a median deal size of $129 million. It is expected to continue to grow, with issuances exceeding US180 billion in 2019 (Climate Bonds Initiative, 2019).
- Strategically investing in large climate-focused or -friendly companies through the public markets or using active ownership and exercising shareholder rights as part of *public equities* investment management to pressure holdings to reduce their emissions (Box 10) and divesting from public holdings when engagement is ineffective.
- Buildings account for as much as 40% of energy consumption in places like the U.S. (UEIA, 2019). Institutional investors can strategically use *real estate* investments to promote energy efficiency, assure environmental health and increase the use of sustainable construction materials. Global Real Estate Sustainability Benchmark (GRESB), established in 2011 by a group of pension funds

provides investors a benchmark against which to assess the energy efficiency of their real estate investments.

- *Real assets and infrastructure* investments in sectors like sustainable forestry have the potential to conserve critical ecosystems, prevent deforestation, sequester carbon and generate economic activity for local communities (GIIN, 2019). On average, institutional investors allocate approximately 3% of their assets in real assets including infrastructure, timber and agriculture and achieve average returns between 6% and 8% in this asset class (Ellsworth and Spalding, 2016). For example, Manulife Investment Management, the global asset management division of Manulife, the Canadian insurance and financial services company, invests in Hancock Timber Resource Group (HTRG), which develops and manages over 6 million acres (2 million hectares) of globally diversified timberland portfolios (Manulife, 2019; Hancock, 2019).

There are also various other investment tools and mechanisms that institutional investors can use to reduce the carbon emissions of their portfolios, including environmentally targeted mutual funds, Exchange-Traded Funds (ETFs), climate-focused indexes and sustainable stock exchanges:

- In addition to the availability of individual publicly traded stocks in alternative energy and energy efficiency companies, a growing number of sustainable mutual and *ETFs* include alternative energy or climate change considerations as part of their broader consideration of ESG factors. These pooled funds have steadily increased over time. For example, of the 37 new ETFs launched in 2018, 18 were sustainable ETFs (Hale, 2019). ETFs are collections of securities (e.g., stocks or bonds) that typically track an underlying index, and which can be traded throughout the day like individual stocks. (Investors in conventional mutual funds can only trade in and out of these funds at the end of each day.) The largest climate-focused ETFs is iShares' MSCI ACWI Low Carbon Target ETF, which tracks an index composed of large and mid-capitalization developed, as well as emerging market equities with relatively low carbon exposure (iShares, 2019).
- Most of the major index providers are increasingly offering sustainable indexes (including MSCI, Standard & Poor's/Dow Jones and FTSE/Russell and Thomson Reuters), with some providing explicitly *climate-focused indexes*. The latter enable institutional investors to integrate climate risk considerations into their global equity investment processes. In 2019, for example, MSCI announced the launch of its MSCI Climate Change Indexes, which re-weight securities based on their exposure to low carbon transition risks, carbon emissions and renewable energy, thereby helping investors build climate resiliency into their global equities portfolios. Other indexes include the Low Carbon 100 Europe Index, based on the performance of the 100 largest European companies with the lowest carbon (CO2) intensity in their respective sectors or sub-sectors, and the FTSE Global Climate Index Series (Bernstead, 2019; MSCI, 2019).

  Institutional investors with a passive investment strategy can use these indexes to ensure that they shift their investment allocations away from high-emitters and to low-emitters. Among these is New York State Common Retirement Fund, which recently doubled its passive equity investments in an internally managed low emissions index to $4 billion. New Zealand Superannuation Fund plans to manage its entire passive equity portfolio against a low-carbon benchmark by 2020 that will reduce its exposure to overall emissions by 20% and to carbon reserves by 40% (Guyattt and Chatterjee, 2018).

Box 9. Active ownership to reduce emissions

Some institutional investors engage directly with companies to address ESG challenges, including those related to climate change. Many do so as an alternative to divesting from problematic holdings, believing that they can better effect change through engagement than divestment. This engagement goes beyond exercising voting rights (however important) and emphasizes ongoing dialogue and progress measurement. These actions are commonly coordinated across shareholders to maximize influence and impact.

Under the leadership of the California Public Employees' Retirement System (CalPERS), for example, 320 investors—including other of the largest investors in the world (GPIF, APG, PGGM, PIMCO, UBS)—have joined Climate Action 100+, an initiative focused on pressuring some of the world's largest carbon-emitting corporates to reduce their carbon footprint (i.e., greenhouse gas emissions) in line with the Paris Agreement goals.

In 2015, CalPERS—one of the ten largest asset owners in the world with more than $375 billion in assets under management—used Carbon Disclosure Project (CDP) data to assess the emissions of its public equities portfolio. It found that approximately 100 of its more than 10,000 holdings generated half of the portfolio's carbon emissions. Furthermore, the analysis revealed that these 100 companies are among the top carbon emitters in the world (including BP and Maersk) and emit 28 gigatons of carbon per year, *more than half of the maximum gigatons (40) at which it is possible to achieve the Paris Agreement 1.5°C goal.*

CalPERS subsequently recruited its peers (e.g., GPIF, APG) whose portfolios also include many of these 100 "focus list" companies, and who collectively represent nearly $34 trillion in assets under management, to join Climate Action 100+ and collaboratively pressure the holdings to: (1) ensure that their governance structures encourage climate risk accountability and oversight; (2) improve their carbon disclosure; and (3) reduce their carbon emissions.

According to CalPERS, such collaborative engagement might be one of the most effective ways that they can help to achieve the Paris Agreement Goals: *The emissions trajectory of these top emitters—or systemically important carbon emitters—is critical to whether the global economy meets the 2 °C temperature-rise limit set out in the Paris Agreement*. According to Anne Simpson, CalPERS' Director of Board Governance and Strategy, it is through Climate Action 100+ that CalPERS and others can "get down to the actual companies - not sectors, that's where we have ownership rights and can engage."

The focus list companies have five years to implement their emissions reduction plans, which correspond with the timeline for achieving the Paris Agreement goals.

Sources: Simpson (2019); Climate Action 100+ (2019); CalPERS (2019); Burckart et al. (2016); Convergence (2018); Richter (2018); The Lab (2019)

- *Sustainable stock exchanges* help investors identify companies with favorable ESG ratings and, in some instances, those with a focus on climate change adaptation and mitigation. Launched in 2009, the Sustainable Stock Exchange (SSE) initiative has helped publicize the utility of stock exchanges for promoting standards, enhancing transparency, guiding issuers, investors, and policymakers, and facilitating the growth of climate finance. It focuses on five areas of action, including: strengthening disclosure (i.e., improving the quality and quantity of disclosure of environmental and social data); clarifying duties (i.e., guiding investors on the integration of sustainability into their decisions); strengthening governance (i.e., introducing board responsibilities related to environmental and social factors); building capacity (i.e., facilitating the training of market participants on sustainability topics); and facilitating investment (i.e., aiding investment flows towards achieving the SDGs via financial products) (SSEI, 2017).

Of interest to institutional investors is the SSE initiative's promotion of listing standards mandating ESG disclosure. For example, the Hong Kong Exchanges and Clearing Limited (HKEX), which has more than 2,200 companies listed on its stock exchange, requires its listed companies to report ESG information, and provides both written guidance and training on this and other sustainability-related topics. As of June 2018, The HKEX was the 74th stock exchange to join the SSE initiative, which now represents nearly 30,000 companies with a market capitalization of $40 trillion (SSEI, 2017).

Local capital market development

Blended finance and each of the investment opportunities, strategies and tools discussed above represent important steps toward developing local capital markets that transform climate change investment *needs* into actual investment *opportunities*. But more work remains—on the part policymakers, regulators and investors alike—to develop markets that not only attract institutional and other private investors to climate finance, but that would also encourage investment in any number of other sustainable and development issues.

Such local capital market development should focus on: (a) providing investment opportunities for institutional investors and other financial system actors (e.g., savers) that—depending on risk profile, liquidity needs and other factors—offer better returns than bank deposits; (b) helping investors diversify their portfolios and manage risk by giving them access to a wider range of securities and instruments, which is particularly important for institutional investors like pension funds and insurance companies (IFC, 2017); and (c) improving risk-sharing and the efficiency with which capital is allocated to the real economy (Laeven, 2014).

In support of these pursuits, regulators and policymakers can develop protections for the rights of investors and creditors, enact well-designed bankruptcy law, increase the availability of liquidity provided by sound banks, enable foreign-owned financial firms to compete on equal terms with domestic-owned firms and enhance the ability to issue internationally recognized safe assets and assets that maintain liquidity in bad times (i.e. hard currencies like US Treasuries) (Rojas-Suarez, 2014; Dam, 2002).

3.3 Creating a path forward: Lessons from Chile's policy changes and regulatory guidance

In just five years, Chile has more than tripled the percentage of energy that it produces from renewable sources. It has also increased energy investment and lowered energy prices. In doing so, Chile has created a renewable energy market that is increasingly enabling private investment while reducing the need for public sector finance.

The Chilean government implemented a series of coordinated policy and regulatory reforms starting in 2014, when the country had some of the highest energy prices in Latin America and was facing a multitude of energy-supply and transmission challenges. These included: disruption in the gas supply from Argentina, damage from the 2010 earthquake, droughts, monopolistic practices by utility companies and public opposition to the construction of new large-scale coal plants (IEA, 2018a; Lenton, 2016).

Chile's *Energy Agenda* and subsequent *Energy 2050* national energy policy—developed by Ministry for Energy in consultation with various stakeholder groups (including the energy industry and the public)—

jointly established Chile's medium- and long-term energy goals (IEA, 2018a). These included deriving 60% of its energy from renewable sources by 2035, and 70% by 2050, along with a 30% reduction in carbon emissions below 2007 levels by 2030. They also established commitments ensuring that Chile's policy and regulatory environment effectively advanced these goals. Since 2015, in line with the *Agenda* and *Energy 2050*, Chile has, among other things:

- *Passed at least seven new energy-related laws*, including the Transmission Law (2016), that created a single independent system of operators and increased the government's role in expanding Chile's energy transmission system (Congreso, 2016; IEA, 2018a; Lenton, 2016).
- *Held a series of energy auctions* under a reformed system, with 18 bidders in 2014, 28 in 2015, 84 in 2016, and 24 in 2017, emphasizing renewable energy developers (IEA, 2018a).
- *Established the first carbon tax in South America* (IEA, 2018a).

Notably, these activities have enabled the interconnection of Chile's two main electrical grids and subsequent creation of the National Electricity System, as well as the awarding of energy projects to small wind- and solar-energy developers, including one solar energy plant bid that broke the record for lowest price received at auction ($0.0291 kWh) (IEA, 2018a).

Chile's Santiago Stock Exchange (SSE) has also spearheaded a series of reforms since 2015 with the explicit focus of enabling investment that contributes to the country's efforts to address climate change. In 2015, SEE launched the Dow Jones Sustainability Chile Index. In 2016, it published the first Integrated Annual and Sustainability Report and hosted its first training on responsible investment for investors at the LatAM Institutional Investor Group's annual conference. In 2017 it issued its Guide to Responsible Investment. In 2018 it issued guidelines for the issuance of green and social bonds. In 2019, SSE partnered with PRI to host a "Ring the Bell for Responsible Investment" event where it announced PRI's first Chilean signatories including pension fund AFP Cuprum (SSEI, 2016; SSEI, 2019).

Together, these policy changes and market activities have set the stage for scaling-up climate finance from the private sector. Once the primary source of renewable energy finance in Chile, DFIs are gradually phasing out their contributions to make way for increasing investment from commercial banks ($900 million in 2017) and from public utilities (CFLI, 2019). In short, these developments send strong signals that Chile's renewable energy market has rapidly matured to the point where its risks and returns align with institutional investors' preferences.

Conclusion

Without more ambitious climate policy, global temperatures are likely to rise by more than 3°C, costing the APEC region and generate expected economic losses equal to 7.3% of GDP by the end of the century. Increasing temperatures are likely to reduce agricultural yields and labor productivity, increase sea levels and flooding, reducing output across the economy and damaging land and capital stock. These impacts will be particularly severe in lower and lower-middle income economies. If adaptation and mitigation measures are not taken, Indonesia, Thailand and Viet Nam are expected to lose more than 20% of GDP from a combination of these impacts by 2100.

