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Climate Change and Financial Risk

CLIMATE PRIMER

FOR INSTITUTIONAL INVESTORS

Supported by:

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WWF is one of the world's most respected conservation organizations, with a network active in more than 100 countries. WWF's mission is to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption.

WWF-Hong Kong has been working since 1981. In support of our global mission, WWF-Hong Kong's vision is to transform Hong Kong into Asia's most sustainable city where nature is conserved, carbon pollution is reduced, and consumption is environmentally responsible.

*A young boy stands on top of a partially submerged seawall in Bairiki, South Tarawa, Kiribati. Kiribati is a small Pacific nation comprised of 32 low-lying coral atolls and one raised coral island and is one of the places most vulnerable to climate change in the world.

Marine Drive, as the name suggests, sits directly along the coastline of Mumbai, India. Nearly 20 million residents of Greater Mumbai will be at risk from rising sea levels by 2050 as rapid urbanization increases exposure and vulnerability to climate extremes.

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Although it's not predicted that the massive Antarctic ice sheets are likely to melt completely, even small-scale melting would raise global sea levels, and cause flooding around the world.

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"Every company, investor, and bank that screens new and existing investments for climate risk is simply being pragmatic."

JIM YONG KIM

President of the World Bank

"Once climate change becomes a clear and present danger to financial stability it may already be too late to stabilise the atmosphere at two degrees."

MARK CARNEY

Governor of the Bank of England

"Fighting climate change isn't just an obligation we owe to future generations. It's also an opportunity to improve public health – and drive economic growth – in the here and now."

MICHAEL BLOOMBERG

Founder, CEO, and Owner of Bloomberg L.P., Former Mayor of New York City

"Get your bosses to go greener and lean on their portfolio companies to be greener – then you'll be able to look your grandchildren in the eye."

JEREMY GRANTHAM

Co-Founder and Chief Investment Strategist of Grantham, Mayo, & Van Otterloo

The Pakerisan River flows through the rain forest and tropical jungle on the island of Bali, Indonesia. Forests, especially tropical forests, play an important role in climate change. Trees store carbon through photosynthesis, so deforestation contributes to carbon emissions. Tropical forests contain about 25% of the world's carbon.

INTRODUCTION

CLIMATE CHANGE PRESENTS AN EXISTENTIAL THREAT TO MODERN CIVILISATION. HOWEVER, BECAUSE ITS EFFECTS MANIFEST OVER GENERATIONAL TIMESCALES, THE PRESENT GENERATION HAS LIMITED INCENTIVE TO ADDRESS THE THREAT.

In the financial sector, institutional investors are becoming more aware of the risks presented by climate change, and more willing to take action. However, this awareness differs by geography, with relatively lower engagement with the issues in the Asia-Pacific region.

This document is intended to provide an introduction to the basics of climate change for the institutional investor community, with a focus on Asia-Pacific and the energy sector. It provides an overview of the science of climate change, an articulation of the global policy response, a survey of technological approaches to the problem, and an outline of the various financial entities and resources involved in addressing the issue.

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The population of the Adélie penguin (*Pygoscelis adeliae*) is increasing in Antarctica. However, in areas where climate change effects are more established, Adélie populations have fallen by more than 65% in the past 25 years. The biggest threat to them right now is climate change.

EXECUTIVE SUMMARY

Climate Change in a Nutshell for Investors

The science of climate change is complex, but the story is not complicated:

1. The Earth's atmosphere naturally traps a certain amount of solar radiation as heat via the greenhouse effect.
2. Carbon dioxide (CO_2) is the primary gas involved in the greenhouse effect, due in part to its extremely long life in the atmosphere. Other gases also play a role.
3. By burning fossil fuels, humans have significantly increased the amount of carbon dioxide in the atmosphere.
4. The higher levels of carbon dioxide have trapped more heat, raising average global land and ocean surface temperatures.

The increased temperatures have numerous consequences that are already detectable. These include rising sea levels, changing weather patterns, reduced polar ice coverage and melting glaciers, higher frequency and/or intensity of extreme weather events, loss of crucial ecosystems, and increased oceanic acidity.

All of these climate-related physical effects have risk implications for investors. Depending on their location, their portfolio investments may face higher levels of acute physical risk – these are mainly event-driven risks from extreme weather events such as typhoons, floods, or drought-related fires and may also affect their own operations. In addition, investors with longer-duration assets may be exposed to chronic physical risk. These unfold over timescales stretching from years to centuries, such as sea level rise or changing weather patterns.

In addition to the physical risks involved, investors also face risks from the policy response to climate change. These include policy and regulatory risk, reputational risk and liability or litigation risk.

The Policy Response to Climate Change

The global policy response to climate change began in 1992 with the signing of the United Nations Framework Convention on Climate Change (UNFCCC). It called for "the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The Paris Agreement is an agreement within the UNFCCC which came into force in November 2016. It deals with the mitigation of GHG emissions, the adaptation to the impacts of climate change, and the financing of these activities. The parties to the Agreement are in the process of negotiating the detailed rules required to implement it. Although the United States has formally notified the UN of its intent to withdraw from the Agreement, this will become effective no earlier than November 4, 2020.

The primary goal of the Agreement is to limit "the increase in the global average temperature to well below 2°C above pre-industrial levels," with a stretch target temperature increase limit of 1.5°C above those levels. Each party to the Agreement is required to develop, communicate, and pursue their own targets and plans for mitigating climate change, known as Nationally Determined Contributions (NDCs). Other key goals include: increasing the emphasis on adaptation, defined as the steps taken to lessen the impact of climate change on human and natural systems; and mobilizing USD100 billion per year in mitigation and adaptation support by 2025, with a higher funding target to be established after that.

There are two primary policy paths to encouraging emissions reductions: market-based approaches and regulatory approaches. Market-based approaches are generally broader, and involve pricing carbon in some way, while regulatory approaches tend to be more sector-specific. Governments are using both approaches in their efforts to address climate change.

For investors, policy or regulatory action may result in direct or indirect effects on their portfolio holdings. The global policy response to climate change in large part boils down to significant changes in the energy sector, particularly with respect to electricity/heat generation. As existing policy commitments are insufficient to get the world on the path to the 2°C target, let alone the 1.5°C target, high-carbon energy assets are likely primary targets for further regulatory activity. Relevant policies for the energy and other sectors include carbon taxes, emissions caps, and higher efficiency standards. Investors may also be exposed to litigation risk for failing to account for these regulatory or policy risks, should their holdings be affected materially.

Finally, investment managers and asset owners face an increasing exposure to climate-related reputational risk. This may initially be closely linked with related litigation, but as climate change impacts become more evident, and more attached to human stories of lost livelihoods or negative health outcomes, the reputational risk to the parties involved in generating these impacts increases.

Approaches to Addressing Climate Change

Responding to climate change ultimately takes the form of adaptation and mitigation. Adaptation is the process of dealing with climate change impacts that are already happening or are expected to occur. Mitigation efforts seek to reduce or stabilise the concentrations of greenhouse gases in the atmosphere. Mitigating and adapting to climate change will require investments in human capabilities, communities, systems, and, most importantly, technology. This presents opportunities for investors.

Across the landscape of mitigation and adaptation investment, the mitigation space offers a wider range of investment opportunities and vehicles that are compatible with the current investment processes of asset owners and managers. This is especially the case for those investors whose mandates focus on secondary market instruments such as listed equities. Asset owners and managers who are able to provide direct investment or debt finance in particular are less limited in their investment options, as across both the mitigation and adaptation spaces, market rate debt via project or corporate finance is the primary form of project funding.

Mitigation

The energy sector is the primary focus of mitigation efforts, as it comprises almost 70% of global emissions of greenhouse gases (CAIT 2015). Other key areas include energy efficiency and land use / afforestation. In Asia-Pacific, the energy sector's emissions share of 70% is similar to the global level, and is driven largely by the largest emitters, China and India. Within the energy sector, the electricity / heat generation sub-sectors comprise the largest component, at almost 30% of global emissions. This prominence makes them the natural primary target for emissions reduction efforts.

The technologies involved in mitigating emissions from electricity generation range from speculative to fully mature. These include renewables, thermal power (from fossil fuels or otherwise) with or without carbon capture and storage (CCS), and nuclear power.

Renewable power is one of only two energy sources that does not release greenhouse gases as part of the electricity generation process and unlike nuclear, does not have a long-term waste disposal issue. In addition, unlike CCS, several renewable power technologies are already demonstrating economic viability and do not require the safe storage of gigatonnes of CO_2 underground every year. As such, the rapid increase in renewable energy is one of the primary contributors to reducing emissions from electricity generation. Renewable resources include hydropower, wind energy, solar energy, geothermal heat, ocean energy (tides, waves, currents and marine thermal energy) and biomass.

Renewables comprised an estimated 24% of electricity generation in 2016. In Asia-Pacific, China is the largest player by far, with approximately two-thirds of renewable electricity generation capacity. While the bulk of installed renewable electricity generation capacity is hydropower, capacity growth is being driven by solar photovoltaic and wind energy.

Investment flows into renewable energy have been strong for over a decade, with total new investment in 2016 of USD242bn representing a compound annual growth rate of 15% since 2004. Exit prospects for investors are also well-established, with aggregate M&A transactions reaching USD110bn in 2016, up 10 times from 2004. Most exits (by dollar value) are via project acquisition / refinancing or through corporate M&A, although public markets and private equity buyouts also play a role. (Frankfurt School-UNEP Centre/ BNEF 2017)

The prominent role expected of renewable power generation as part of the transition to low-carbon generation requires additional investments in supporting technologies. This is due to the variability and intermittency of certain renewables (known as variable renewable energy, or VRE) – in many cases, the grid and/or the regulatory regime have to adapt to integrate their power in a cost-effective and sustainable manner.

Key areas for investment to support this transition include energy storage, smart grids, demand-side management, monitoring and sensors. Such integration will also require adjustments to or a redesign of the regulatory regime under which electricity is delivered. Investment in appropriate infrastructure and energy efficiency also has the potential to mitigate energy-related emissions. In particular, district energy, light rail, and electrical charging networks have significant potential to facilitate emissions reductions, both directly and indirectly.

Adaptation

In the context of climate change, adaptation is defined as action taken or investments made to anticipate and prevent or reduce the negative effects of climate change on human and natural systems. These effects generally fall under the category of physical risk discussed in the Science chapter and affect areas such as agriculture, forestry and fisheries, water supply, human health, coastal zones, and infrastructure.

This spectrum of affected sectors overlaps significantly with development assistance. As a result, much of the investment into adaptation is driven by the public sector, including governments, official development assistance, and multilateral institutions. This implies that most potential adaptation investments will have some form of public finance linkage, whether in the form of a public-private partnership or via instruments such as green bonds or project bonds. It also implies that pure-play exposure to adaptation investments via listed equities is uncommon; rather, such exposure is embedded in the companies that may be involved.

Climate Finance

Climate finance flows originate ultimately from public or private sources. On the public side are governments and various public financial intermediaries, while the private side includes corporates, households, project developers, and private financial intermediaries. In 2015-16, climate finance flows from public and private sources averaged USD410bn per year, 12% more than

the annual average of the previous two years (CPI 2017).

Public finance is a crucial player in addressing climate change, in particular by getting the private sector to focus a portion of its far-larger resource base on the problem. In combination with the appropriate policies and regulatory environment, public finance can help stimulate and direct flows of private capital by demonstrating feasibility, creating markets, fostering innovation, and reducing risk. In addition, public finance also provides critical support for delivering those public goods – such as many adaptation projects – that the private sector is unwilling or unable to provide. (Amerasinghe, et al. 2017)

Public climate finance players include multilateral development banks, official development assistance agencies, other official sources of funding, and a variety of multilateral and bilateral climate investment funds. All of these players are involved in some combination of mitigation, adaptation, or the building of capacity at the national or subnational level to improve a given country's ability to develop and implement climate projects.

The private finance ecosystem can play both direct and indirect roles with respect to addressing climate change. The private sector is the predominant source of direct investment in mitigation, led by project developers, with non-bank private financial intermediaries currently playing a smaller role.

This smaller direct role is a function of the structure of the financial system, which tends to focus on more mature sectors with relatively high minimum funding needs. This does not match up well with the comparative newness of the various technologies and business models involved in delivering climate investment, nor with the limited scale of many projects.