Climate change is also expected to cause significant human damages across APEC member economies. Rising temperatures are expected to increase the number of days of dangerous heat, the frequency of fatal flooding and the disease burden. By 2100, the APEC region could experience an additional 350,000 deaths per year due to more days of extreme heat if adaptation and mitigation measures are not in place. The continued combustion of carbon intensive fuels is also expected to continue to degrade air quality, causing respiratory disease and premature mortality from unsafe levels of air pollution.

Considerable uncertainties in the response of the climate to greenhouse gas emissions and the economy to climate change remain and impacts could be substantially larger, leading to considerable risks from inaction. An extra degree of warming, which is a plausible outcome of current policy, could double the economic losses from declining labor and agricultural productivity. There is also a risk of “tipping points” in the climate system, where if greenhouse gas concentrations exceed a certain level, small changes in one variable could lead to large changes in another. Failure to acknowledge and mitigate climate change risks could lead to substantially more costly to GDP and human health impacts for the APEC region.

Reducing emissions to achieve the goals of the Paris Agreement and transitioning to a low-carbon economy is likely less costly than the losses from unabated climate change and brings sizeable co-benefits. Reducing emissions to a level compatible with the objects of the Paris Agreement is expected to cost an average of 3.4% of GDP across APEC members. The costs as a proportion of GDP are lowest in developed economies and highest in energy-exporting economies. Mitigation would also reduce coastal flooding and avoid chronic impacts such as lower agricultural and labor productivity. Importantly, reducing fossil fuel consumption is expected to reduce deaths from air pollution by 500,000 per year throughout the APEC region.

Transitioning to a low carbon economy consistent with the Paris Agreement could also offer significant investment opportunities in low carbon energy and adaptation measures. By 2050, reducing emissions to levels consistent with the Paris Agreement across the APEC region is expected to require an additional $470 billion per year in energy investment. In the short term, this will require increasing investment in energy efficiency, renewable generation and transmission and distribution infrastructure. Commensurate decreases in investment in fossil fuels would cause low carbon investment to overtake fossil fuel investment by around 2025.

Climate change will have an impact on all aspects of life in APEC: it will influence financial systems, supply chains, worker productivity, facilities, equipment and even consumer behavior. The empirical evidence presented in this report shows that the physical and transition costs from climate change have already impacted equity and debt instrument payoffs and valuations and will likely continue to do so. Financial institutions, including central banks, are not immune to these financial costs. Evidence indicates that financial institutions, on average, are underestimating climate change risks.

To guarantee their survival, financial institutions must integrate climate financial risk management into their operations. For countries at the very beginning of the process of climate financial risk management, central banks and financial regulators can raise awareness by surveying financial institutions practices regarding climate financial risk management. Additionally, central banks and financial supervisors can develop their own tools to assess the exposure of the financial sector and individual institutions to climate financial risks. Finally, central banks and financial regulators can require financial institutions to run climate financial stress tests. This allows financial supervisors to assess the exposure to climate financial risks of individual financial institutions, as well as of the whole financial sector.

The transition to a low-carbon economy will require the mobilization of large amounts of capital and the development of new financial products. This represents a unique opportunity for financial institutions and can translate into a significant comparative advantage and be an efficient way to reduce an institution's overall risk exposure.

Given their tremendous size, influence, and long-term investment horizons, institutional investors in APEC – with their more than $42 trillion in AUM – are uniquely exposed to the long-term threats of climate change and uniquely positioned to invest in long-term climate solutions. Many institutional investors in APEC member economies are increasingly acknowledging and voluntarily managing climate-related risks. They are joining, supporting, and helping to lead sustainability-focused initiatives such as PRI and TCFD. They are also increasingly integrating climate change considerations into their investment analyses alongside social and governance issues. It does not appear, however, that they are systematically investing in efforts to mitigate or adapt to climate change, such as renewable energy or climate-resilient infrastructure.

Fortifying institutional investors in APEC member economies against climate risk and scaling-up their contributions to climate finance will require policymakers, regulators, and financial markets alike to confront the systemic structural barriers that inhibiting progress. Governments, regulators, and investors throughout APEC provide examples of the way forward, which includes among other things:

- Establishing new and expanding existing carbon pricing mechanisms that align with economists' recommendations (≥ $40 per ton);
- Looking to economies like Viet Nam and Chile for examples of effective feed-in-tariffs and renewable energy auctions;
- Learning from Singapore's sovereign wealth fund's approach to long-term investment management and reporting;
- Widely adopting TCFD recommendations for carbon-related disclosures;
- Setting standards for climate-related financial products like People's Bank of China and other Chinese regulators;
- Leveraging blended finance structures provided by various DFIs; and
- Pressuring holdings to reduce their emissions like CalPERS, GPIF, and other members of the Climate Action 100+.

Institutional investors in APEC member economies need not sit on the sidelines and await change. They can and should play an important role in signaling their need. They can continue voluntarily incorporating climate considerations into their investment strategies and seize on the increasing number of climate-related products and tools available to them across asset classes. And they can continue to use their size, influence and platform to advocate for any number of policy, regulatory, and market reforms. The momentum that they create will carry the investment community beyond the tipping point where a focus on climate-related investment is no longer avoidable but is inevitable.

Appendix A. Methodological Assumptions and Additional Data Tables

Physical climate change impacts

Estimates for future temperature, days with dangerous heat, extreme rainfall and drought probability are extracted from the World Bank Climate Knowledge Portal (WBCKP). For all member economies apart from Hong Kong (China) and Chinese Taipei, the WBCKP provides estimates on the country level. For Hong Kong (China) and Chinese Taipei, the data is downloaded using coordinates for those economies. Sea level rise extracted from Kopp et al. (2014). The paper provides estimates of sea-level rise under RCP 2.6, 4.5 and 8.5 scenarios for a global network of tide gauges. In order to generate country-level estimates of Sea Level Rise (SLR), we match countries to their nearest tide gauges and take average values. For the climate change mitigation scenario, we report RCP 2.6 SLRs. The baseline scenario in this chapter is defined by RCP 6.0. Kopp et al. (2014) paper does not provide estimates for RCP 6.0, since "21st-century sea-level rise projections for this pathway are nearly identical to those for RCP 4.5". Therefore, we report RCP 4.5 SLRs for the baseline scenario.

Coastal flood modelling

Coastal flood modelling results, both GDP and mortality impacts, are derived from the DIVA model (Hinkel & Klein, 2009). DIVA is an integrated, state-of-the-art research modelling framework for coastal systems that assesses biophysical and socio-economic consequences of sea-level rise and socio-economic development. It accounts for coastal erosion (both direct and indirect), coastal flooding (including river mouths), wetland change and salinity intrusion into deltas and estuaries. The DIVA was run in support of this chapter under RCP 6.0 and RCP 2.6 concentration pathways under the SSP2 economic growth scenario in order to estimate economic costs of coastal floods and number of people affected with and without adaptation.

River flood modelling

River flood modelling results, both economic losses and mortality impacts, are derived the from estimates by Dottori et al. (2018). This uses a multi-model framework to estimate human losses and direct economic damage from riverine floods at a range of temperatures. It assumes current vulnerability levels and the absence of future adaptation. Climate change is accounted for using the inter-sectoral impact model intercomparison project (ISIMIP) ensemble of river flow projections, comprising ten hydrological models and five driving climate runs. It uses a detailed modelling framework to simulate river flow and flooding processes. This chapter used supplementary data published in support of Dottori et al. (2018) and aligns outputs to a SSP2 growth scenario for consistency with other models run in support of this chapter.

Air pollution

Mortality impacts of air pollution are calculated using TM5-FASST. The TM5-FASST model is a reduced-form air quality source-receptor which of estimates the impact of ambient pollutant concentrations on human health for 56 regions, including most APEC member economies. TM5-FASST is based on a calculation of the relationship between emissions and air pollution at a 1-degree by 1-degree spatial resolution (van Dingenen et al., 2018).

Emissions under the RCP 6.0 and RCP 2.6 scenario are extracted from Fujimori, Hasegawa, Ito, Takahashi, & Masui (2018), which provide gridded emissions data for 2005-2100 under combinations of SSPs and emissions trajectories. The emissions data was extracted and re-aggregated to the 56 TM5-FASST regions and used as input into TM5-FASST.

Mortality from extreme hot and cold days

This report draws on the estimates of temperature-related excess mortality from Gasparrini et al. (2017) to estimate the future impacts of extreme hot and cold days on human health. The paper provides estimates of excess mortality for cold and heat and their net change in 1990–2099 under each scenario of climate change, assuming no adaptation or population changes. For this chapter, estimates are adjusted to take account of population growth according to the SSP2 pathway

Economic costs of climate change and emissions reductions, revenues from carbon taxation

The effect of chronic climate change impacts, the costs of emissions reductions and revenues from carbon taxation are calculated using GTAP-IAM. The GTAP-IAM model is an integrated assessment model that combines a climate module with SSPs and the GTAP and GTAP E (Energy) and P (Power) databases. It is an extension of Global Trade Analysis Project (GTAP)-INT, which has previously been used to model the economic impacts of climate change on GDP at the country-level (Kompas, Pham, & Che, 2018). GTAP Power database allows for a distinction between fossil fuels and renewable sources of energy. The GTAP framework allows for both climate and trade interactions across countries in a large-dimensional setting.

Along with the separation of energy demand from the rest of the demands for other commodities, GTAP-IAM also provides a foundation for climate change analysis by incorporating carbon dioxide emissions, a carbon tax and emissions trading. The carbon tax is converted into percentage form before entering price linkage equations. The tax also serves as trading revenue when countries decide to undergo emissions trading within a trading bloc.

The model is calibrated for 37 countries/regions across 60 commodity groups, solved with forward-looking behavior to 2100. It allows for both a measure of the damages from climate change, relative to an assumed RCP, and the costs of emissions reduction. The bulk of parameter values are as contained in the original GTAP and GTAP E-P databases.

The model accounts for the following climate-change damages, drawing on country-level estimates from Roson and Sartori (2016). For more details on integration into the model, see Kompas, Pham, & Ch (2018):

- Reduction of labor productivity due to temperature increases, modelled for agricultural, manufacturing and service sectors
- Reduction of labor productivity due to increased disease burden
- Reduction of agricultural productivity, modelled for maize, wheat and rice separately and for other crops together
- Inundation of coastal lands due to sea level rise

Energy components have four layers in the model:

- Energy is a composite product from electricity and non-electricity energy
- Non-electricity energy is a composite product of coal and non-coal energy
- Non-coal energy is a composite product of crude oil, gas, and petroleum products
- Crude oil, gas, petroleum products, as well as electricity and coal, are composite products of domestically produced commodities and imports (of these commodities)

All layers of the 'energy tree' are governed by CES technology with various given values of the elasticity of substitution.

The emission reduction estimates the economic costs of limiting temperature rise to a level consistent with the Paris Agreement under the SSP2 growth scenario using the GTAP-IAM model. The emissions reduction scenario assumes the current trajectory in energy efficiency improvements for fossil fuels of 1.78% per year continues, while the efficiency improvement in other GHGs rises from 0.87% per year to 1.5% per year.

To mitigate policy costs, the model permits the use of negative emissions technologies to offset the continued release of GHG emissions in 'hard to treat' sectors. The model solves for the necessary carbon tax rate in order for each member economy to achieve emissions reductions consistent with a below 2°C degree pathway. Revenues from carbon taxation are therefore endogenous to the model. Emissions trade between countries is not modelled, so the modelled carbon tax varies across member economies.

Energy investment needs

Energy investment needs are reported based on estimates published by McCollum et al. (2018). This paper uses an ensemble of models to estimate energy investment needs to transform the energy system into a low carbon system consistent with keeping warming well below 2°C.

The estimates presented in chapter 1 are generated by averaging outputs of 6 Integrated Assessment Models (AIM/CGE, IMAGE, MESSAGEix-GLOBIOM, POLES, REMIND-MagPIE and WITCH-GLOBIOM), under 'Current Policy' and '2C' scenarios, which reflect the baseline and climate change mitigation scenarios in chapter 1.