This mismatch is precisely why public financial institutions are involved: to accelerate the development of the climate mitigation and adaptation investment space such that perceived risk of these projects is lowered to the point that those institutional investors – asset owners as well as asset managers – capable of providing direct finance are able to get involved.

Until that happens, in most cases, indirect investment via equity or debt securities is the primary channel through which most institutional investors will be able to apply their capital to address climate change.

Climate issues have become more mainstream in the world of private finance, and generally fall into the ESG category (environmental, social, and governance) in industry parlance. A 2017 survey by HSBC found that 68% of global investors plan to increase their investment into climate-related or low carbon themes (Knight 2017). European and US investors were the leaders in this regard, with investors in Asia, and especially the Middle East, lagging.

For asset owners and asset managers, the quality and availability of relevant information is one of the key barriers to incorporating climate issues in their investment processes. In part to address this deficiency, on June 29, 2017, the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) issued its final report, providing recommendations on climate-related financial disclosures that are applicable to organisations across sectors and jurisdictions. If adopted widely, the recommendations will normalise and improve the standards of corporate climate risk disclosures, allowing investors to better assess their own climate-related portfolio risk and provide this information to their clients and beneficiaries. The disclosing organisations themselves will also benefit from the process, gaining a better understanding of the real financial implications of climate-related risks and their potential impacts on business models, strategy and cash flows.

Asset owners as well as asset managers need to integrate the assessment of climate change issues into their operations and investment processes. Ideally, this would be driven from the top – with the board level establishing the asset owner's climate-related beliefs, policies and targets, and communicating them down the organisation. For asset managers, the need for such integration is partially about client service – asset owners with climate processes will likely have a preference for engaging asset managers with complementary capabilities.

The various influencers in the financial ecosystem play important supporting roles with respect to the investment processes of asset owners and managers. This support ultimately comes down to the provision of information and recommendations with respect to specific issues institutional investors face or decisions they need to make. Because of this influence, it is critical that asset owners and managers engage with these parties on climate change issues.

SCIENCE

Even if CO_2 emissions cease immediately, the world will continue warming for several decades, due to the delay in climatic effects.

© Global Warming Images / WWF

The Great Barrier Reef is one of the world's richest ocean environments, home to more than 1,500 species of fish, six of the world's seven species of threatened marine turtles, and more than 30 species of marine mammals. Rising temperatures from climate change are driving mass coral bleaching and also turning green turtle (*Chelonia mydas*) populations almost completely female.

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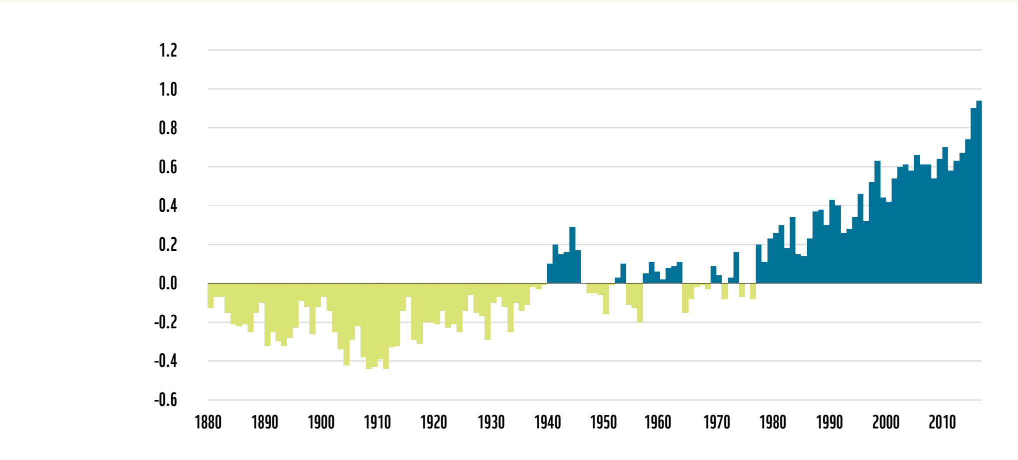
WHAT IS HAPPENING AND WHY?

Climate is the typical weather that occurs in a given location at a given time of year. Climate change is an alteration in these usual weather patterns, such as a shift in when temperatures begin to rise after winter or when the rainy season starts. Because of the natural variability in the weather, climate change is measured in time scales of multiple decades or longer. At the global level, climate change can manifest in multiple ways, such as a change in the Earth's temperature, or changes in the location, timing, or intensity of rainfall.

How is the Climate Changing?

The evidence is clear that the world is warming. Time-series metrics tracking indicators such as temperature, sea ice, precipitation, and sea level all show a warming trend that is accelerating, leading to climate change. It is also clear that human influence, particularly the ever-increasing emission of greenhouse gases (GHGs), is the primary driver of this process.

Figure 1: Global Land & Ocean Surface Temperature Relative to 20th Century Mean (°C)

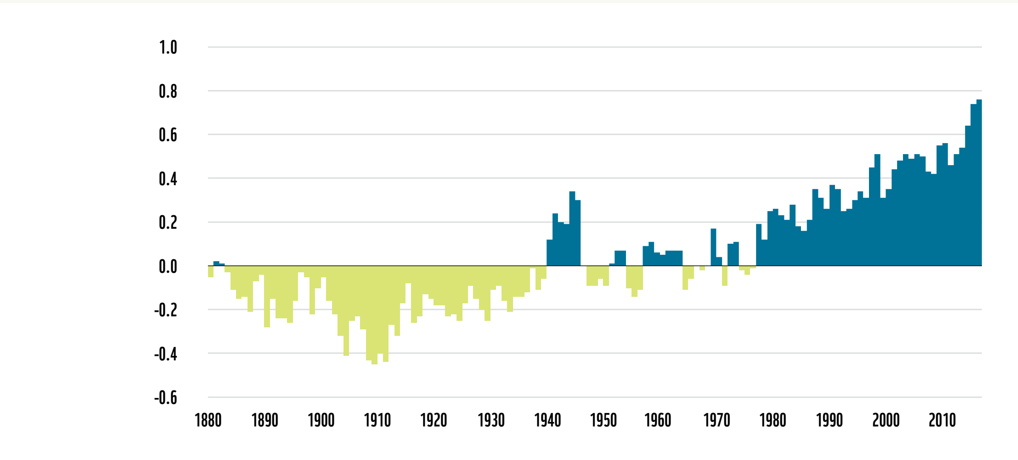


Source: NOAA (2017a)

Temperature

The Earth's average surface temperature (land and ocean) has increased approximately 1.1°C since the late 1800s. This is about 10 times faster than post-ice age warming episodes over the past million years, when the planet's temperature increased 4-7°C over approximately 5,000 years (NASA 2017).

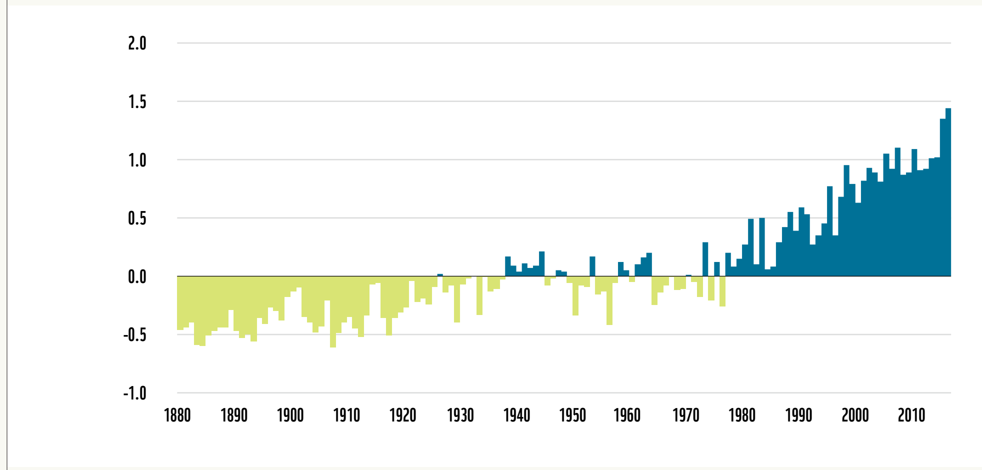
Figure 2: Global Ocean Surface Temperature Relative to 20th Century Mean (°C)



Source: NOAA (2017a)

Ocean warming is the predominant way in which increased energy in the climate system is absorbed. From 1971-2010, over 90% of the increased energy was stored this way, with only about 1% in the atmosphere. This warming is strongest near the ocean surface, with the upper 75m increasing in temperature by 0.11°C per decade since 1971. (IPCC 2014)

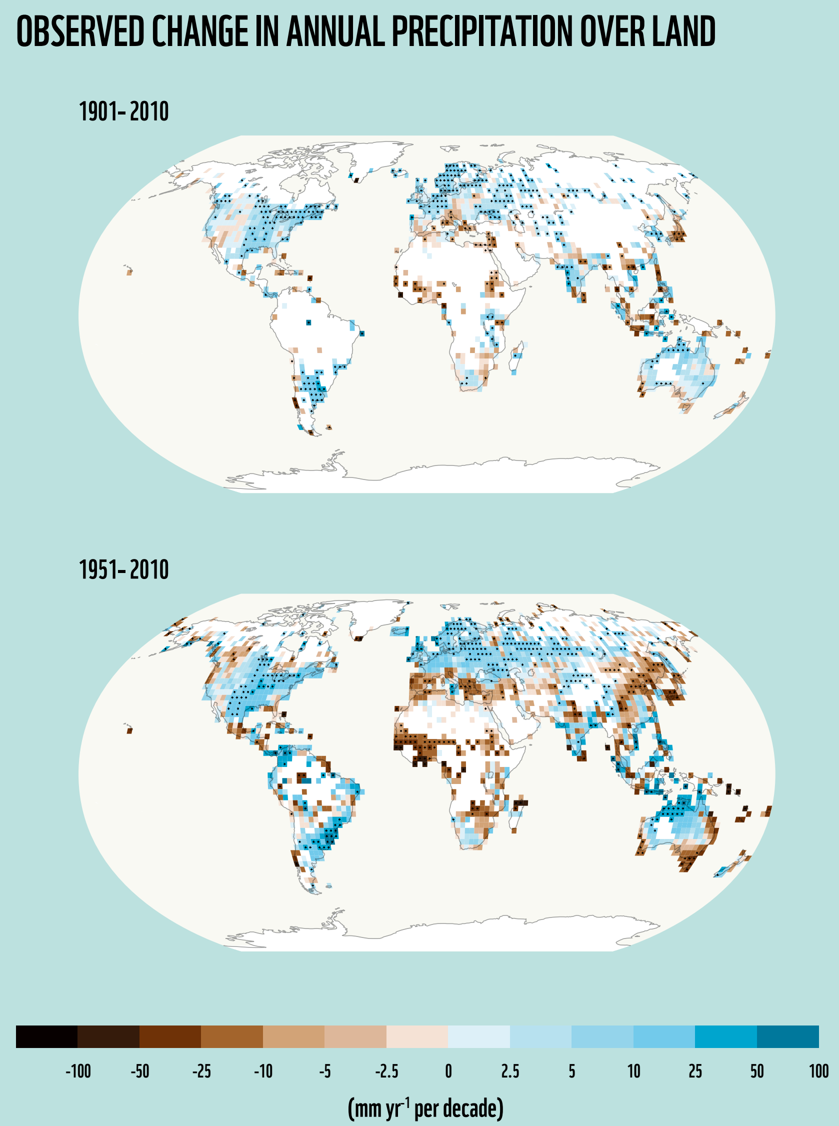
Figure 3: Global Land Surface Temperature Relative to 20th Century Average (°C)



Source: NOAA (2017a)

On land, in each of the past three decades, global surface temperatures grew progressively warmer, and those 30 years were hotter than any other similar period over the past 800 years (IPCC 2014). Indeed, 16 of the 17 hottest years on record came after 2001 (NASA 2017).