McCollum et al. (2018) reports results for the United States and China separately as well as the 5 regions from the SSP database. For United States and China, McCollum model estimates are used directly. For APEC member economies other than the United States and China, energy investment needs are calculated based on a member economy's share of its corresponding region's 2050 GDP. For example, Indonesia's 2050 GDP is 11% of the IAM 'Asia' region (less China), therefore 11% of the energy investment need identified by McCollum et al. is assigned to Indonesia. The results are presented undiscounted in 2015$ terms.

Formal/informal sector model

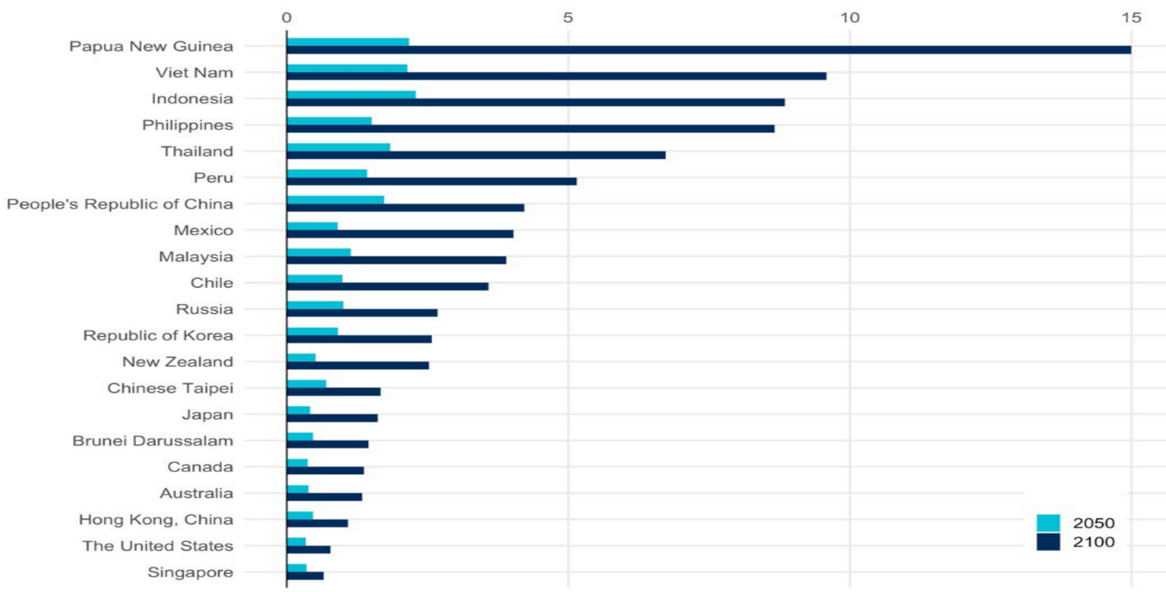
The co-benefits of environmental policy with regards to formal/informal sector substitution are modelled using a new implementation of the model published by Bento, Jacobsen and Liu (2018). Following Piggott

& Whalley (2001), the model encompasses three sectors: manufactured goods, formal services and informal services. Manufacturing and formal services are taxed, while informal services not. Inside the model, energy taxes fall more heavily on manufactured goods, which have no substitutes in the informal economy, whereas labor taxes fall on services, which can be substituted by the formal sector.

We calibrate the model for each country individual based on baseline data. Manufacturing's share of the formal economy, the service sector's share of the formal economy is calibrated to World Bank data (World Bank databank). The energy intensity of the whole economy, energy intensity of the manufacturing sector, energy intensity of the service sector is calculated using GTAP IO database. The size of the informal sector for each APEC country is drawn from Schneider (2005).

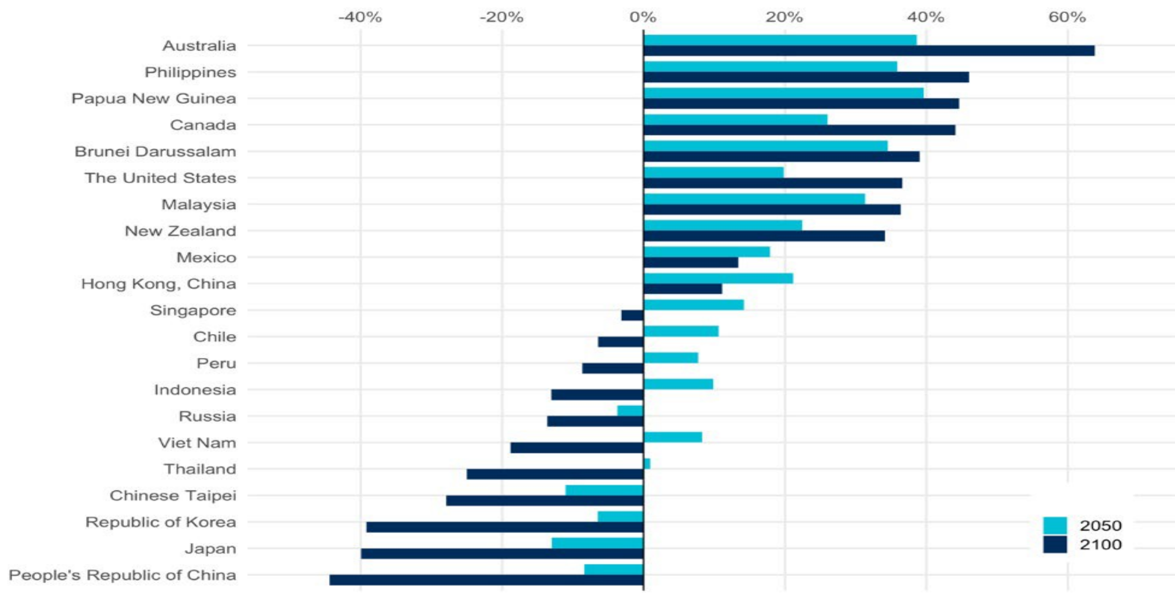
SSP2 scenario assumptions on GDP and population

Figure A.1. SSP2 assumptions on GDP per capita in 2050 and 2100 expressed as a multiple of 2020 levels



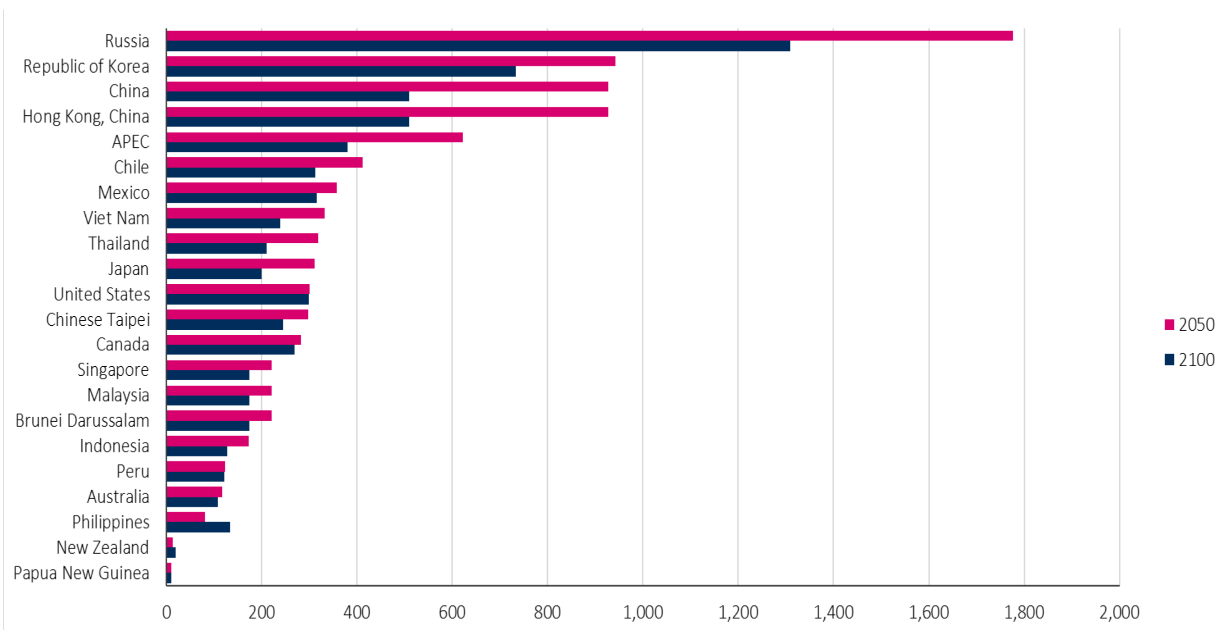
Source: Fricko et al. (2017) and Crespo Cuaresma (2017)

Figure A.2. SSP2 assumptions on population growth, relative to 2020



Source: Samir & Lutz (2017)

Figure A.3. Annual deaths from air pollution per million of population in 2050 and 2100 under the baseline scenario



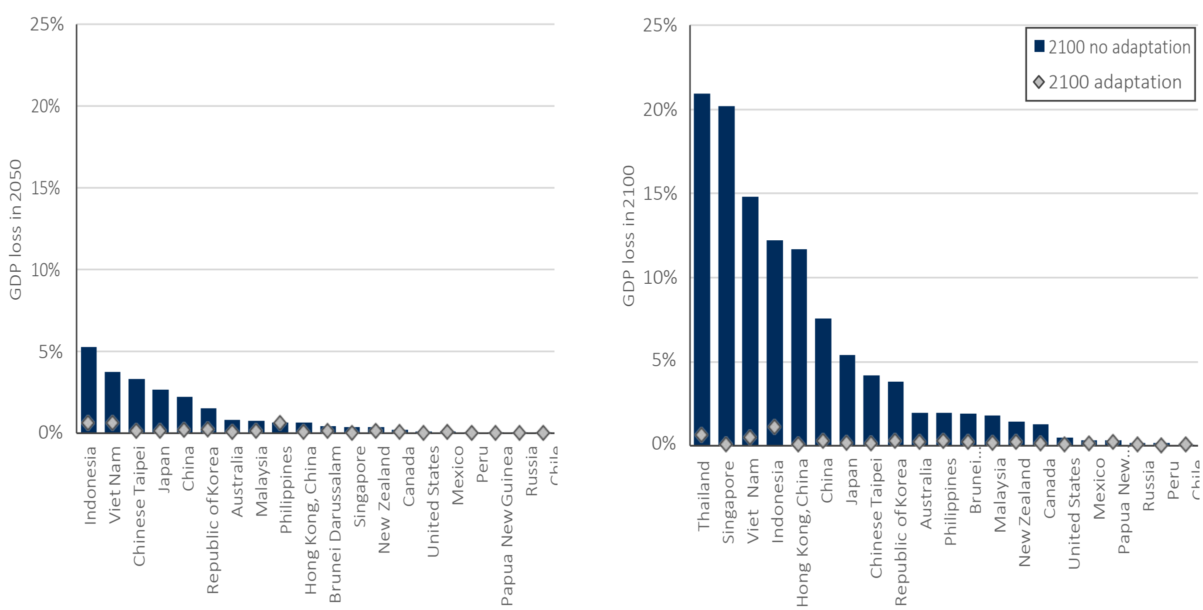
Source: Vivid Economics

Table A.1. Change in sea level, rainfall and drought likelihood

Member	Sea level rise		Expected largest monthly rainfall amount in 25 Years		Annual severe drought likelihood	
	2050	2100	2050	2100	2050	2100
Australia	26 cm	61 cm	14 mm	25 mm	21%	37%
Brunei Darussalam	26 cm	62 cm	14 mm	70 mm	5%	5%
Canada	12 cm	30 cm	11 mm	19 mm	7%	11%
Chile	19 cm	49 cm	-5 mm	-11 mm	28%	45%
Chinese Taipei	25 cm	60 cm	52 mm	125 mm	14%	16%
Hong Kong, China	25 cm	58 cm	28 mm	101 mm	11%	11%
Indonesia	24 cm	58 cm	48 mm	120 mm	6%	7%
Japan	27 cm	62 cm	27 mm	72 mm	9%	9%
Malaysia	24 cm	58 cm	36 mm	93 mm	5%	6%
Mexico	30 cm	67 cm	25 mm	33 mm	25%	45%
New Zealand	28 cm	61 cm	10 mm	14 mm	8%	13%
Papua New Guinea	26 cm	62 cm	94 mm	121 mm	7%	8%
People's Republic of China	26 cm	61 cm	25 mm	64 mm	18%	29%
Peru	21 cm	52 cm	54 mm	102 mm	15%	22%
Philippines	33 cm	75 cm	14 mm	100 mm	4%	3%
Republic of Korea	27 cm	62 cm	53 mm	115 mm	9%	11%
Russia	14 cm	32 cm	8 mm	19 mm	9%	11%
Singapore	24 cm	58 cm	6 mm	89 mm	7%	17%
Thailand	31 cm	72 cm	53 mm	187 mm	8%	8%
The United States	18 cm	44 cm	15 mm	26 mm	15%	25%
Viet Nam	17 cm	45 cm	2 mm	73 mm	10%	9%