Figure 4: Trends in Annual Precipitation Over Land, 1901-2010

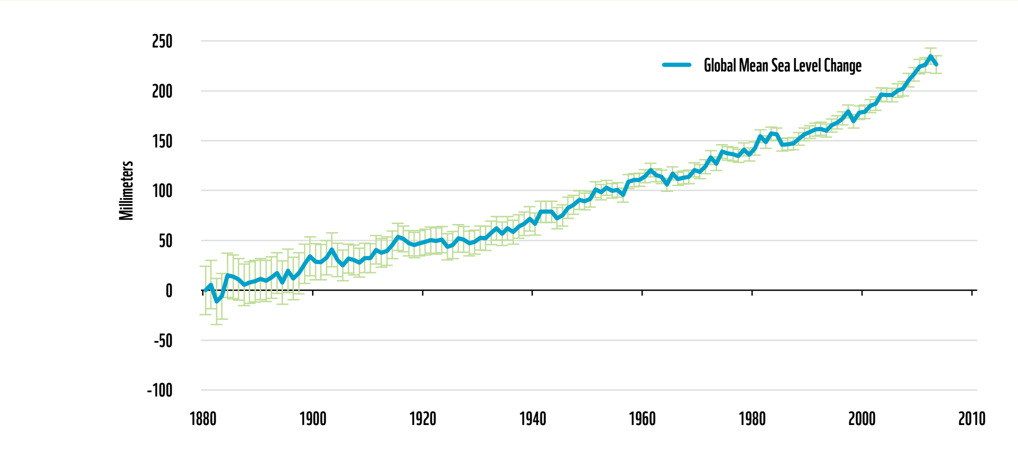


Source: IPCC (2013)

Precipitation

Observed precipitation over land has increased by approximately 1-3mm per decade (on a globally averaged basis) since 1901, with higher increases seen since 1951. Although confidence in this observation at the global level is not strong due to data availability issues, trends are clearer at some regional and latitudinal levels. In particular, precipitation in the mid-latitudes of the Northern Hemisphere has increased over the past century, while tropical precipitation has increased over the past decade. (IPCC 2013)

Figure 5: Global Mean Sea Level Change Since 1880



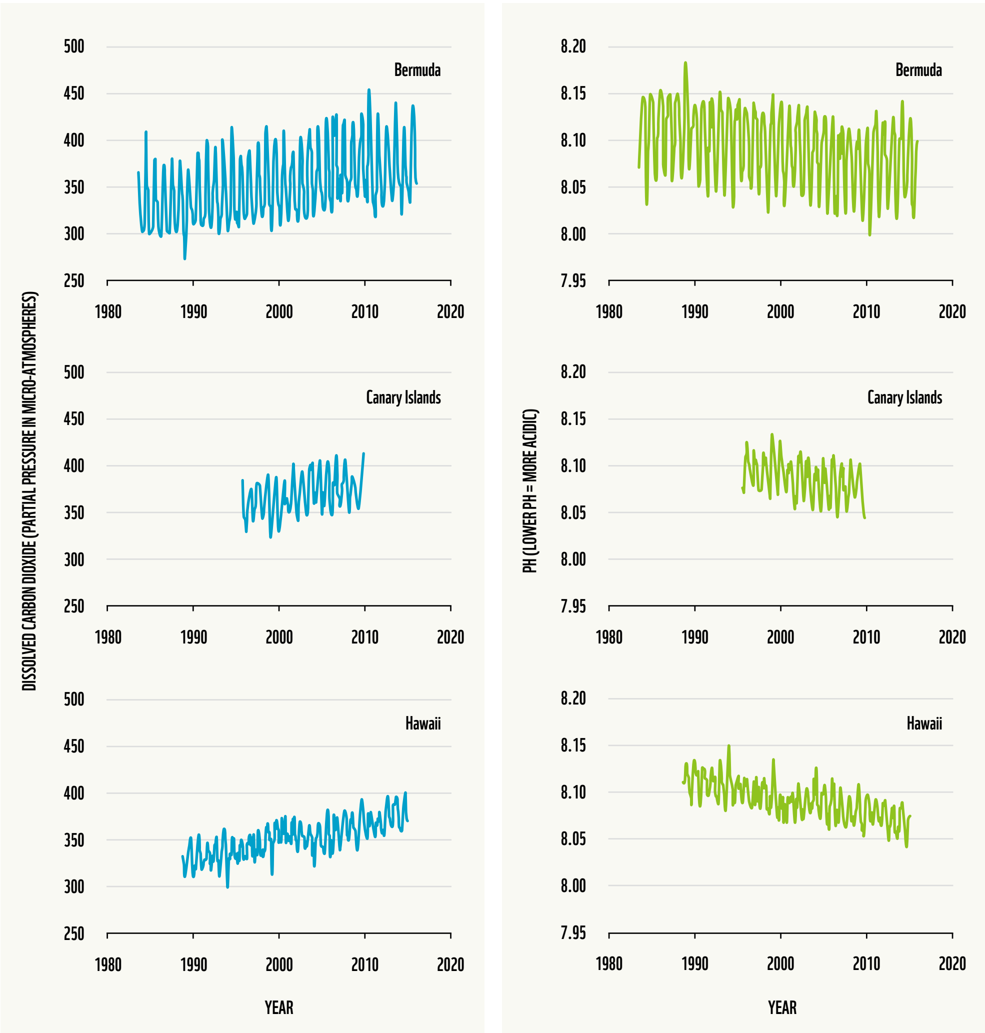
Note: Tidal gauge data from 1880-2013.
Source: Church & White (2011) via CSIRO

Sea Level Rise

From 1901-2010, the global mean sea level rose 1.7mm per year (0.19m total), and the rate of increase over the past 150 years is higher than the mean rate seen over the past 2000 years. This rate is continuing to increase: from 1993-2010, the rate of increase was 3.2mm/year. (IPCC 2014)

Sea level rise is driven by the melting of land-based ice and by thermal expansion (water expands as it warms). Between the 1970s and the early 2000s, the contributions of these two factors to sea level rise was approximately equal. However, the rate of melting of land-based ice has continued to increase and over the past decade the contribution of melting to sea level rise is now almost double that of thermal expansion. (NOAA 2017b)

Figure 6: Ocean Dissolved Carbon Dioxide Levels and Acidity, Selected Locations, 1983-2015



Source: U.S. EPA (2016)

Ocean Acidification

The ocean is one of the primary sinks for the additional carbon dioxide released into the atmosphere. As increased CO_2 has dissolved into the ocean, it has become more acidic – since the beginning of the industrial era, the pH of ocean surface water has dropped by 0.1 which translates into a 26% increase in acidity, as pH is measured on a logarithmic scale.

Extreme Climate Events

Observed extreme climate events have increased since 1950. For temperature events, these generally comprise less frequent cold temperature episodes, and more frequent hot temperature episodes. In addition, the frequency of heat waves has increased across much of Europe, Asia, and Australia. In terms of precipitation, heavy precipitation events have increased in frequency and intensity in North America and Europe, as has North Atlantic tropical cyclone activity (since 1970). (IPCC 2014)

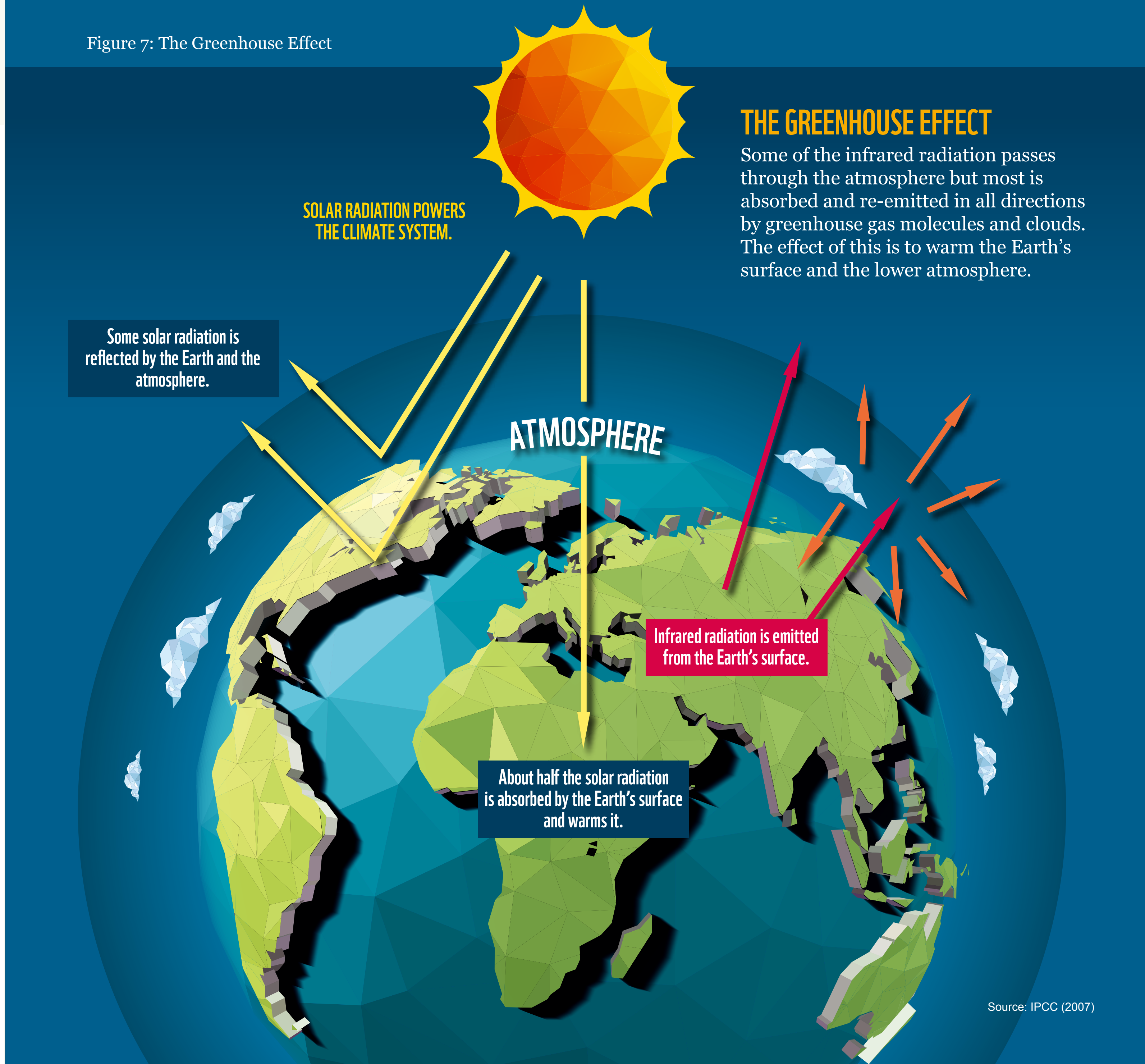
What is Causing Climate Change?

The Greenhouse Effect

A physical greenhouse is an enclosed space where the walls and roof are made of glass. It warms the enclosed space by allowing sunlight to enter and by trapping the heat generated. The warmer temperature in the greenhouse causes the ground and plants inside to release more water vapor, which in turn absorbs additional heat, warming the greenhouse further.