Note: Sea level rise relative to 2000, expected largest monthly rainfall amount in 25 years and drought likelihood relative to 1986-2005. Severe drought is defined as a Standardized Precipitation Evaporation Index below negative 2. Source: Kopp et al. (2014), World Bank Climate Portal, Vivid Economics

Figure A.4. 2100 Coastal flood losses as a % of GDP under baseline scenario



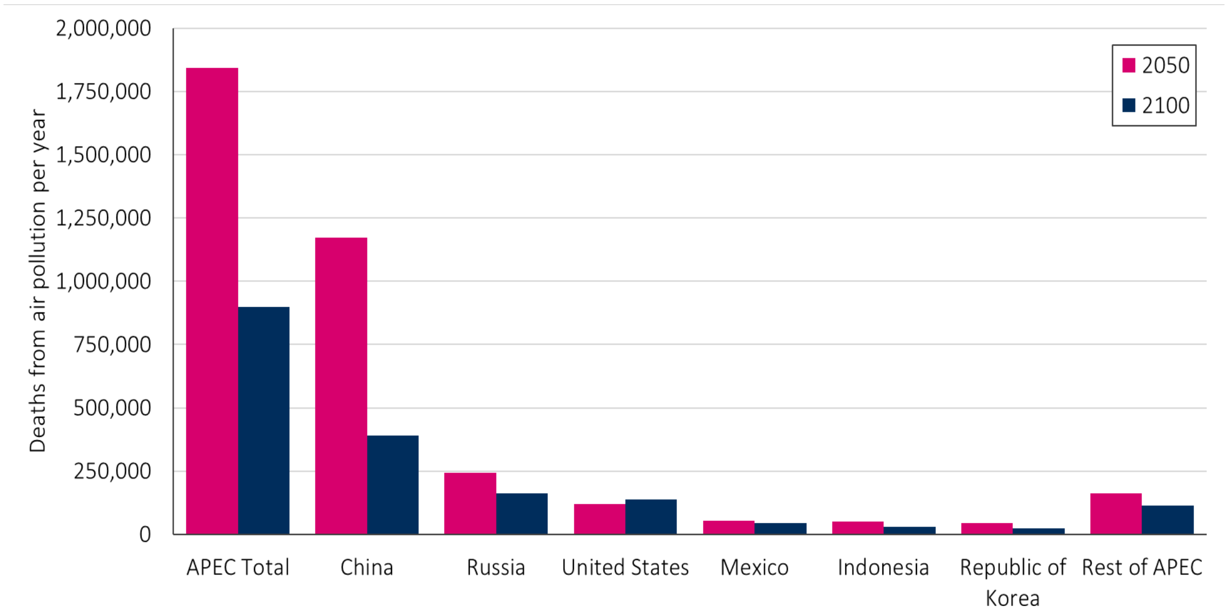
Source: Vivid Economics, based on Hinkel, J., & Klein, R. J. T. (2009)

Table A.2. Change in health impacts from 2020 to 2050 under the baseline scenario

	Hot and cold	River flood	Coastal flood
	Change in annual deaths per million		
Australia	-61	0.0	1.0
Brunei Darussalam	-66	0.1	0.9
Canada	0	0.1	0.2
Chile	-31	0.0	0.0
People's Republic of China	-41	0.2	0.9
Chinese Taipei	13	0.0	3.5
Hong Kong, China	-38	0.0	0.6
Indonesia	119	0.0	0.6
Japan	-103	0.0	3.2
Malaysia	105	0.1	0.6
Mexico	89	0.0	0.3
New Zealand	-71	0.1	0.6
Papua New Guinea	-49	0.1	0.1
Peru	-25	0.4	0.2
Philippines	-52	0.1	0.3
Republic of Korea	0	0.0	1.7
Russia	-72	0.0	0.0
Singapore	156	0.0	0.4
Thailand	171	0.1	1.5
The United States	-21	0.0	0.2
Viet Nam	126	0.3	2.4
APEC	-5	0.1	0.8

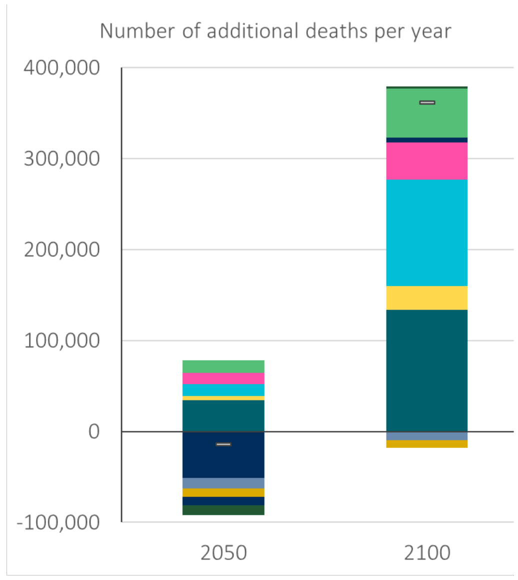
Source: Vivid Economics, based on World Bank Climate Portal

Figure A.5. The impact of air pollution on mortality in 2050 and 2100 under the baseline scenario



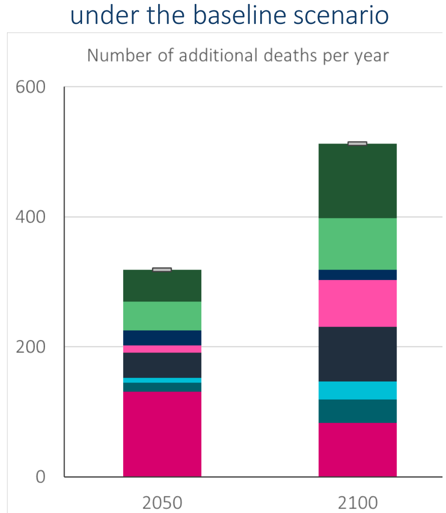
Source: Vivid Economics, based on TM5-FASST model

Figure A.6. Changes in mortality due extreme temperatures from 2020 to 2050 and 2100 under the baseline scenario



Source: Vivid Economics, based on Gasparrini et al. (2017)

Figure A.7. Increase in mortality from river flooding from 2020 to 2050 and 2100 under the baseline scenario



Source: Vivid Economics, based on Dottori et al. (2018)

Table A.3. Avoided physical impacts through Paris compatible policy: heat

Member	Avoided change in annual average temperature		Avoided change in days with dangerous heat	
	2050	2100	2050	2100
Australia	0.3°C	1.3°C	6	24
Brunei Darussalam	0.1°C	1.0°C	8	53
Canada	0.2°C	2.4°C	0	0
Chile	0.2°C	1.1°C	0	-0
Chinese Taipei	0.0°C	1.1°C	0	38
Hong Kong, China	-0.0°C	1.0°C	2	50
Indonesia	0.1°C	1.0°C	9	70
Japan	0.0°C	1.3°C	-0	4
Malaysia	0.2°C	1.1°C	8	59
Mexico	0.2°C	1.5°C	2	12
New Zealand	0.2°C	1.1°C	0	0
Papua New Guinea	0.2°C	1.1°C	5	33
People's Republic of China	0.1°C	1.7°C	1	6
Peru	0.2°C	1.4°C	3	24
Philippines	0.1°C	1.0°C	15	102
Republic of Korea	-0.0°C	1.3°C	-1	3
Russia	0.2°C	2.3°C	-0	0
Singapore	0.1°C	1.0°C	34	120
Thailand	0.1°C	1.1°C	17	67
The United States	0.1°C	1.7°C	0	6
Viet Nam	0.1°C	1.1°C	11	53

Source: Vivid Economics, based on World Bank Climate Change Knowledge Portal

Table 24. Avoided physical impacts through Paris compatible policy: sea level rise, precipitation and drought

Member	Avoided sea level rise		Avoided change in expected largest monthly rainfall in 25 Years		Avoided change in annual severe drought likelihood	
	2050	2100	2050	2100	2050	2100
Australia	2 cm	11 cm	12 mm	31 mm	0%	13%
Brunei Darussalam	2 cm	11 cm	-22 mm	59 mm	-3%	-1%
Canada	-0 cm	9 cm	-1 mm	7 mm	0%	4%
Chile	1 cm	9 cm	6 mm	-13 mm	4%	25%
Chinese Taipei	1 cm	10 cm	-19 mm	89 mm	0%	4%
Hong Kong, China	2 cm	10 cm	-62 mm	42 mm	4%	2%
Indonesia	2 cm	10 cm	1 mm	55 mm	-0%	1%
Japan	2 cm	11 cm	-10 mm	32 mm	4%	4%
Malaysia	2 cm	10 cm	-8 mm	58 mm	0%	1%
Mexico	1 cm	9 cm	4 mm	17 mm	6%	25%
New Zealand	3 cm	12 cm	2 mm	8 mm	2%	7%
Papua New Guinea	2 cm	11 cm	56 mm	41 mm	0%	3%
People's Republic of China	2 cm	11 cm	-4 mm	30 mm	3%	13%
Peru	1 cm	9 cm	25 mm	60 mm	-1%	6%
Philippines	2 cm	12 cm	-1 mm	57 mm	1%	-1%
Republic of Korea	2 cm	11 cm	11 mm	65 mm	-2%	3%
Russia	1 cm	9 cm	-1 mm	8 mm	1%	3%
Singapore	2 cm	10 cm	-6 mm	70 mm	-3%	4%
Thailand	2 cm	11 cm	-6 mm	126 mm	2%	-2%
The United States	1 cm	10 cm	1 mm	12 mm	2%	12%
Viet Nam	2 cm	12 cm	-7 mm	61 mm	3%	1%

Source: Vivid Economics, based on Kopp et al. (2014) and the World Bank Climate Change Knowledge Portal

Table A.5. Change in health impacts from 2020 to 2100 under the baseline scenario

	Hot and cold	River flood	Coastal flood
	Change in annual deaths per million		
Australia	-103	0.0	2.3
Brunei Darussalam	-29	0.1	2.8
Canada	39	0.1	1.3
Chile	-13	0.0	0.1
People's Republic of China	0	0.6	3.1
Chinese Taipei	104	0.3	3.9
Hong Kong, China	0	0.1	10.8
Indonesia	586	0.2	2.0
Japan	-123	0.3	5.9
Malaysia	593	0.4	1.4
Mexico	819	0.2	0.6
New Zealand	-128	0.1	1.8
Papua New Guinea	-21	0.5	0.2
Peru	-12	1.3	0.3
Philippines	-25	0.3	0.7
Republic of Korea	189	0.4	3.9
Russia	-70	0.1	0.1
Singapore	599	0.1	18.9
Thailand	747	1.7	5.5
The United States	11	0.0	0.6
Viet Nam	689	1.4	6.9
APEC	154	0.3	2.2

Source: Vivid Economics

Table A.6. Health benefits from Paris compatible policy in 2050 compared to baseline