The greenhouse effect as applied to the climate works in a similar way. When solar radiation reaches the Earth, some of the energy is reflected by the Earth and atmosphere, and some is absorbed by the ground, clouds, and greenhouse gases. This absorbed energy is re-emitted in all directions as infrared radiation, warming the Earth's surface and lower atmosphere. (IPCC 2013)

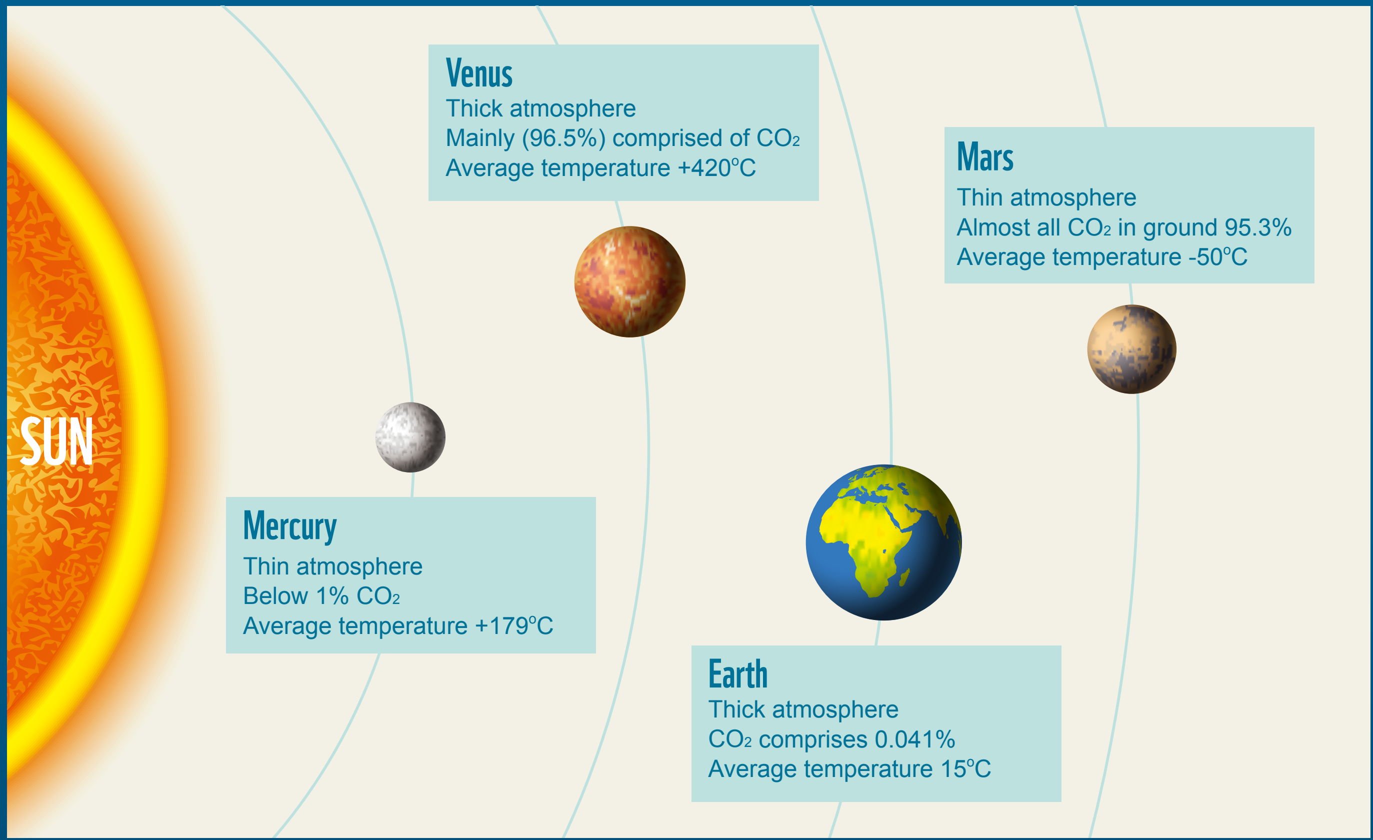
Figure 7: The Greenhouse Effect



Source: IPCC (2007)

Historically, this has been a natural phenomenon – without the warming role played by these gases, the Earth would be a much colder planet, and it is possible that life would not have evolved without the warmer temperatures resulting from the heat trapped by the gases. Conversely, the example of Venus shows the temperature effect of a high concentration of atmospheric greenhouse gases (see Figure 8).

Figure 8: Planetary comparison of atmospheric CO_2 and average temperature



Source: WWF presentation: "Climate Finance - Investing for Life on Earth"

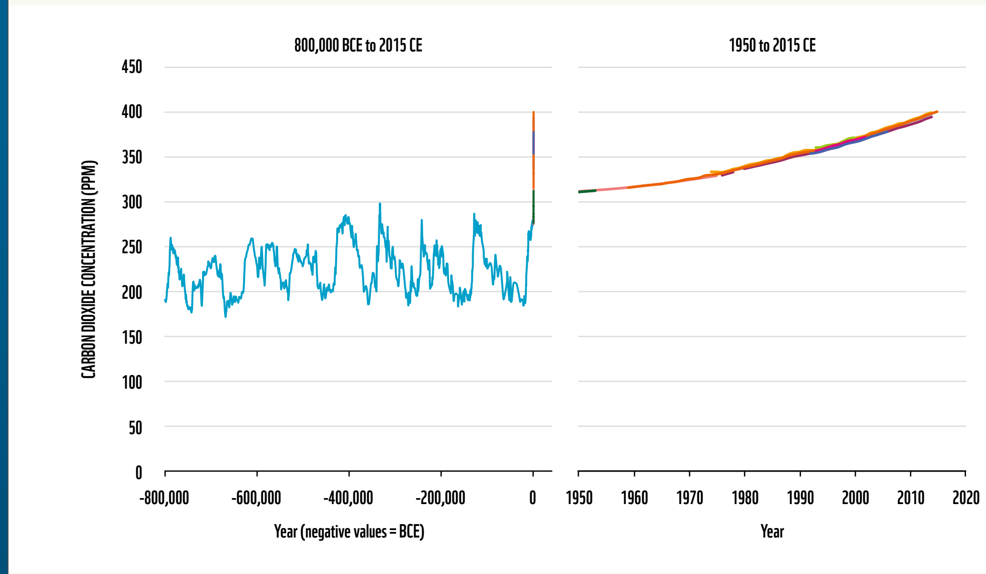
"HUMAN ACTIVITY SINCE THE INDUSTRIAL REVOLUTION HAS RESULTED IN A DRAMATIC INCREASE IN THE CONCENTRATIONS OF GREENHOUSE GASES IN THE ATMOSPHERE."

Greenhouse Gases

Climate change happens when there is a shift in the energy balance of the climate system. Human activity since the industrial revolution has resulted in a dramatic increase in the concentrations of greenhouse gases in the atmosphere. These gases increase the amount of energy, and thus heat, contained in the climate system. The contribution to warming by the various gases is quantified through a process known as radiative forcing. This is measured in watts per square meter (W/m^2) and is the difference between sunlight absorbed by the Earth and the energy radiated back into space. A positive figure for radiative forcing will lead to net surface warming (increased energy in the climate system), while a negative figure leads to net cooling of the Earth's surface.

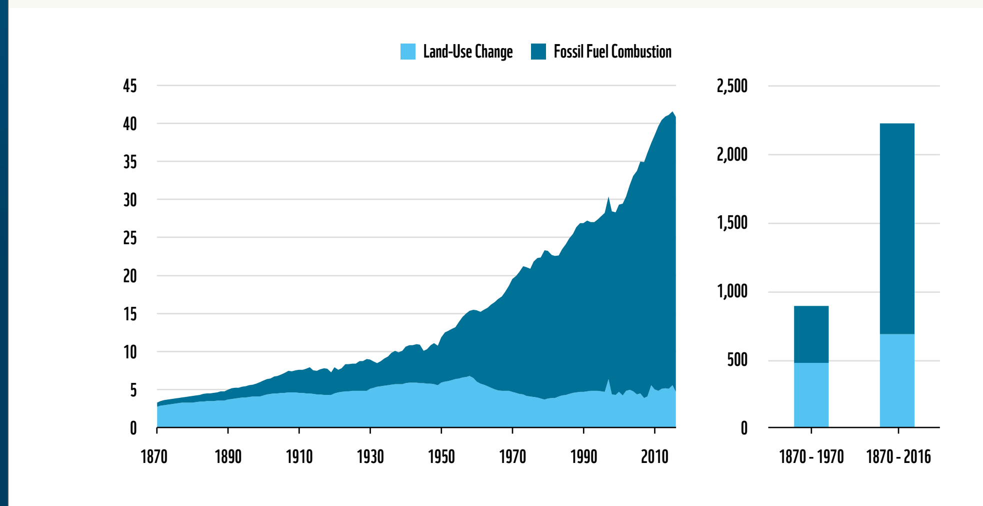
The largest contributor to warming is carbon dioxide, followed by methane (CH_4), Nitrous oxide (N_2O), and the various synthetic F-gases (fluorinated gases such as chlorofluorocarbons (CFCs) and their relations). Aerosols contribute a modest net cooling effect, although with high uncertainty. Water vapour is the most abundant greenhouse gas. However, due to its short duration in the atmosphere (days, rather than years), it acts via feedback, rather than as a forcing agent, amplifying the temperature effects of the other greenhouse gases – NASA suggests that water vapour may double the warming effect of CO_2 alone (NASA 2008).

Figure 9: Global Atmospheric Concentrations of Carbon Dioxide Over Time



Source: U.S. EPA (2016)

Figure 10: Annual and Cumulative Global Anthropogenic CO_2 Emissions, $GtCO_2$, 1870-2016



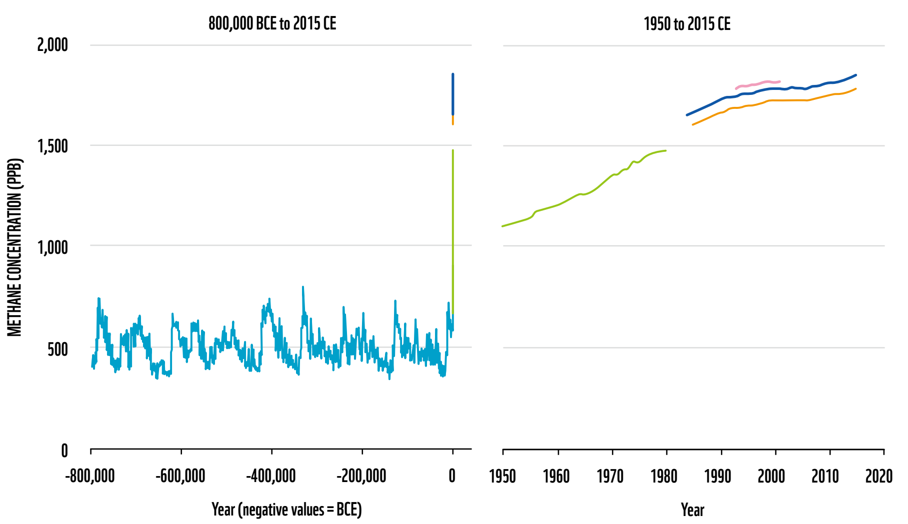
Source: Quéré, et al. (2017)

Carbon Dioxide

CO_2 is a warming gas and currently comprises approximately 410 parts per million (ppm), or 0.041%, of the Earth's atmosphere by volume. In addition to the natural processes of the carbon cycle, where it circulates among the atmosphere, the oceans, soil, plants and animals, CO_2 is released into the atmosphere through human activities such as burning fossil fuels, cement production and flaring, as well as through changes in land use such as deforestation, particularly through burning. Deforestation has also reduced the capacity of natural carbon sinks to remove carbon dioxide from the atmosphere.

For at least 800,000 years prior to the Industrial Revolution, atmospheric concentrations of CO_2 fluctuated between about 200-250 ppm, with a few spikes up to a maximum of 300 ppm. Since the Industrial Revolution, the CO_2 level has passed 400 ppm and is rising at an accelerating rate: while the average rate of increase in the 1980s and 1990s was 1.5 ppm per year, it was 2.2 ppm per year during the 10 years to 2017. In 2016, the CO_2 concentration increased by 2.9 ppm, second only to the increase in 2015 (NOAA 2017c).

Figure 11: Global Atmospheric Concentrations of Methane Over Time



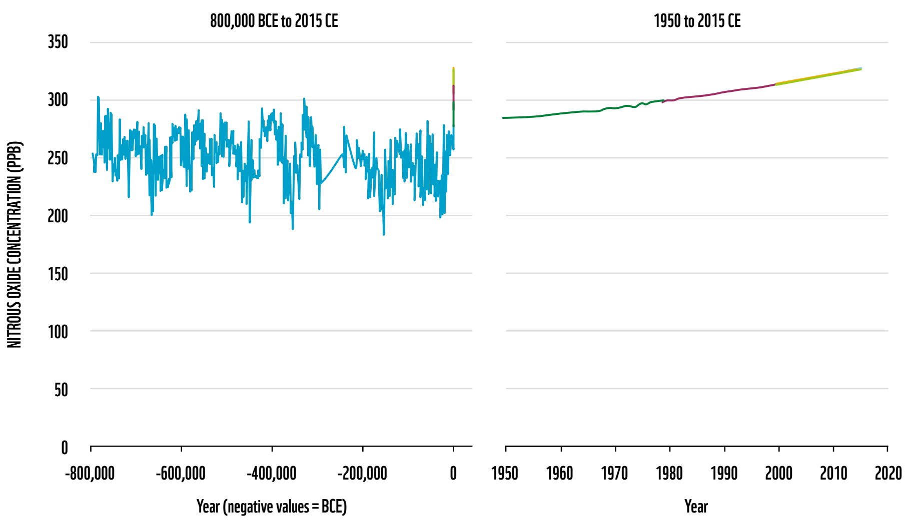
Source: U.S. EPA (2016)

Methane (CH_4)

Methane currently comprises approximately 1,840 parts per billion (ppb), or 0.00018%, of the Earth's atmosphere by volume. With an atmospheric lifetime of about a decade, it is much shorter-lived in the atmosphere than carbon dioxide. However, methane traps heat more effectively; on a 100-year time scale, it contributes 28 times the radiative forcing effect as an equivalent amount CO_2. In addition to natural sources such as wetlands, the gas is released into the atmosphere through human activities such as energy use, agriculture and livestock, and biological waste decomposition. Human activities account for approximately 70% of methane emissions.