	Air pollution	Hot and cold	River floods	Coastal floods
	Avoided annual deaths per million			
Australia	-7	-35	0.0	-0.1
Brunei Darussalam	41	-11	0.1	0.0
Canada	44	11	0.1	-0.2
Chile	66	-10	-0.0	0.0
People's Republic of China	311	0	0.1	-0.2
Chinese Taipei	108	13	0.0	-0.1
Hong Kong, China	311	0	0.0	0.2
Indonesia	29	90	0.0	0.0
Japan	96	-59	0.0	0.0
Malaysia	41	79	0.1	0.0
Mexico	81	54	0.0	0.0
New Zealand	1	-41	0.0	0.0
Papua New Guinea	1	-8	0.1	0.0
Peru	10	-8	0.3	0.0
Philippines	20	-9	0.1	0.0
Republic of Korea	263	-15	0.0	-0.3
Russia	167	-29	0.0	0.0
Singapore	41	117	0.0	0.2
Thailand	116	128	0.1	0.6
The United States	38	-11	0.0	0.0
Viet Nam	73	95	0.2	0.1
APEC	171	13	0.1	-0.1

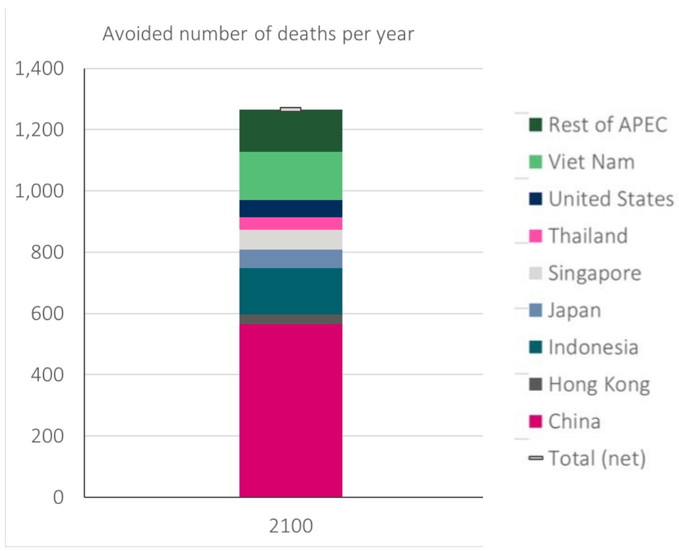
Source: Vivid Economics, based on Gasparrini et al (2017), Dottori et al (2018) and the DIVA model (Hinkel et al, 2009)

Table A.7. Health benefits from Paris compatible policy in 2100 compared to baseline

	Air pollution	Hot and cold	River floods	Coastal floods
	Avoided annual deaths per million			
Australia	-19	-94	-0.0	0.4
Brunei Darussalam	27	58	0.1	1.0
Canada	45	49	-0.0	0.1
Chile	77	26	0.0	0.0
People's Republic of China	127	27	0.4	0.7
Chinese Taipei	54	83	0.2	0.6
Hong Kong, China	127	21	0.1	3.6
Indonesia	17	525	0.1	0.7
Japan	64	-82	0.2	0.8
Malaysia	27	531	0.2	0.4
Mexico	77	806	0.2	0.1
New Zealand	1	-117	0.1	0.7
Papua New Guinea	0	42	0.5	0.0
Peru	7	23	0.9	0.0
Philippines	16	49	0.2	0.3
Republic of Korea	168	173	0.3	0.3
Russia	77	-59	0.1	0.0
Singapore	27	536	0.1	12.0
Thailand	61	669	1.5	0.7
The United States	50	21	-0.0	0.1
Viet Nam	37	640	1.1	2.0
APEC	72	161	0.3	0.5

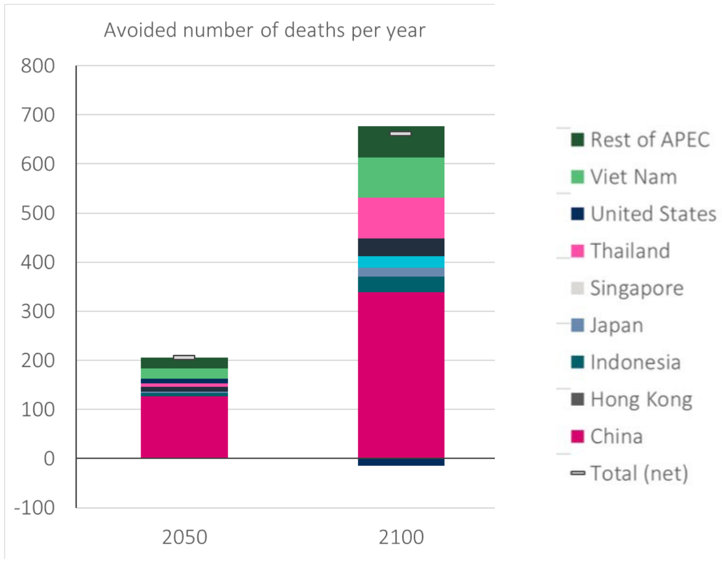
Source: Vivid Economics, based on Gasparrini et al (2017), Dottori et al (2018), the DIVA model (Hinkel et al, 2009) and the TM5-FASST model (van Dingenen et al, 2018).

Figure A.8. Benefits of emissions reduction in avoided mortality from coastal flooding



Source: Vivid Economics, based the DIVA model (Hinkel et al, 2009)

Figure A.9. Benefits of emissions reduction in avoided mortality from river flooding



Source: Vivid Economics, based on Dottori et al (2018)

Table A.8. Air pollution co-benefits from emissions reduction in 2050 and 2100

Member		Avoided annual deaths per million 2050	2100
Australia		-7	-19
Brunei Darussalam		41	27
Canada		44	45
Chile		66	77
People's Republic of China		311	127
Chinese Taipei		108	54
Hong Kong, China		311	127
Indonesia		29	17
Japan		96	64
Malaysia		41	27
Mexico		81	77
New Zealand		1	1
Papua New Guinea		1	0
Peru		10	7
Philippines		20	16
Republic of Korea		263	168
Russia		167	77
Singapore		41	27
Thailand		116	61
The United States		38	50
Viet Nam		73	37
APEC		171	72

Source: Vivid Economics

Appendix B. Trends in Global Climate Finance Over Time

Table B.1. Total climate finance, 2012-2016 (billions USD)

Year	Amount
2012	$359
2013	$342
2014	$392
2015	$472
2016	$455
2017 (projected)	*$510-$530*

Table B.2. Private vs. public climate finance, 2012-2016 (billions USD)

	2012	2013	2014	2015	2016
Private					
Commercial FI	21	21	46	54	42
Corporate actors	66	47	59	46	28
Households	33	40	41	39	44
Institutional investors	0.4	1	1	3	2
PE, VC, Infrastructure funds	1.2	2	2	2	1
Project developers	102	88	92	124	113
Total private	224	199	241	267	230
Public					
Climate Funds	1.6	2	2	2	3
Governments and their agencies	12	12	14	17	19
Total public FI	122	129	134	185	202
Public FI – Bilateral	*15*	*15*	*22*	*17*	*14*
Public FI – Multilateral	*38*	*44*	*48*	*44*	*48*
Public FI – National	*69*	*70*	*64*	*124*	*140*
Total public	136	143	151	205	224

Table B.3. Climate finance by use, 2012-2016 (billions USD)

	2012	2013	2014	2015	2016
Adaptation					
Coastal protection	2	0.5	1	0.2	0.1
Industry, extractive industries, manufacturing & trade		0.5	0.3	0.1	0.1
Policy and national budget support and capacity building	0.2	0.7	0.9	0.2	0.4
Infrastructure, energy, and other built environment		3	2	1	1
Agriculture, forestry, land-use, and natural resource management	3	2	4	4	5
Water and wastewater management	10	15	15	11	11
Other adaptation	7	4	4	5	6
Total adaptation	22	27	27	22	22
Mitigation					
Non-energy GHG reductions		7	0.2	0.1	0.1
Policy and national budget support and capacity building		0.4	0.1	0.2	0.3
Waste and wastewater management		1	1	1	0.7
Low-carbon technologies		0.3	4	2	2

Transmission & distribution systems		1	3	6	3
Agriculture, forestry, land-use, and natural resource management		6	4	5	4
Energy efficiency	32	31	26	26	33
Sustainable transport		17	22	78	106
Renewable energy generation	265	244	284	321	269
Other mitigation	40	4	16	6	10
Total mitigation	337	311	360	445	427
Dual Benefits		4	4	5	6

Table B.4. Climate finance by geographical destination, 2013-2016 (billions USD)

	2013	2014	2015	2016
Non-OECD				
Central Asia and Eastern Europe	11	12	11	8
East Asia and Pacific	95	118	175	184
Latin America and the Caribbean	24	27	32	20
Middle East and North Africa	5	9	8	7
South Asia	13	17	20	24
Sub-Saharan Africa	13	10	13	12
Transregional	10	13	12	13
Total non-OECD	169	206	270	269
OECD				
Americas	38	44	54	59
Japan, Korea, Israel	35	40	36	17
Other Oceania	5	3	3	5
Western Europe	94	98	109	105
Total OECD	172	185	202	186

Table B.5. International and domestic climate finance flows, 2013-2016 (billions USD)

	2013	2014	2015	2016
Domestic				
Non-OECD	123	150	214	214
OECD	130	140	168	156
Total domestic	253	290	382	370
International				
From non-OECD to other non-OECD	11	10	12	10
From non-OECD to OECD	3	2	3	3
From OECD to other OECD	40	43	31	27
From OECD to non-OECD	36	47	44	45
Total international	90	102	90	85

Table B.5. Climate finance by instrument type, 2012-2016 (billions USD)

	2012	2013	2014	2015	2016
Grant	11	13	13	18	18
Project-level equity	11	17	27	40	36
Low-cost project debt	69	74	48	45	45
Balance sheet financing	198	164	177	179	142
Project-level market rate debt	70	74	125	190	215

Sources for all tables in this appendix:

Climate Policy Initiative (CPI) (2018). *Global Climate Finance: An Updated View 2018*. November 2018.
CPI (2016). *Global Climate Finance: An Updated View on 2013 & 2014 Flows*. October 2016.
CPI (2013). *The Global Landscape of Climate Finance 2013.* October 2013.

References

Chapter 1

Bento, A. M., Jacobsen, M. R., & Liu, A. A. (2018). Environmental policy in the presence of an informal sector. *Journal of Environmental Economics and Management*, *90*, 61–77. https://doi.org/10.1016/j.jeem.2018.03.011

Brück, T., & d'Errico, M. (2019). Food security and violent conflict: Introduction to the special issue. World Development, 117, 167–171. https://doi.org/10.1016/j.worlddev.2019.01.007

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, *527*(7577), 235–239. https://doi.org/10.1038/nature15725

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, *4*(4), 287–291. https://doi.org/10.1038/nclimate2153

Coffel, E. D., Horton, R. M., & de Sherbinin, A. (2018). Temperature and humidity-based projections of a rapid rise in global heat stress exposure during the 21st century. Environmental Research Letters, 13(1), 014001. https://doi.org/10.1088/1748-9326/aaa00e

Dellink, R., Chateau, J., Lanzi, E., & Magné, B. (2017). Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change, 42, 200–214. https://doi.org/10.1016/j.gloenvcha.2015.06.004

Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. Proceedings of the National Academy of Sciences, 201816020. https://doi.org/10.1073/pnas.1816020116

Dottori, F., Szewczyk, W., Ciscar, J.-C., Zhao, F., Alfieri, L., Hirabayashi, Y., … Feyen, L. (2018). Increased human and economic losses from river flooding with anthropogenic warming. *Nature Climate Change*, *8*(9), 781–786. https://doi.org/10.1038/s41558-018-0257-z

Ebi, K. L., & Mills, D. (2013). Winter mortality in a warming climate: a reassessment. *Wiley Interdisciplinary Reviews: Climate Change*, *4*(3), 203–212. https://doi.org/10.1002/wcc.211

Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Fricko, O., Havlik, P., Rogelj, J., Klimont, Z., Gusti, M., Johnson, N., … Riahi, K. (2017). The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century. Global Environmental Change, 42, 251–267. https://doi.org/10.1016/j.gloenvcha.2016.06.004

Fujimori, S., Hasegawa, T., Ito, A., Takahashi, K., & Masui, T. (2018). Gridded emissions and land-use data for 2005–2100 under diverse socioeconomic and climate mitigation scenarios. *Scientific Data*, *5*(1), 180210. https://doi.org/10.1038/sdata.2018.210

Gasparrini, A., Guo, Y., Sera, F., Vicedo-Cabrera, A. M., Huber, V., Tong, S., … Armstrong, B. (2017). Projections of temperature-related excess mortality under climate change scenarios. *The Lancet Planetary Health*, *1*(9), e360–e367. https://doi.org/10.1016/S2542-5196(17)30156-0

The Global Commission on Adaptation. (2019). Adapt now: a global call for leadership on climate resilience.

Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2019. Lifelines: The Resilient Infrastructure Opportunity. Sustainable Infrastructure; Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/31805 License: CC BY 3.0 IGO

Hamilton, K., Brahmbhatt, M., & Liu, J. (2017). Multiple benefits from climate change mitigation: assessing the evidence. *Policy Report*.

Hauer, M. E., Evans, J. M., & Mishra, D. R. (2016). Millions projected to be at risk from sea-level rise in the continental United States. *Nature Climate Change*, *6*(7), 691–695. https://doi.org/10.1038/nclimate2961

Hauer, M. E. (2017). Migration induced by sea-level rise could reshape the US population landscape. *Nature Climate Change*, *7*(5), 321–325. https://doi.org/10.1038/nclimate3271

Hinkel, J., Lincke, D., Vafeidis, A. T., Perrette, M., Nicholls, R. J., Tol, R. S. J., … Levermann, A. (2014). Coastal flood damage and adaptation costs under 21st century sea-level rise. Proceedings of the National Academy of Sciences, 111(9), 3292–3297. https://doi.org/10.1073/pnas.1222469111

Hinkel, J., & Klein, R. J. T. (2009). Integrating knowledge to assess coastal vulnerability to sea-level rise: The development of the DIVA tool. Global Environmental Change, 19(3), 384–395. https://doi.org/10.1016/j.gloenvcha.2009.03.002

Horton, B. P., Kopp, R. E., Garner, A. J., Hay, C. C., Khan, N. S., Roy, K., & Shaw, T. A. (2018). Mapping Sea-Level Change in Time, Space, and Probability. Annual Review of Environment and Resources, 43(1), 481–521. https://doi.org/10.1146/annurev-environ-102017-025826

Huang, C., Barnett, A. G., Wang, X., Vaneckova, P., FitzGerald, G., & Tong, S. (2011). Projecting Future Heat-Related Mortality under Climate Change Scenarios: A Systematic Review. *Environmental Health Perspectives*, *119*(12), 1681–1690. https://doi.org/10.1289/ehp.1103456

Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the Influence of Climate on Human Conflict. *Science*, *341*(6151), 1235367–1235367. https://doi.org/10.1126/science.1235367

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].

IPCC, 2018: Summary for Policymakers. In: 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 [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Krogstrup, S., & Oman, W. (2019). Macroeconomic and Financial Policies for Climate Change Mitigation: A Review of the Literature (No. 19/185). International Monetary Fund. Islam, N. S., & Winkel, J. (2017). Climate Change and Social Inequality. UN/DESA Working Papers.

Kompas, T., Pham, V. H., & Che, T. N. (2018). The Effects of Climate Change on GDP by Country and the Global Economic Gains From Complying With the Paris Climate Accord. Earth's Future, 6(8), 1153–1173. https://doi.org/10.1029/2018EF000922

Kriegler, E., Edmonds, J., Hallegatte, S., Ebi, K. L., Kram, T., Riahi, K., … van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared climate policy assumptions. *Climatic Change*, *122*(3), 401–414. https://doi.org/10.1007/s10584-013-0971-5

Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., & Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences*, *105*(6), 1786–1793. https://doi.org/10.1073/pnas.0705414105

Levi, M., Kjellstrom, T., & Baldasseroni, A. (2018). Impact of climate change on occupational health and productivity: A systematic literature review focusing on workplace heat. La Medicina Del Lavoro, 109.3, 163–179.

Long, J., & Siu, H. (2018). Refugees from Dust and Shrinking Land: Tracking the Dust Bowl Migrants. The Journal of Economic History, 78(4), 1001–1033. https://doi.org/10.1017/S0022050718000591

Mach, K. J., Kraan, C. M., Adger, W. N., Buhaug, H., Burke, M., Fearon, J. D., … von Uexkull, N. (2019). Climate as a risk factor for armed conflict. *Nature*, *571*(7764), 193–197. https://doi.org/10.1038/s41586-019-1300-6

McCollum, D. L., Zhou, W., Bertram, C., de Boer, H.-S., Bosetti, V., Busch, S., … Riahi, K. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy*, *3*(7), 589–599. https://doi.org/10.1038/s41560-018-0179-z

McKibbin, W., Morris, A., Wilcoxen, P., & Panton, A. (2017). Climate Change and Monetary Policy: Dealing with Disruption. Climate Energy Discussion Paper.

Mundaca, L., Ürge-Vorsatz, D., & Wilson, C. (2019). Demand-side approaches for limiting global warming to 1.5 °C. *Energy Efficiency*, *12*(2), 343–362. https://doi.org/10.1007/s12053-018-9722-9

Newbold, T. (2018). Future effects of climate and land-use change on terrestrial vertebrate community diversity under different scenarios. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1881), 20180792. https://doi.org/10.1098/rspb.2018.0792

Piggott, J., & Whalley, J. (2001). VAT Base Broadening, Self-Supply, and the Informal Sector. *American Economic Review*, *91*(4), 1084–1094. https://doi.org/10.1257/aer.91.4.1084

Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., … Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change, 42, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Roson, R., & Sartori, M. (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Database. *Journal of Global Economic Analysis*, *1*(2), 78–115. https://doi.org/10.21642/JGEA.010202AF

Rozenberg, Julie; Fay, Marianne. 2019. Beyond the Gap: How Countries Can Afford the Infrastructure They Need while Protecting the Planet. Sustainable Infrastructure. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/31291 License: CC BY 3.0 IGO."

Samir, K., & Lutz, W. (2017). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Global Environmental Change, 42, 181–192. https://doi.org/10.1016/j.gloenvcha.2014.06.004

Schewe, J., Gosling, S. N., Reyer, C., Zhao, F., Ciais, P., Elliott, J., … Warszawski, L. (2019). State-of-the-art global models underestimate impacts from climate extremes. *Nature Communications*, *10*(1), 1005. https://doi.org/10.1038/s41467-019-08745-6

Schneider, F. (2005). Shadow economies around the world: what do we really know? *European Journal of Political Economy*, *21*(3), 598–642.

Schellnhuber, H., Hare, B., Serdeczny, O., Adams, S., Coumou, D., Frieler, K., … Warszawski, L. (2012). Turn Down the Heat: Why a 4°C Warmer World Must be Avoided. 1–85.

Sweet, W.V., R. Horton, R.E. Kopp, A.N. LeGrande, and A. Romanou, 2017: Sea level rise. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 333-363, doi: 10.7930/J0VM49F2.

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., ... & Donges, J. F. (2018). Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Sciences, 115(33), 8252-8259.

Takakura, J. Y., Fujimori, S., Hanasaki, N., Hasegawa, T., Hirabayashi, Y., Honda, Y., ... & Takahashi, K. (2019). Dependence of economic impacts of climate change on anthropogenically directed pathways. Nature Climate Change, 9(10), 737-741.

Van Dingenen, R., Dentener, F., Crippa, M., Leitao, J., Marmer, E., Rao, S., … Valentini, L. (2018). TM5-FASST: a global atmospheric source–receptor model for rapid impact analysis of emission changes on air quality and short-lived climate pollutants. *Atmospheric Chemistry and Physics*, *18*(21), 16173–16211. https://doi.org/10.5194/acp-18-16173-2018

Vrontisi, Z., Luderer, G., Saveyn, B., Keramidas, K., Lara, A. R., Baumstark, L., … van Vuuren, D. (2018). Enhancing global climate policy ambition towards a 1.5 °C stabilization: a short-term multi-model assessment. Environmental Research Letters, 13(4), 044039. https://doi.org/10.1088/1748-9326/aab53e

Warner, K., & Afifi, T. (2014). Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development*, *6*(1), 1–17. https://doi.org/10.1080/17565529.2013.835707

Weitzman, M. L. (2009). On Modeling and Interpreting the Economics of Catastrophic Climate Change. *Review of Economics and Statistics*, *91*(1), 1–19. https://doi.org/10.1162/rest.91.1.1

World Bank. 2019. Using Carbon Revenues. Partnership for Market Readiness Technical Note;No. 16. World Bank, Washington, DC. © World Bank. https://openknowledge. worldbank.org/handle/10986/32247 License: CC BY 3.0 IGO.

Chapter 2

2° Investing Initiative (2016): *Transition risk toolbox. Scenarios, data and models*.

Addoum, J., Ng, D. And Ortiz-Bobea, A. (2019): “Temperature shocks and earning news”, *Review of Financial Studies*, forthcoming.

Alexander, K. and Fisher, P. (2018): “Banking regulation and sustainability”, SSRN Working Paper.

Balvers, R., Du, D. and Zhao, X. (2017): “Temperature shocks and the cost of equity capital: implications for climate change perceptions”, *Journal of Banking and Finance*, 77, 18-34.

Bank of England (2019): Financial Stability Report, July.

Bansal, R., Kiku, D. and Ochoa, M. (2016): “Price of long-run temperature shifts in capital markets”, NBER Working Paper Series No 22259.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F. and Visentin, G. (2017): “A climate stress-test of the financial system”, *Nature Climate Change*, 7, 283-290.

Bernardini, E., Di Giampaolo, J., Faiella, I. and Poli, R. (2019): “The impact of carbon risk on stock returns: evidence from the European electric utilities”, *Journal of Sustainable Finance and Investment*, forthcoming.

Bezemer, D., Ryan-Collins, J., van Lerven, F. and Zhang, L. (2018): “Credit where it’s due: a historical, theoretical and empirical review of credit guidance in the 20th century”, Institute for Innovation and Public Purpose Working Paper 2018-11.

Cahen-Fourot, L., Campiglio, E., Dawkins, E., Godin, A. and Kemp-Benedict, E. (2019): “Capital stranding cascades: the impact of decarbonization on productive asset utilisation”, WU Working Paper Series 18/2019.

Cambridge Institute for Sustainability Leadership (2015): *Unhedgeable risk: How climate change sentiment impacts investment.*

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G. AND Tanaka, M. (2018): “Climate change challenges for central banks and financial regulators”, *Nature Climate Change*, 8, 462-468.

Campiglio, E., Monnin, P. and von Jagow, A. (2019): "Climate risks in financial assets", Council on Economic Discussion Note 2019/2, November.

Carbon Delta (2018): *Carbon Delta methodologies overview*.

Carney, M. (2015): "Breaking the tragedy of the horizon – climate change and financial stability", speech at Lloyd's of London, September 29.

Climate Bond Initiative (2019): *Green bonds: the state of the market 2018*.

Colas, J., Khaykin, I. and Pyanet, A. (2019): *Climate change: managing new financial risks*, Oliver Wyman.

Cui, Y., Geobey, S., Weber, O. and Lin, H. (2018): "The impact of green lending on credit risk in China", *Sustainability*, 10(6), 1-16.

Dankert, J., van Doorn, L., Reinders, H. J. and Sleijpen, O. (2018). "A green supporting factor – The right policy?" SUERF Policy Note, Issue No 43, October.

Delis, M., de Greiff, K. and Ongena, S. (2019): "Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans", Swiss Finance Institute Research Paper Series No 18-10.

Dikau, S. and Ryan-Collins, J. (2017): *Green Central Banking in Emerging Market and Developing Country Economies*, New Economics Foundation.

Dikau, S. and Volz, U. (2019): "Central Banking, Climate Change, and Green Finance" in Sachs, J., Thye Woo, W., Yoshino, N. and Taghizadeh-Hesary, F., *Handbook of Green Finance*, Springer, 81-102.

D'Orazio, P., Popoyan, L. and Monnin, P. (2019): "Prudential regulation can help in tackling climate change", Council on Economic Policies Blog, 13 February.

European Banking Federation (2017): *Toward a green finance framework.*

EU Technical Expert Group on Sustainable Finance (2019): *Taxonomy Technical Report*, June.

Ford, G. (2018): *A green supporting factor would weaken banks and do little for the environment*.