During pre-industrial times, atmospheric concentrations of CH_4 fluctuated between about 400-600 ppb, with a few spikes up to a maximum of 700-800 ppm. Since the Industrial Revolution, the CH_4 level has passed 1,800 ppb and is rising at an accelerating rate: following a brief plateau in the early 2000s, methane concentrations increased by an average of 5.7 ppb per year from 2007-2013 and since then has accelerated to an average of 10.1 ppb per year through 2016 (NOAA 2017c).

Figure 12: Global Atmospheric Concentrations of Nitrous Oxide Over Time



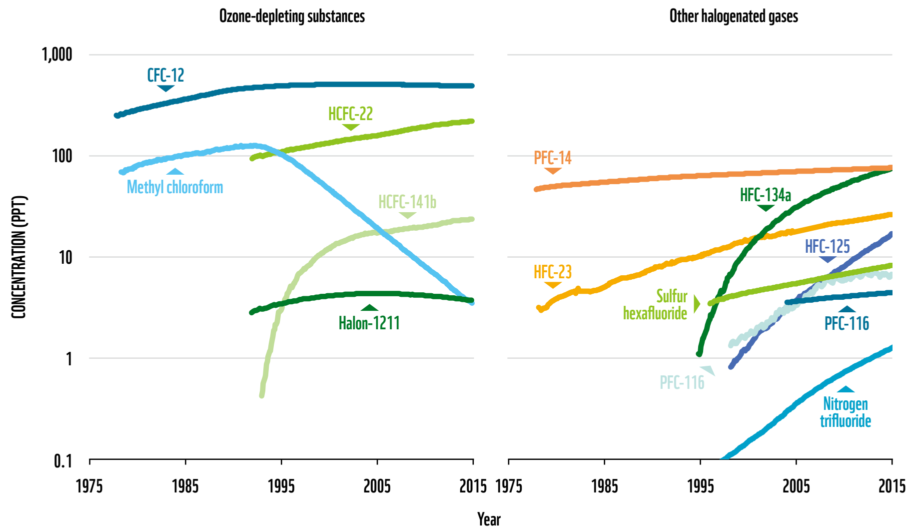
Source: U.S. EPA (2016)

Nitrous Oxide (N_2O)

Nitrous oxide currently comprises approximately 327 ppb, or 0.00003%, of the Earth's atmosphere by volume. It persists in the atmosphere for over a century and contributes over 250 times the radiative forcing effect as an equivalent amount CO_2 on a 100-year time scale. Approximately 40% of emissions come from human sources, primarily agriculture, transportation and industrial processes, while the remaining 60% stems from the nitrogen cycle, mainly from bacteria.

From 800,000 years ago until the Industrial Revolution, atmospheric concentrations of N_2O were centred at about 250 ppb ±50 ppb. Since then, the N_2O level has approached 330 ppb and is rising at an accelerating rate: in the 10 years to 2015, the rate of increase was 0.90 ppb per year, as compared to 0.78 ppb per year for the 10 years to 2005, and 0.67 ppb per year for the previous 10 years. (US EPA 2016)

Figure 13: Global Atmospheric Concentrations of F-Gases Over Time



Source: U.S. EPA (2016)

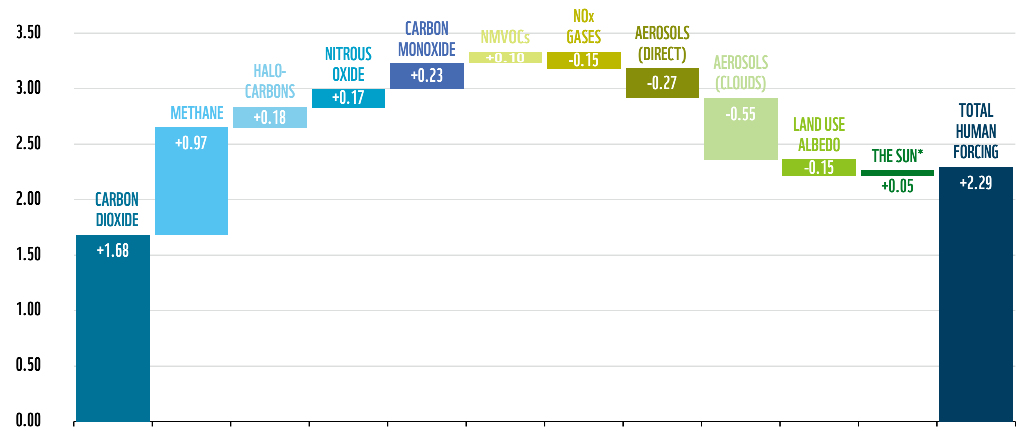
Fluorocarbons (F-gases)

The various F-gases (and other halocarbons) do not exist in nature; their concentration in the atmosphere all stems from human activity. These include refrigeration, industrial processes such as aluminium production and semiconductor manufacturing, and the transmission and distribution of electricity. While their atmospheric concentrations are extremely low, measured in parts per trillion, their lifespan in the atmosphere can be extremely long, ranging from 300 years to 50,000 years. Depending on the gas, they contribute between 10,000-20,000 times the radiative forcing effect as an equivalent amount CO_2 on a 100-year time scale, and many are only removed from the environment through interaction with sunlight in the upper reaches of the atmosphere.

Aerosols

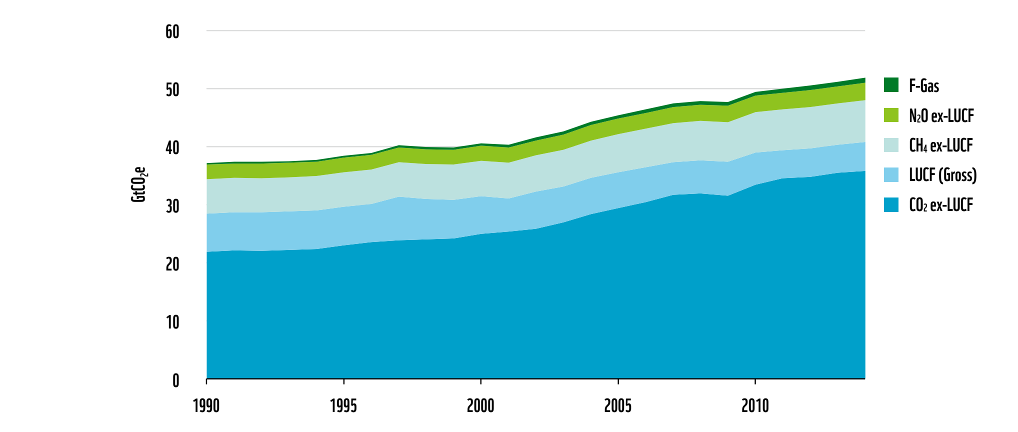
Aerosols are particles (liquid or solid) small enough to remain suspended in the air. Natural examples include volcanic aerosols, desert dust (wind-blown), and fog, while human-generated aerosols include smoke from burning tropical forests, as well as black soot and sulphate aerosols resulting from the burning of fossil fuels. Aerosols can have either a warming or cooling effect on the climate, depending on whether the suspended particles reflect or absorb incoming sunlight. On aggregate, aerosols exert a net cooling effect, countering an estimated 30% of the warming effect from the primary greenhouse gases since 1750.

Figure 14: Radiative Forcing (W/m²) In 2011 Relative To 1750 By Emitted Compounds



Note: Simplified version of Figure SPM.5 from IPCC WG1 AR5. In particular, uncertainty ranges have been omitted. The total anthropogenic radiative forcing for 2011 relative to 1750 is 2.3 W/m² (uncertainty range 1.1 to 3.3 W/m²). This corresponds to a CO_2-equivalent concentration of 430 ppm (uncertainty range 340 to 520 ppm). *The sun is a natural change
Source: IPCC (2013). Figure concept from Shrink That Footprint

Figure 15: Total Annual Anthropogenic GHG Emissions by Gases 1990-2014



Note: LUCF = Land Use Change & Forestry. Presented on gross basis, i.e., excludes LUCF removals of GHGs. F-Gas = fluorinated gases covered under the Kyoto Protocol.
Source: CAIT (2015); FAO (2014)

Recent Greenhouse Gas Emissions Trends

From 1970-2014, annual human-derived GHG emissions continued to increase, with the size of the increase growing between 2000 and 2014. In this latter period, emissions (measured in gigatons of CO_2-equivalent amounts, or $GtCO_2e$) grew by 0.8 $GtCO_2e$ (2.0%) per year, as compared with 0.4 $GtCO_2e$ (1.3%) per year for the previous 30 years. This occurred despite an increasing number of climate change mitigation policies. Anthropogenic GHG emissions in 2014 were 52 $GtCO_2e$, and the total amount released from 2000-2014 was the highest in human history. (IPCC 2014)

Greenhouse Gas Emissions Projections

The Intergovernmental Panel on Climate Change (IPCC) condenses its modelling of future greenhouse gas emissions and atmospheric GHG concentrations, air pollutant emissions, and land use, and the resulting impact on the climate into 4 scenarios. These are known as "Representative Concentration Pathways," and are referred to as RCP2.6, RCP4.5, RCP6.0 and RCP8.5, in increasing order of emissions, with the numbers referring to the level of radiative forcing in watts/m^2.

The first scenario, RCP2.6, is the most aggressive in terms of limiting emissions and removing significant amounts of carbon from the atmosphere. It reflects the future emissions profile required for at least a 66% probability of limiting the global temperature increase in 2100 to 1°C above the 1986-2005 reference period (and 2°C above pre-industrial temperatures).

RCP8.5 is the highest GHG emissions scenario and is associated with a temperature increase of 3.7°C by 2100. While there is no explicit "business-as-usual" scenario, the IPCC notes that "scenarios without additional efforts to constrain emissions" fall between RCP6.0 and RCP8.5.

The key implication of this range of scenarios is that either drastic action is taken on GHG emissions, or dangerous climate change prevails. Both outcomes have implications for the financial sector, which are discussed later in this and subsequent chapters.

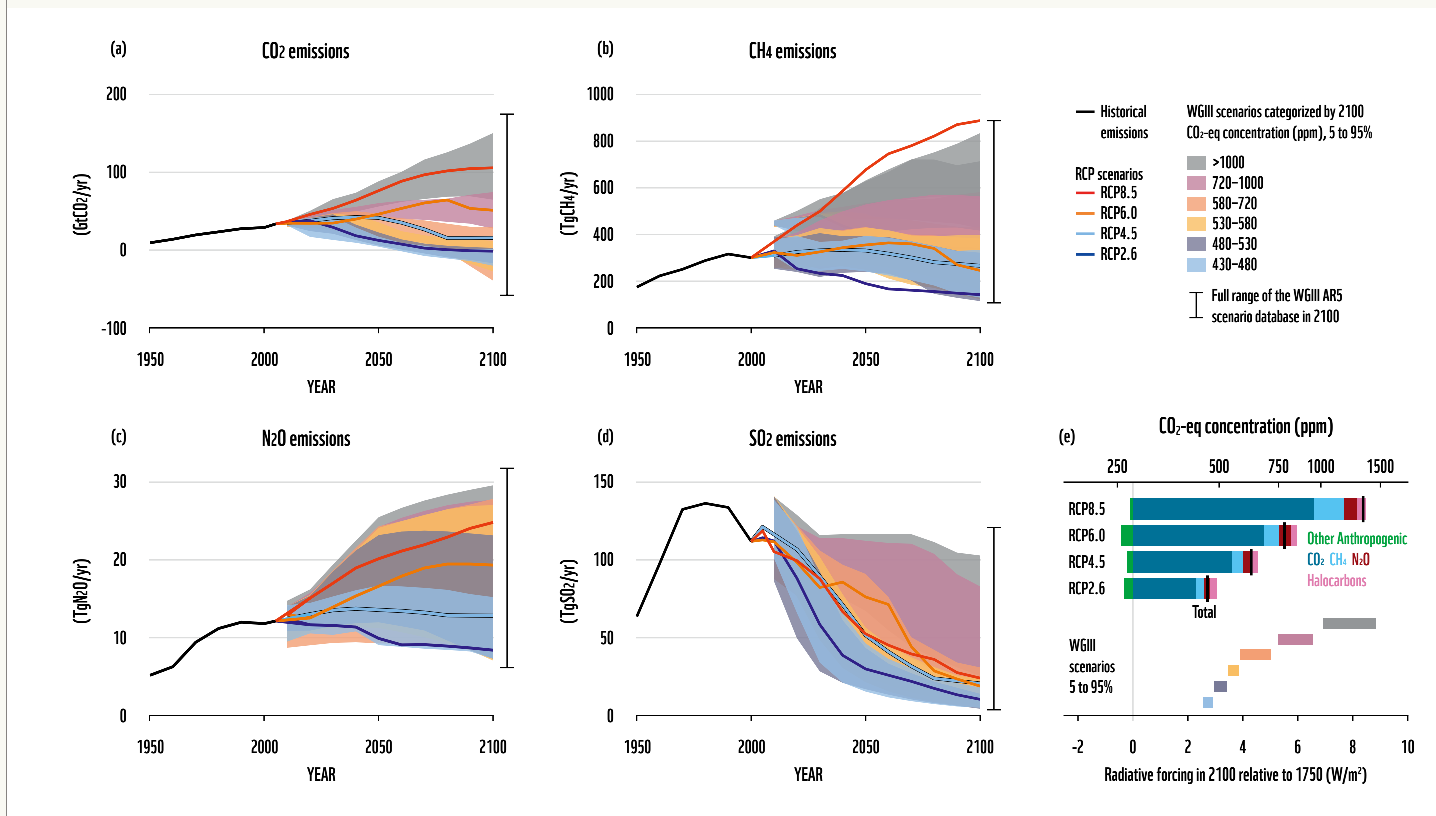
Table 1: Projected change in global mean surface temperature and global mean sea level for the mid- and late 21st century, relative to 1850-1900

		2046-2065		2081-2100	
	Scenario	Mean	Likely range	Mean	Likely range
Global Mean Surface Temperature Change (°C) relative to pre-industrial period	RCP2.6	1.6	1.0 to 2.2	1.6	0.9 to 2.3
	RCP4.5	2.0	1.5 to 2.6	2.4	1.7 to 3.2
	RCP6.0	1.9	1.4 to 2.4	2.8	2.0 to 3.7
	RCP8.5	2.6	2.0 to 3.2	4.3	3.2 to 5.4
	Scenario	Mean	Likely range	Mean	Likely range
Global Mean Sea Level Rise (m) relative to pre-industrial period	RCP2.6	0.41	0.34 to 0.49	0.57	0.43 to 0.72
	RCP4.5	0.43	0.36 to 0.50	0.64	0.49 to 0.80
	RCP6.0	0.42	0.35 to 0.49	0.65	0.50 to 0.80
	RCP8.5	0.47	0.39 to 0.55	0.80	0.62 to 0.99

Note: Adds 0.61°C to surface temperatures and 0.17m to mean sea level to compare with pre-industrial figures (1850-1900).
Source: IPCC (2014)

A power plant in Inner Mongolia, China. Sub-critical coal-fired power plants are found across Asia-Pacific and release greenhouse gases including carbon dioxide, contributing to the rise in global temperatures.

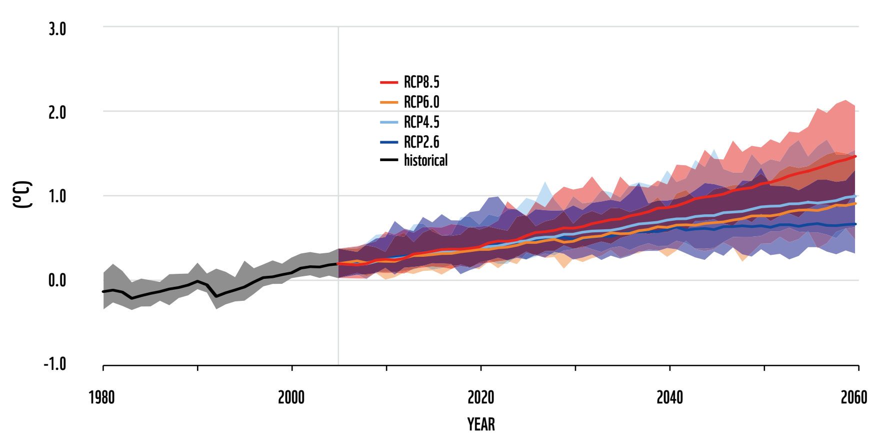
Figure 16: GHG emissions forecasts of the four primary IPCC scenarios



Source: IPCC (2014)

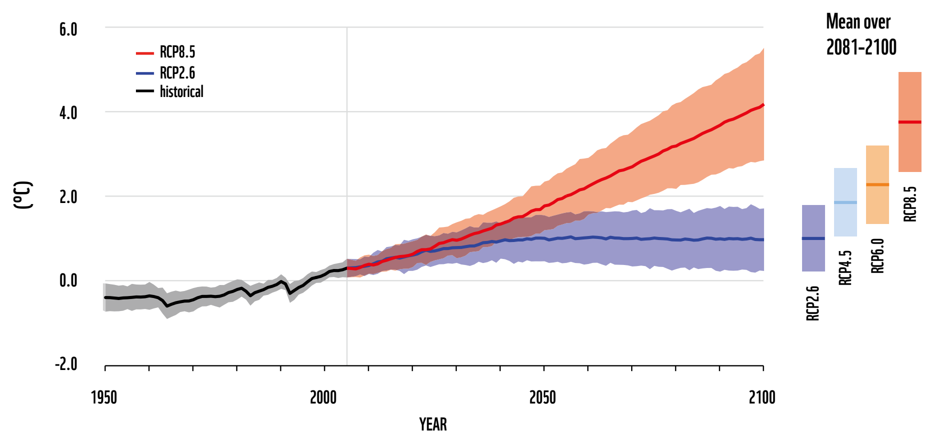
What Does the Near Future Look Like?

Figure 17: Projected Global Average Ocean Surface Temperature Change Relative to 1986-2005



Source: IPCC (2013)

Figure 18: Projected Global Average Surface Temperature Change Relative to 1986-2005



Source: IPCC (2013)

Temperature Scenarios

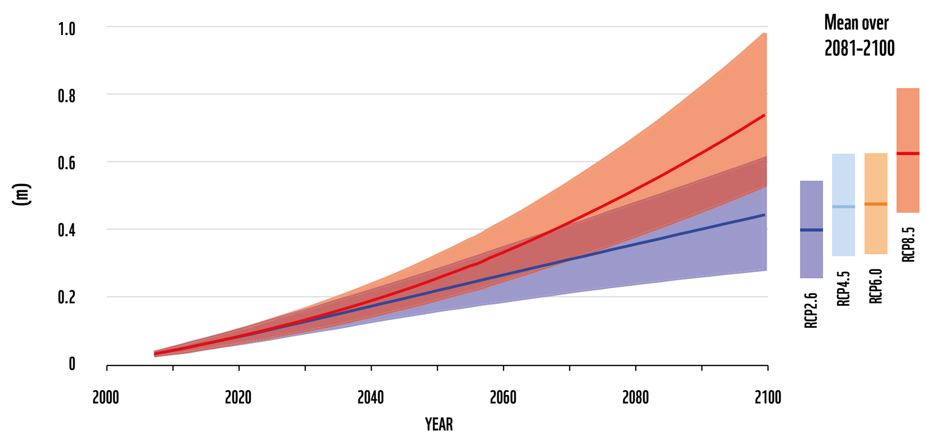
Ocean warming is projected to continue, particularly at the surface in the tropics. At lower depths, the most warming is expected in the Southern Ocean. Ocean warming will also lead to continued reductions in sea ice cover in the Arctic Ocean. Indeed, the highest emission scenario expects that ocean to be nearly ice-free in September by mid-century.

On land, the surface warming trend is expected to continue for at least the rest of this century. Across the four main warming scenarios put forth by the IPCC, likely warming ranges from 0.3°C to 4.8°C, relative to 1986-2005 average temperatures. All the scenarios expect at least 1°C of warming by mid-century.

Precipitation

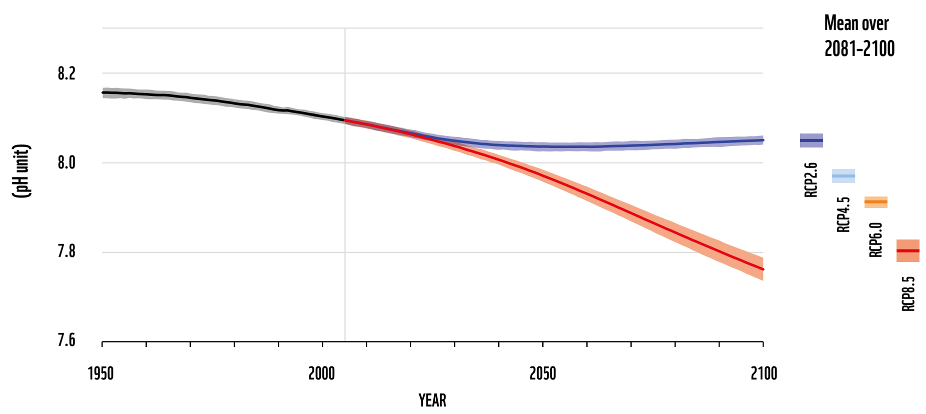
The forecast scenarios show a high degree of variability in expected future precipitation trends with respect to region and latitude. For example, in the RCP8.5 scenario, high latitudes and the Pacific tropics are expected to see increases in precipitation, while climate change will make dry regions drier and wet regions wetter in the mid-latitudes. All of the scenarios expect more intense monsoon precipitation and expand the areas affected by monsoon systems, as well as higher-intensity El Niño events. (IPCC 2014)

Figure 19: Projected Global Mean Sea Level Rise Relative to 1986-2005



Source: IPCC (2013)

Figure 20: Projected Global Mean Ocean Surface pH



Source: IPCC (2013)

Sea Level Rise

All forecast scenarios have the global average sea level rising faster than the observed rate of 2mm/year from 1971-2010, with the highest-emission RCP8.5 scenario expecting 8-16 mm per year for the final two decades of the 21st century. This translates into an average total sea level rise in 2100 of 0.4-0.63 m, relative to the final two decades of the 20th century.

Ocean Acidification

The ocean pH is projected to decrease further, by 0.06-0.32 by 2100, depending on the emissions scenario. This corresponds to an increase in acidity of 15-109%.

Extreme Climate Events

The observed trends – fewer cold events, more hot events, more frequent and intense heavy precipitation events – are all expected to continue and potentially accelerate through the balance of the 21st century.

Changes in water availability is a direct effect of both rising temperatures and changing precipitation patterns.

Workers toiling in the fields in Shanxi Province, northern China. China is in the middle of its worst drought on record, with over 100 of its major cities facing serious water shortages. One of the main consequences of this is that many areas which previously produced much of China's food are seeing crop yields falling, potentially putting China's long-term food security at risk.

What are the Impacts of Climate Change?

The observed changes to the climate increase the risk of a variety of potentially detrimental effects on a wide variety of physical, biological, and human systems and environments. Some of these risks and effects are global, while others are regional or local, and many are interlinked. Some risks and effects may be mitigated, while others may build to a point of no return if current trends persist for an extended period. One example of this is the thawing of permafrost in arctic regions – once it is gone, it may take many centuries to be re-established even if the world stops warming. Due to the complexity, interconnectedness and feedback loops involved in these systems, this section is intended to give an extremely broad overview of the kinds of risks and effects involved, rather than a detailed catalogue of impacts.