Frisari, G. and Monnin, P. (2019): "Financial system resilience to climate-related risks: international practices in using supervisory and regulatory instruments" in: Frisari, G., Gallardo, M., Nakano, C., Cárdenas, V. and Monnin, P., Climate risk and financial systems of Latin America: regulatory, supervisory and industry practices in the region and beyond, Inter-American Development Bank Technical Note N°IDB-TN-01823, December.

Gianfrate, G. and Peri, M. (2019): "The green advantage: exploring the convenience of issuing green bonds", *Journal of Cleaner Production*, 219, 127-135.

Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M. and Wilkens, M. (2019): "Carbon risk", working paper.

Griffin, P., Myers Jaffe, A., Lont, D. and Dominguez-Faus, R. (2015): "Science and the stock market: Investors' recognition of unburnable carbon", *Energy Economics*, 52(A), 1-12.

Guan, R., Zheng, H., Hu, J., Fang, Q. and Ren, R. (2017): "The higher carbon intensity of loans, the higher non-performing loan ratio: the case of China", *Sustainability*, 9(667), 1-17.

Hong, H., Li, F. W. and Xu, J. (2019): "Climate risks and market efficiency", *Journal of Econometrics*, 208(1), 265-281.

Huang, B., Punzi, M. T. and Wu, Y. (2019): "Do banks price environmental risk? Evidence from a quasi natural experiment in the People's Republic of China", Asian Development Bank Institute Working Paper Series No 974.

Hugon, A. and Law, K. (2019): "Impact of climate change on firm earnings: evidence from temperature anomalies", SSRN working paper.

Institute of International Finance (2019): *Sustainable finance in focus: green loans – Kick-off time!*, May 1.

IPCC (2018): *Global warming of 1.5°C*, Intergovernmental Panel on Climate Change, October.

Klomp, J. (2014): “Financial fragility and natural disasters: an empirical analysis”, *Journal of Financial Stability*, 13©, 180-192.

Krishnamurthy, A. (2010): “Amplification mechanism in liquidity crisis”, *American Economic Journal: Macroeconomics*, 2(3), 1-30.

Kruttli, M., Roth Tran, B. and Watugala, S. (2019): “Pricing Poseidon: extreme weather uncertainty and firm return dynamics”, Finance and Economics Discussion Series 2019-054, Board of Governors of the Federal Reserve System, Washington D.C.

Kumar, A., Xin, W. and Zhang, C. (2019): “Climate sensitivity and predictable returns”, working paper.

Matikainen, S. (2017): *Green doesn’t mean risk-free: why we should be cautious about a green supporting factor in the EU*.

McCollum, D., Nagai, Y., Riahi, K., Marangoni, G., Calvin, K., Pietzcker, R., Van Vliet, J. and Van der Zwaan, B. (2013): “Energy investments under climate policy: a comparison of global models”, *Climate Change Economics*, 4(4).

Monnin, P. (2018): “Integrating climate risks into credit risk assessment: current methodologies and the case of central banks corporate bond purchase”, Council on Economic Policies Discussion Note 2018/4.

Nanayakkara, M. and Colombage, S. (2019): “Do investors in green bond market pay a premium? Global evidence”, *Applied Economics*, 50(40), 4425-4437.

NGFS (2019): *A call for action: climate change as a source of financial risk*, April.

Noth, F. and Schüwer, U. (2018): “Natural disaster and bank stability: evidence from the U.S. financial system”, SAFE Working Paper No. 167.

Pielichata, P. (2019): “Demand for green bonds crimped by lack of supply”, Pensions & Investments, July 22.

PRA (2015): *The impact of climate change on the UK insurance sector*, September.

PRA (2018): *Transition in thinking: the impact of climate change on the UK banking sector*, September.

PRA (2019a): “Enhancing banks’ and insurers’ approaches to managing the financial risks from climate change”, Supervisory Statement SS3/19, April.

PRA (2019b): *Life Insurance Stress Test 2019 – Scenario Specification, Guidelines and Instructions*, 18 June 2019.

PRA (2019c): *General Insurance Stress Test 2019 – Scenario Specification, Guidelines and Instructions,* 18 June 2019.

Regelink, M., Reinders, H. J., Vleeschhouwer, M. and van de Wiel, I. (2017): *Waterproof? An exploration of climate-related risks for the Dutch financial sector*, De Nederlandsche Bank.

S&P Global (2018): “Investors may pay ‘greenium’ as green bond demand outstrips supply”, S&P Global Market Intelligence, March 28.

SBN (2018): *Creating green bond markets – Insights, innovations and tools from emerging economies*, October.

Schotten, G., van Ewijk, S., Regelink, M., Dicou, D. and Kakes, J. (2016): “Time for transition: an exploratory study of the transition to a carbo-neutral economy”, *DNB Occasional* Studies, vol. 14 – 2.

Shleifer, A. and Vishny, R. (2011): “Fire sales in finance and macroeconomics”, *Journal of Economic Perspectives*, 25(1), 29-48.

Schroders (2017): *Climate change: redefining the risks*, September.

Tang, D. Y. and Zang, Y. (2019): “Do shareholders benefit from green bonds?”, *Journal of Corporate Finance,* forthcoming.

TCFD (2017): “Recommendations of the Task Force on Climate-related Financial Disclosures”, Final report, June.

Tooze, A. (2019): “Why central banks need to step up on global warming”, *Foreign Policy*, July.

UBS (2018): *Explaining the mechanics: tilting to Climate Aware*.

UNEP Financial Initiative (2019): *Changing course: a comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD*, May.

Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jansen, D.-J. and Heeringa, W. (2018): *An energy transition risk stress test for the financial system of the Netherlands*, De Nederlandsche Bank.

Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jensen, D.-J. and Heeringa, W. (2019): "The Heat is on: a framework for measuring financial stress under disruptive energy transition scenarios", DNB Working Paper No. 625.

Villeroy de Galhau, F. (2018). "Green Finance – A New Frontier for the [2]1st Century", opening keynote at the International climate risk conference for supervisors, Amsterdam, April 6.

Wei Ping, He (2018): "The one bank-three commissions regulatory structure" in *The Regulation of Securities Markets in China*, Springer, 171-207.

World Bank (1993): *The East Asian Miracle, Economic Growth and Public Policy*, Oxford University Press.

Zerbib, O. D. (2019): "The effect of pro-environmental preferences on bond prices: evidence from green bonds", *Journal of Banking and Finance*, 98, 39-60.

Zheng, L. (2018): "The Macro Prudential Assessment Framework of China: background, evaluation and current and future policy", CIGI Papers No. 164, March.

Chapter 3

Ambachtsheer, Keith and John McLaughlin (2015). *How effective is pension fund governance today? and Do pension funds invest for the long term? Findings from a new survey*. KPA Advisory Services.

Asian Development Bank (n.d.). *Indonesia: Sarulla Geothermal Power Generation Project.* Project Fact Sheet.

Baker Mackenzie (2019). *Update to New Draft Policy on Feed-in-Tariffs Post-30 June 2019 for Solar Power Projects in Vietnam.* February 28, 2019.

Barton, Dominic and Mark Wiseman (2014). "Focusing Capital on the Long Term." *Harvard Business Review*. January-February 2014.

Bellini, Emiliano and Max Hall (2019). *China auction allocates subsidies for 22.7 GW of solar with lowest bid of $0.0407/kWh.* PV Magazine. July 12, 2019.

Bernstead, Sam (2019). *MSCI launches new climate change indexes.* CityWide Selector, June 20, 2019.

Bhidé, Amar (2010). *A Call for Judgment: Sensible Finance for a Dynamic Economy*. New York: Oxford University Press.

Blended Finance Taskforce (2018). *Better Finance, Better World: Consultation Paper of the Blended Finance Taskforce.* February 2018.

Bolsa Comercio Santiago (2019). "Green and Social Bonds." Accessed October 21, 2019. http://inter.bolsadesantiago.com/sitios/en/labolsa/Paginas/Green-and-Social-Bonds.aspx

Brown, Jessica and Michael Jacobs (2011). *Leveraging private investment: the role of public sector climate finance.* Background note. Overseas Development Institute, April 2011.

Burckart, William and Jessica Ziegler (2019). *Fundamentals of Sustainable Investment: A Guide for Financial Advisors.* Money Management Institute (MMI) and The Investment Integration Project (TIIP), March 2019.

Burckart, William Steve Lydenberg, and Jessica Ziegler 2016). *Tipping Points 2016: Summary of 50 Asset Owners' and Managers' Approaches to Investing in Global Systems.* The Investment Integration Project, 2016.

California Public Employees' Retirement System (CalPERS) (2019). “Climate Change”. Accessed October 21, 2019. www.calpers.ca.gov/page/investments/sustainable-investments-program/climate-change.

Cambridge Institute for Sustainability Leadership (2015). *Unhedgeable risk: How climate change sentiment impacts investment.*

Carbon Pricing Leadership Coalition (2017). *Report of the High-Level Commission on Carbon Prices*. May 29, 2017.

Castelli, Massimiliano and Phillip Salman (2019). “Central Banks and Climate Change: Taking Up the Challenge” UBS.

Center for International Environmental Law (2016). *Trillion Dollar Transformation: Fiduciary Duty, Divestment, and Fossil Fuels in an Era of Climate Risk.* Washington, DC, December 2016.

Ceres (2018). *In Sight of the Clean Trillion: Update on Expanding Landscape of Investor Opportunities.* May 2018.

Climate Action 100+. www.climateaction100.org. Accessed October 21, 2019.

Climate Bonds Initiative (2019). Green Bonds: *The State of the Market 2018*.

Climate Disclosure Standards Board (2014). *Climate Resilient Stock Markets: Climate change reporting proposals for adoption or support by stock exchanges.* December 2014.

Climate Finance Leadership Initiative (2019). Financing the Low-Carbon Future: A Private-Sector View on Mobilizing Climate Finance. September 2019.

Climate Leadership Council (2019). “Economists’ Statement on Carbon Dividends.” Accessed October 21, 2019. https://www.econstatement.org/.

Climate Policy Initiative (2013a). *The Global Landscape of Climate Finance 2013.* October 2013.

Climate Policy Initiative (2013b). *Risk Gaps: Policy Risk Instruments.* January 2013.

Climate Policy Initiative (2016). *Global Climate Finance: An Updated View on 2013 & 2014 Flows*. October 2016.

Climate Policy Initiative (2018). *Global Climate Finance: An Updated View 2018*. November 2018.

Coady, David, Ian Parry, Nghia-Piotr Le and Baoping Shang (2019). *Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates.* Working Paper. International Monetary Fund, August 2019.

Congreso da nue8ransmisria a ministro Máximo Pacheco y aprueba nueva ley 8ransmissionión eléctrica (2016). El Mostrador Mercados. July 7, 2016.

Convergence (2018). *The State of Blended Finance 2018.*

Dam, Kenneth W. (2002). “Strengthening Financial Sectors in Emerging Markets” Speech on at conference on "Further Liberalization of Global Financial Services Markets?". Institute for International Economics, June 2002.

Davis, Stephen, Jon Lukomnik, and David Pitt-Watson (2016). *What They Do with Your Money.* New Haven and London: Yale University Press.

DFI Working Group on Blended Concessional Finance for Private Sector Projects. *Joint Report.* Update. African Development Bank, the Asian Development Bank, the Asia Infrastructure Investment Bank, the European Bank for Reconstruction and Development, European Development Finance Institutions, the European Investment Bank, the Inter-American Development Bank Group, the Islamic Corporation for the Development of the Private Sector, and the International Finance Corporation. October 2018.

Dina, Terry (2017). “Federal Support for Developing, Producing, and Using Fuels and Energy Technologies.” Senior Adviser Microeconomic Studies Division, United States Congressional Budget Office. Testimony before the Subcommittee on Energy Committee on Energy and Commerce U.S. House of Representatives. March 29, 2017.

Ellsworth, Peter and Kirsten Snow Spalding (2016). *The 21st Century Investor: Ceres Blueprint for Sustainable Investing*. Ceres, June 2013, Updated June 2016.