Climatic Effects

Changes in water availability is a direct effect of both rising temperatures and changing precipitation patterns. In cold regions, warmer temperatures have led to the shrinkage of many glaciers, potentially compounded by shifting precipitation patterns to reduce the snowfall required to replenish them. This can lead to less glacial runoff in spring, affecting natural systems downstream including local ecosystems, microclimates and groundwater reservoirs. This may change the ability of the affected landscapes to support terrestrial species, leading to shifts in their ranges or even to extinction.

In warmer regions, increasing temperatures may also lead to shifting ranges of animals and plants, to the extent they are able to do so. Summer heat has become more intense, which, depending on locality, may lead to a higher incidence of drought, a longer fire season, increased monsoon precipitation, flooding, and more frequent and more intense extreme weather events such as tropical cyclones. All of these effects have consequences for local ecosystems.

Human-Related Effects

These natural system effects also have significant potential to disrupt human systems. For example, the changes in water availability described above may have a direct impact on food production and industry. Extreme weather events can disrupt transport, logistics, and even infrastructure for extended periods, disrupting livelihoods and potentially fostering disease outbreaks. Heat waves can lead to increased mortality of vulnerable populations, and also contribute to worsening fire seasons by drying out forests. Rising surface temperatures may negatively impact agricultural yields, worsening food security.

In the ocean, marine warming, as with surface warming, has led in some cases to the shifting of ranges for fish and seafood stocks, with potentially adverse effects on the fishing industry as well as aquaculture. Globally, 40% of the world's population lives in coastal zones (i.e., within 100km of the coastline, as defined by the UN), making a large fraction of humanity vulnerable to sea level rise. Rising seas present increased risk of damage to infrastructure, property and lives via flooding, particularly in combination with events such as storm surges.

Resource stress, particularly regarding food and suitable land, has the potential to lead to conflict, with concomitant risk of loss of life as well as further disruption to livelihoods and communities.

Archipelagic nations such as Indonesia or the Philippines are much more exposed to the risks of rising sea levels than are landlocked countries like Mongolia or Laos.

Roxas Boulevard, in Manila, Philippines. Manila is a low-lying coastal city which is highly vulnerable to rising sea levels, floods, and other impacts of climate change.

© AAR Studio / Shutterstock.com

How has Climate Change Manifested in Asia?

While climate change is a global phenomenon, it also manifests regionally and locally. All of the climate effects described above are also being observed in Asia, at the continental, regional and country levels. Temperatures are rising, precipitation patterns are changing, the sea level is rising, and extreme weather events are increasing in frequency and intensity, among other effects. For Asia this can be seen on a country-by-country basis in **Annex A**.

Given the diversity of geographies, topographies, and climates among the various countries in Asia, the specific climate-related risks faced by the different countries vary significantly. For example, archipelagic nations such as Indonesia or the Philippines are clearly much more exposed to the risks of rising sea levels than are landlocked countries like Mongolia or Laos.

WHY ACT NOW AND WHAT CAN BE DONE?

Changes to the climate occur slowly, in human terms, and often with a delay. Even if CO_2 emissions cease immediately, the world will continue warming for several decades, due to the delay in climatic effects impacting on the climate and the decadal time scales required for natural systems to re-absorb CO_2. Responding to climate change ultimately takes the form of adaptation or mitigation. Adaptation is the process of dealing with climate change impacts that are already happening or are expected to occur. Mitigation efforts seek to reduce or stabilise the concentrations of greenhouse gases in the atmosphere.

There are only two ways to lower the concentration of atmospheric carbon dioxide: reduce the rate of emissions (mitigation), and increase the rate at which it is removed from the atmosphere (sequestration). The former option has been the primary focus of policy commitments under the UN Framework on Climate Change, signed in 1992, which has articulated a goal of limiting the rise in the Earth's temperature to 2°C above pre-industrial temperatures by 2100 (consistent with RCP2.6). But the Paris Agreement, signed in 2015, included adaptation to climate change and appropriate financial flows as equally important priorities. The policy response is discussed further in the next chapter.

Regarding the latter option, although development efforts are ongoing (see the Technology chapter), no technologies currently exist with the scale required at an acceptable economic or environmental cost to remove sufficient CO_2 from the atmosphere to make a difference to the climate system. The only potentially viable option at present with sufficient scale is to use reforestation and afforestation to improve the capacity of natural carbon sinks while also severely curtailing deforestation.

As even this will take multiple decades to show results, notwithstanding the amount of land required, curtailing greenhouse gas emissions is a critical component of the effort to stabilise the Earth's climate. The longer it takes the world to reach and pass peak emissions, the larger the problem becomes, and the more dependent it becomes on inventing or developing the necessary technology.

WHY SHOULD WE CARE?

Risk Implications

From a financial perspective, climate change presents a number of different types of risks that some investors are only beginning to take under consideration. As the policy and market responses to climate change continue to evolve, additional risk categories for investors may come to the fore. These include policy and regulatory risk, reputational risk and litigation risk. These will be discussed in the next chapters.

In terms of the physical risks of climate change, investor exposure may vary, depending on a given investor's liquidity horizon (short, medium or long term) and/or duration of the asset class held. In particular, in a world of more frequent and more intense extreme weather events, investors and asset owners with long-duration assets and liabilities, such as insurance companies and pension funds (and their investors), are increasingly exposed to the costs and liability risks related to the damage and disruption these events cause.

These risks and costs will rise as temperatures increase. In the words of insurer AXA's US Chairman and CEO, "A world that gets warmer by two degrees may be insurable, but a world that gets warmer by four degrees is certainly not." (AXA 2015)

Metrics and Action Points for Physical Risk

In order to account for and mitigate risks, investors require relevant information. For the physical risks discussed in this chapter, there are a number of relevant metrics that are updated at least annually. Changes in these indicators consistent with more warming may herald worsening extreme weather events, with implications for insurers and other investors with relevant exposure, such as real estate asset owners with significant coastal holdings. Depending on their progression, these metrics may also have predictive value with respect to potential changes in the intensity of the regulatory response to climate change.

Table 2: Selected Metrics for Tracking the Progression of Warming

METRIC	SOURCE	COMMENT	WARMING EFFECT
Atmospheric concentration of CO_2	NOAA	CO_2 molecules trap heat, so a useful indicator of future warming	Increases
Globally averaged land-sea temperature anomaly	NOAA	Difference in Earth's average temperature from a reference time period	Increases
Global land surface air temperature anomaly	NOAA	Same as above, but only for the air above land, which heats faster than water	Increases
Mean sea-level rise	NASA	Shows the impact of climate change in a slow onset event	Increases
Northern hemisphere snow extent	NOAA	Maximum normally in February; snow reflects heat energy back into space	Decreases
Global glacier mass balance	WGMS via NOAA	Indicates rate of glacial retreat/advance. Important sources of fresh water	Decreases

Source: HSBC, WWF

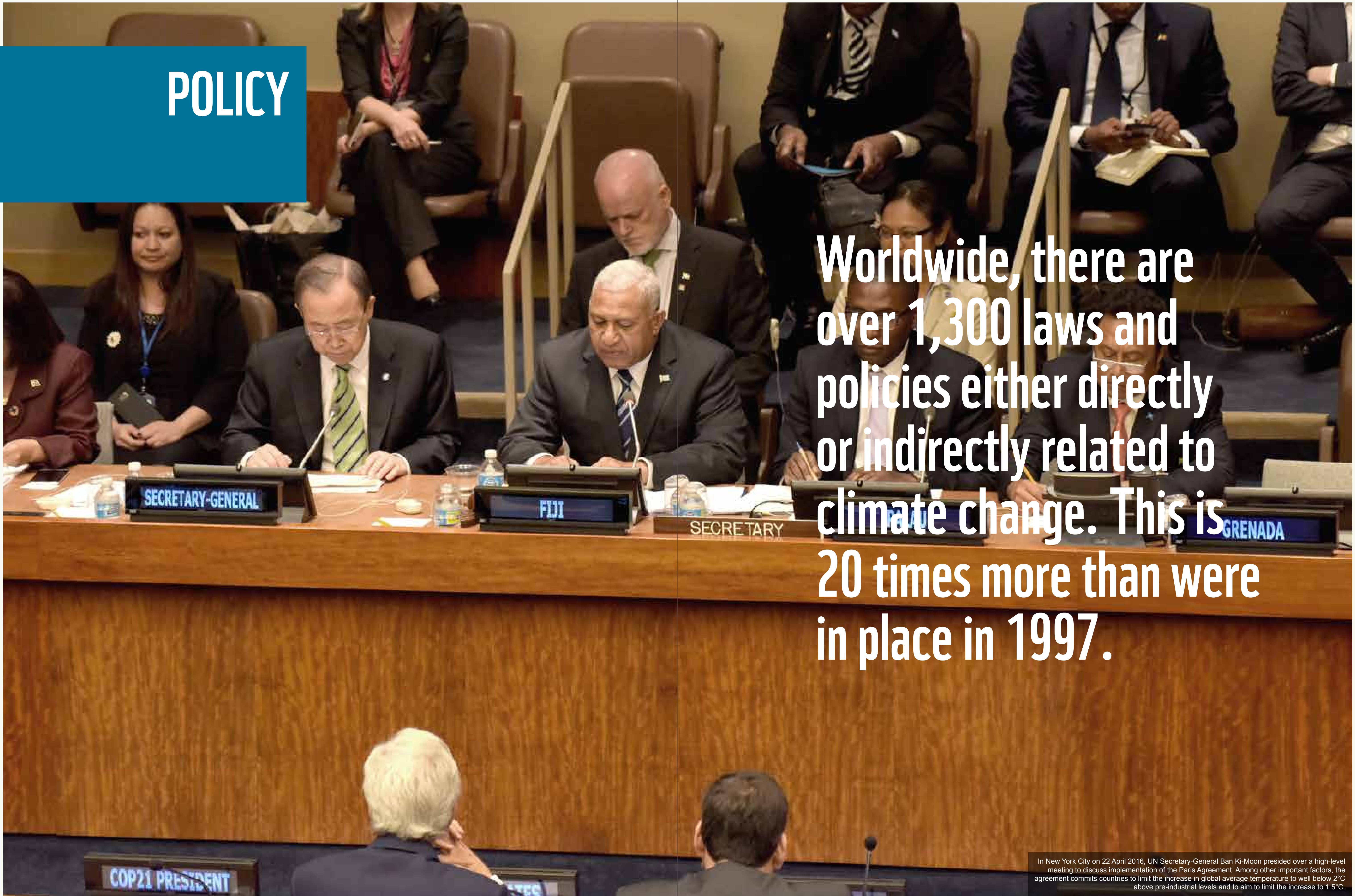
Investment Opportunities

Given the scale of the challenge, responding to climate change will require significant investment, in a wide range of areas, to both mitigate and adapt to its effects. Opportunities exist across the range of investment risk profiles, from co-financing a multilateral-led loan facility intended to develop infrastructure to combat sea level rise, to funding seed-stage technology companies with new ideas about how to remove CO_2 from the atmosphere. An overview of some of the technologies involved in both mitigation and adaptation is presented in the Technology chapter.


A tea plantation in Doi Ang Khang, Chiang Mai, Thailand. Tea growth is sensitive to climatic conditions making it vulnerable to climate change. An increase in average temperatures as expected with climate change could reduce the productivity of tea plantations.

POLICY

Worldwide, there are over 1,300 laws and policies either directly or indirectly related to climate change. This is 20 times more than were in place in 1997.



In New York City on 22 April 2016, UN Secretary-General Ban Ki-Moon presided over a high-level meeting to discuss implementation of the Paris Agreement. Among other important factors, the agreement commits countries to limit the increase in global average temperature to well below 2°C above pre-industrial levels and to aim to limit the increase to 1.5°C.

THE PARIS AGREEMENT

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC). It deals with the mitigation of GHG emissions, the adaptation to the impacts of climate change, and the financing of these activities. The Agreement was adopted by 195 countries in December 2015 and came into force in November 2016. The parties to the Agreement are in the process of negotiating the detailed rules required to implement it, targeting for their adoption in late 2018.