Focusing Capital on the Long Term (2015). *Long-term Portfolio Guide.*

Focusing Capital on the Long Term (2018). *Balancing Act: Managing Risk across Multiple Time Horizons*. December 2018.

FTSE Russell (2019). "FTSE Global Climate Index Series." Accessed August 13, 2019. FTSE. https://www.ftserussell.com/products/indices/global-climate.

GlobalData Entry (2019).*"Vietnam's solar drive.* Power Technology. July 30, 2019.

Global Impact Investing Network (2019). "Climate Investing Track." Accessed September 23, 2019. https://thegiin.org/climate-investing-track.

Global Sustainable Investment Alliance (2017). *2016 Global Sustainable Investment Review.* March 2017.

Global Sustainable Investment Alliance (2019). *2018 Global Sustainable Investment Review.* June 2019.

Guarascio, Francesco (2016). *EU requires pension funds to assess climate change risks.* Reuters. November 24, 2016.

Guyattt, Danyelle and Sagarika Chatterjee (2018). *How to invest in the low-carbon economy: An institutional Investors' Guide.* Principles for Responsible Investment.

Hale, Jon (2019). *Sustainable Funds U.S. Landscape Report*. Morningstar Research, January 2019.

Hancock Timber Resource Group (2019). "About Us." Accessed September 17, 2019. http://htrg.com/about/.

Initiative for Responsible Investment and The Hauser Institute for Civil Society, Harvard Kennedy School (n.d.). *A Note on Short-Termism.* Trustee Leadership Forum for Retirement Security.

International Energy Agency (2017). *World Energy Investment 2017: Executive Summary.* July 2017.

International Energy Agency (2018a). *Energy Policies Beyond IEA Countries: Chile 2018 Review*. January 23, 2018.

International Energy Agency (2018b). *World Energy Investment 2018: Executive Summary.* July 2018.

International Energy Agency (2019a). *Are auctions forecast to be the primary policy mechanism driving utility-scale renewable electricity capacity expansion?* February 1, 2019.

International Energy Agency (2019b). "Energy Subsidies." Accessed August 13, 2019. www.iea.org/weo/energysubsidies/.

International Energy Agency and Organisation for Economic Co-operation and Development (2019). *Update on Recent Progress in Reform of Inefficient Fossil-Fuel Subsidies that Encourage Wasteful Consumption.* Contribution by to the G20 Energy Transitions Working Group.

Institute for Energy Research (2018). *Global Fossil Fuel Consumption Subsidies Abound, But Not in the United States.* April 2, 2018.

International Finance Corporation (n.d.). *Blended Concessional Finance Principles for Private Sector Projects.* World Bank Group, n.d.

International Finance Corporation (2017). *The Importance of Local Capital Markets for Financing Development.* EMCompass. Note 28. January 2017.

International Finance Corporation (2018). *Crowding-In Capital Attracts Institutional Investors to Emerging Market Infrastructure Through Co-Lending Platform.* Note 23. April 2018.

International Institute for Sustainable Development (2019). "Unpacking Canada's Fossil Fuel Subsidies." Accessed September 11, 2019.

International Renewable Energy Agency (2017). *Renewable Energy Auctions: Analyzing 2016.* June 2017.

International Renewable Energy Agency (2019). *Renewable Energy Auctions: Status and Trends Beyond Price.*

iShares by Blackrock (2019). "iShares MSCI ACWI Low Carbon Target ETF." Accessed August 12, 2019. iShares by BlackRock. https://www.ishares.com/us/products/271054/ishares-msci-acwi-low-carbon-target-etf.

Jackson, Felicia (2019). *Chile's Cheap Power – Sign of a Solar Future?.* Forbes. June 5, 2019.

Kay, John (2016). *Other People's Money: The Real Business of Finance.* (reprint). New York, NY: Public Affairs.

Laeven, Luc (2014). *The Development of Local Capital Markets: Rationale and Challenges.* International Monetary Fund Working Paper (WP/14/234). December 2014.

Lenton, Christopher (2016). *Chile's Unlikely Energy Success Story.* America's Quarterly. August 18, 2016.

Lewis, Elizabeth, Ariel Pinchot, and Guilia Christianson (2016). *Navigating the Sustainable Investment Landscape.* Working paper. World Resources Institute, December 2016.

Manganaro, John (2018). "Industry Left Confused by DOL's ESG 'Clarification'". *PlanAdvisor.* May 25, 2018.

Manulife Investment Management (2019). "Timberland." Accessed September 17, 2019. https://www.manulifeam.com/ca/Strategies/Private-Markets/Timberland/.

Matsumura, Wataru and Zakia Adam (2018). *Commentary: Hard-earned reforms to fossil fuel subsidies are coming under threat.* International Energy Agency, October 29, 2018.

Meagher, Caitlin (2019). *Leaving Investors in the Dark: The SEC's Growing Silence on Guidance Related to the Business and Legal Developments on Climate Change*. Georgetown Law: February 7, 2019.

Milanés-Montero, Patricia, Alberto Arroyo-Farrona and Esteban Pérez-Calderón (2018). *Assessment of the Influence of Feed-In Tariffs on the Profitability of European Photovoltaic Companies.* Accounting and Financial Department, Faculty of Economics, University of Extremadura. Badajoz, Spain: September 29, 2018.

Ministry of Energy, Government of Chile (n.d.(a)). *Energy 2050: Chile's Energy Policy.*

Ministry of Energy, Government of Chile (n.d.(b)). *Energy Agenda: A challenge for the country, progress for everyone.*

Morales, Alvaro Enrique Pedraza, Olga Fuentes, Pamela Searle, and Fiona Stewart (2017). *Pension Funds and the Impact of Switching Regulation on Long-term Investment*. IOPS Working Papers on Effective Pensions Supervision, No.28. July 2017.

MSCI (2019). "Introducing the MSCI Climate Change Indexes." Accessed August 13, 2019. https://www.msci.com/climate-change-indexes.

New Zealand Super Fund (2017). *Invested in New Zealand the world: Annual Report 2017*.

New Zealand Super Fund (2018). *Staying the course through times of change: Annual Report 2018*.

Organisation for Economic Co-operation and Development (2018). *OECD Survey of Investment Regulation of Pension Funds.*

Organisation for Economic Co-operation and Development (2019). "OECD.Stat." Accessed September 26, 2019. stats.oecd.org.

Principles for Responsible Investment (n.d.). *French Energy Transition Law: Global Investor Briefing.*

Principles for Responsible Investment (2019). "Signatories." Accessed September 4, 2019. https://www.unpri.org/signatories.

Principles for Responsible Investment and UN Global Compact (n.d.). *Coping, Shifting, Changing 2.0. Corporate and investor strategies for managing short-termism.*

Prudential Regulatory Authority (2019). *Enhancing banks' and insurers' approaches to managing the financial risks from climate change.* Supervisory Statement SS3/19, April 2019

Renewable Energy Policy Network for the 21st Century (2019). *Renewables 2019 Global Status Report.* May 2019.

Richter, Alexander (2018). *330 MW Sarulla geothermal plant in Indonesia completed with third unit online.* Think Goeenergy. May 8, 2018.

Rojas-Suarez, Liliana (2014). *Strengthening Capital Markets in Emerging Economies: Two Key Issues that the G20 Should Not Miss.* Center for Global Development. February 21, 2014.

Securities and Exchange Commission (2010). *Commission Guidance Regarding Disclosure Related to Climate Change*. Code of Federal Regulations. Parts 211, 231, and 241. Release Nos. 33-9106; 34-61469; FR-82. Effective February 8, 2010.

Simpson, Anne (2019). Telephone interview with the Investment Integration Project (TIIP). August 1, 2019;

Sustainability Accounting Standards Board (2019). Accessed October 21, 2019. www.sasb.org.

Sustainable Stock Exchanges Initiative (2016). *2016 Report on Progress: A Paper Prepared for the Sustainable Stock Exchanges 2016 Global Dialogue.*

Sustainable Stock Exchanges Initiative (2017). *How Stock Exchanges Can Grow Green Finance: A Voluntary Action Plan.* November 2017.

Sustainable Stock Exchanges Initiative (2019). "Bolsa de Comercio de Santiago (Santiago Exchange)". Accessed September 29, 2019. https://sseinitiative.org/fact-sheet/bcs/.

SwissRe Institute (2018). *Pension schemes in Latin America: addressing the challenges of longevity.* February 2018.

Task Force on Climate-Related Financial Disclosures (2019a). *2019 Status Report.* June 2019.

Task Force on Climate-Related Financial Disclosures (2019b). "TCFD Supporters." Accessed September 23, 2019. https://www.fsb-tcfd.org/tcfd-supporters/. Estimates reflect number of supporters labelled in the database as: Asset Owner; Banking and Insurance; Insurance; Pension; Pension Insurance.

Task Force on Climate-Related Financial Disclosures (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report*. June 2017.

The Investor Agenda: Accelerating Action for a Low-Carbon World (2019). *Global Investor Statement to Governments on Climate Change.* Asia Investor Group on Climate Change, CDP, Ceres, Investor Group on Climate Change, Institutional Investors Group on Climate Change, Principles for Responsible Investment, and the UN Environment Finance Initiative.

The Lab (2019). www.climatefinancelab.org. Accessed September 22, 2019.

Tokyo Stock Exchange (2018). *Japan's Corporate Governance Code: Seeking Sustainable Corporate Growth and Increased Corporate Value over the Mid- to Long-Term.* June 1, 2018.

United Nations Environment Programme Finance Initiative (n.d.). *Investor Obligations and Duties in 6 Asian Markets.*

United Nations Environment Programme Finance Initiative and the Global Commission on Adaptation (2019). *Driving Finance Today for the Climate Resilient Society of Tomorrow.* July 2019.

United Nations Framework Convention on Climate Change (2017). "G20 Must Phase Out fossil fuel Subsidies by 2020." Investor statement, February 15, 2017.

United Nations Global Compact (2019). "Short-Termism in Financial Markets." Accessed October 21, 2019. https://www.unglobalcompact.org/take-action/action/long-term.

United Nations Environment Programme Finance Initiative, Principles for Responsible Investment, Generation Foundation (2017). *Fiduciary Duty in the 21st Century: Progress Report.* December 2017.

United Nations Global Compact, United Nations Environment Programme Finance Initiative, United Nations Environment Programme Inquiry Design of a Sustainable Financial System, Principles for Responsible Investment (2015). *Fiduciary Duty in the 21st Century.* September 2015.

United States Energy Information Administration (2019). *Synthesis of data from monthly and annual energy consumption estimates for the residential sector and commercial sector.* Accessed September 24, 2019. https://www.eia.gov/tools/faqs/faq.php?id=86&t=1.

US SIF Foundation (2016). *The Impact of Sustainable and Responsible Investment*. June 2016.

Watson, Brian (2016). "The troubling evolution of corporate greenwashing." *The Guardian.* August 20, 2016.

Whinerary, Matt and Anne-Maree O'Conner (2019). *Climate Change Investment Strategy.* How we invest white paper. New Zealand Superannuation Fund. March 2019.

Whitley, Shelagh, Han Chen, Alex Doukas, Ipek Gencsu, Ivetta Gerasimchuk, Yanick Touchette and Leah Worrall (2018). *G7 fossil fuel subsidy scorecard: Tracking the phase-out of fiscal support and public finance for oil, gas and coal.* Briefing paper. ODI, NDRC, IIISD, Oil Change International, June 2018.

Williams, Cynthia and Jill Fisch (2018). Letter to Brent J. Fields, Secretary, Securities and Exchange Commission. October 1, 2018.

Willis Towers Watson, Thinking Ahead Institute (2018). *The Thinking Ahead Institute's Asset Owner 100: The most influential capital on the planet.*

World Bank Group (2019a). "Carbon Pricing Dashboard." Accessed September 17, 2019. carbonpricingdashboard.worldbank.org.

World Bank Group (2019b). *Climate Auctions: A Market-Based Approach to National Climate Action.* January 1, 2019.

World Economic Forum (2016). *Renewable Infrastructure Investment Handbook: A Guide for Institutional Investors.* December 2016.

World Resources Institute (2019). *Multilateral Development Bank Climate Finance in 2018: The Good, the Bad and the Urgent.* June 21, 2019.

WORLD BANK GROUP