History: UN Framework and Kyoto

The UN Framework Convention on Climate Change marked the first global legal agreement to respond to global warming. It was signed in 1992 in the Rio Conference and came into effect in 1994 and has been ratified by 197 countries. It called for:

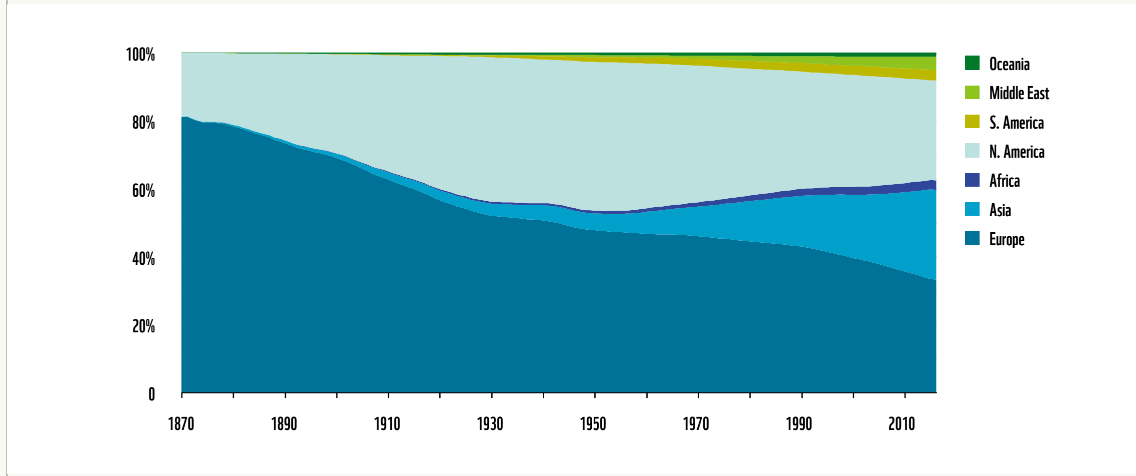
> "The stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The Convention set a goal of reducing developed-country GHG emissions to 1990 levels by 2000 (UNFCCC 1992). However, this goal was only voluntary and most developed countries failed to meet it.

Even ahead of this failure, the targets for 2000 were seen as "not adequate" (UNFCCC 1995), so the parties to the Convention negotiated the Kyoto Protocol, which was adopted in 1997. The Protocol only came into effect in 2005, following its ratification by Russia, which ensured that a sufficient share of global emissions was covered by the ratifying countries.

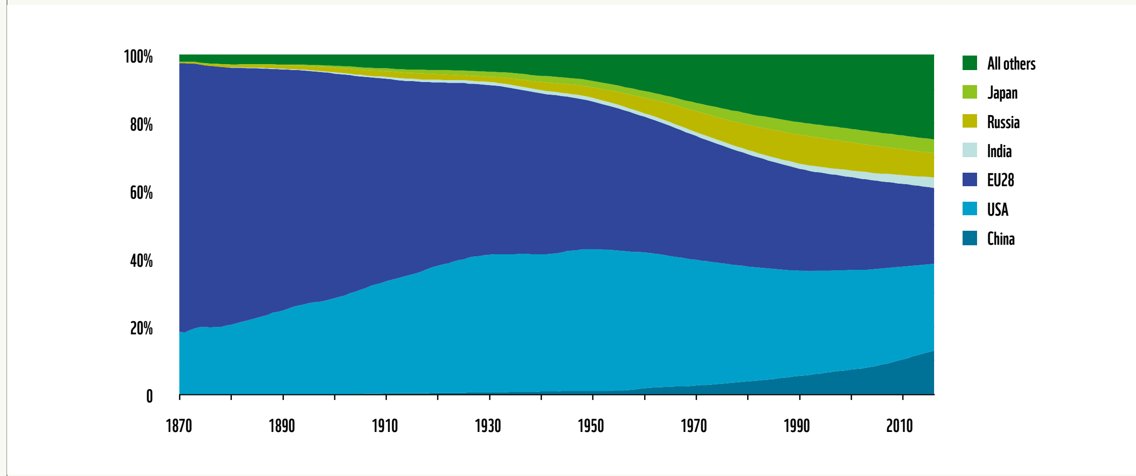
Because historical GHG emissions were overwhelmingly released by developed countries, the Protocol required those countries to commit to emissions reduction targets and to support developing countries' efforts to address climate change.

Figure 21: Share of Cumulative CO_2 Emissions by Continent, 1870-2016



Source: Quéré, et al. (2017)

Figure 22: Share of Cumulative CO_2 Emissions by Country, 1870-2016



Source: Quéré, et al. (2017)

The Protocol:

- Established binding emissions targets for the developed countries on an individual basis, relative to 1990 levels;
- Allowed for flexibility in meeting these targets, specifically with respect to emissions trading through Joint Implementation and the Clean Development Mechanism, which enables countries to offset domestic emissions with emission reduction projects elsewhere;
- Required member countries to articulate implementation policies and measures to reduce their domestic GHG emissions and also to increase the absorption of these gases;
- Reaffirmed the principle, articulated in the Convention, that developed countries have to provide funding and supply technology to developing countries for climate-related studies and adaptation projects.

The first commitment period under the Kyoto Protocol ran from 2008-2012 and aimed for an aggregate reduction of 5% in GHG emissions by 2012, relative to 1990 levels. Canada withdrew from the Protocol in 2011 once it became clear that it would not meet its emissions reduction commitments. The 36 remaining countries with emissions targets, and the EU, achieved full compliance with their commitments (Shishlov, Morel and Valentin 2016).

In December 2012, member countries agreed to amend the Protocol to extend it until 2020 via a second commitment period, with a successor agreement (namely, the Paris Agreement) to cover the period after 2020. The second commitment period runs from 2013-2020, with committed parties agreeing to reduce GHG emissions by at least 18% below 1990 levels by the end of the period. However, the amendment has yet to be ratified by 75% of the parties to the Convention and has thus not yet come into force. Further, several countries have declined to participate in the second period.

What the Paris Agreement Seeks to Do

Mitigation

The Paris Agreement aims to mitigate climate change by reducing emissions of greenhouse gases, to adapt to climate change and provide financial support to countries that need resources to help their mitigation or adaptation needs. The primary goal of the Agreement is to limit “the increase in the global average temperature to well below 2°C above pre-industrial levels,” with a stretch target temperature increase limit of 1.5°C above those levels. The parties to the Agreement also aim to reach “global peaking of greenhouse gas emissions as soon as possible,” and to pursue rapid reductions thereafter, with the understanding that this process may take longer for developing nations.

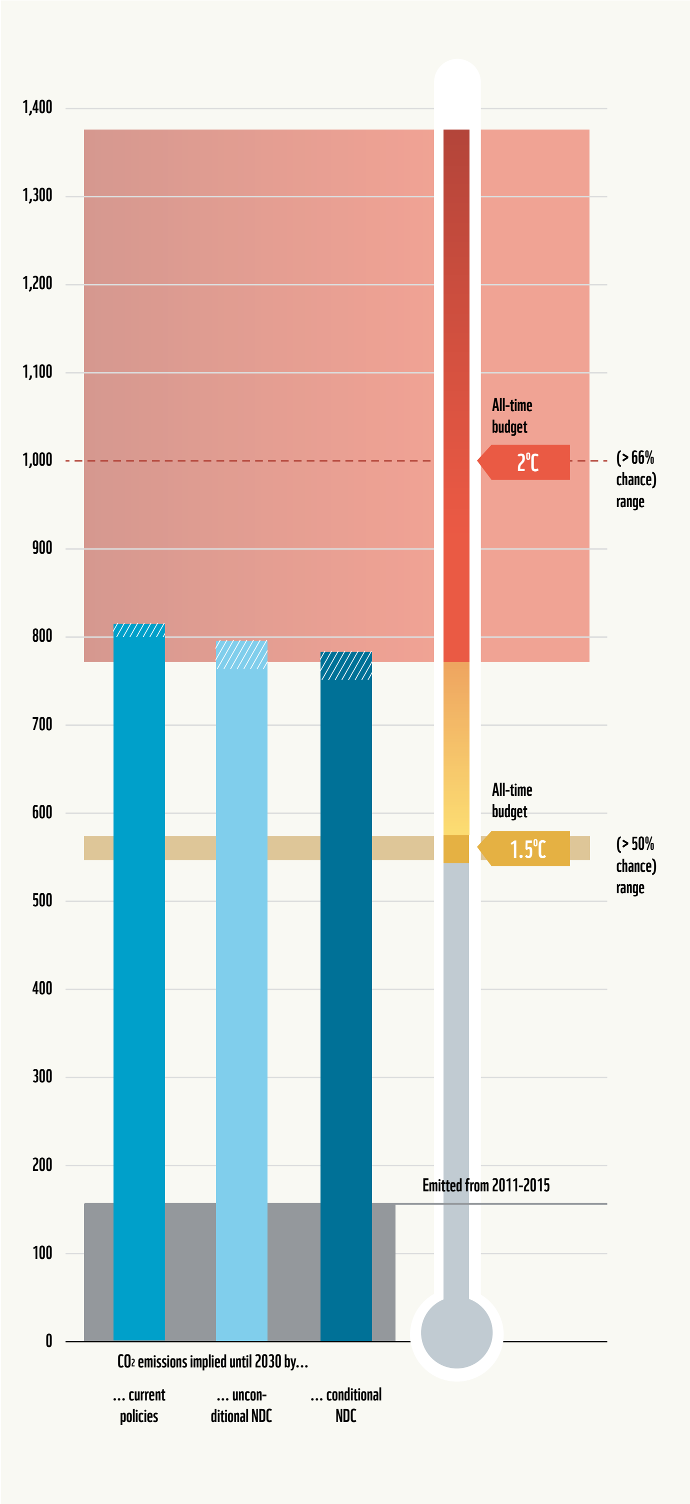
That said, with respect to emissions cuts, the Agreement largely does away with the developed/developing country split that characterised its predecessors, as well as the one-size-fits-all approach to emissions cut targets. It instead requires each country to develop, communicate, and pursue their own targets and plans for mitigating climate change, known as Nationally Determined Contributions (NDCs), or as Intended Nationally Determined Contributions (INDCs), for those who have not ratified the Agreement. While the achievement of these targets is not legally binding, the process is.

The Agreement allows for the use of “internationally transferred mitigation outcomes,” also known as carbon markets, for countries to meet their NDC commitments, but seeks to ensure that the reductions involved are not double counted. It also establishes a successor to the Kyoto Protocol’s Clean Development Mechanism, which is used to create cross-border emissions offsets.

Mitigation: Carbon Budget and the Emissions Gap

A carbon budget can be defined as the remaining quantity of greenhouse gas emissions that can be emitted in total over a specified time to hold temperature rise to a given level. The budget is calculated from atmospheric models of global warming. Carbon budgeting should not be confused with the use of targets, thresholds or caps to set emissions reduction goals (WWF 2014). The carbon budget associated with providing at least a 66% likelihood of achieving the 2°C warming target (known as the 2 Degree Scenario, or 2DS) is 1,000 $GtCO_2$ from 2011-2100, according to the IPCC. Since 2011, the world has emitted almost 245 $GtCO_2$, or about 40-41 $GtCO_2$ a year between 2011 and 2016 (Quéré, et al. 2017).

Figure 23: Cumulative CO_2 emissions 2011–2030, $GtCO_2$



Source: WWF after UNEP (2017)

The majority of the parties to the Paris Agreement have submitted their NDCs (or INDCs) for the initial period. In aggregate, the commitment levels are insufficient to limit the temperature increase to 2°C. In carbon budget terms, in its annual Emissions Gap report, the United Nations Environment Programme (UNEP) estimates that emissions from 2011-2030 under current policies will be at least 800 $GtCO_2$, or 80% of the all-time carbon budget associated with the 2 Degree Scenario. Some countries have submitted two targets within their NDC: a “conditional” target that it proposes to achieve if it obtains financial or technological support, and a lower “unconditional” target it will meet in the absence of support. Emissions under unconditional and conditional NDCs were estimated at a minimum of about 750 and 770 $GtCO_2$ respectively, highlighting the similar levels of ambition between current NDCs and current policy.

In temperature terms, under current policies, UNEP estimates warming relative to pre-industrial temperatures is expected to reach 3.6°C by 2100. Factoring in unconditional NDCs and INDCs, the forecast temperature increase is still 3.2°C. Including conditional contributions makes the forecast 3.0°C. This failure to even get close to 2°C implies that the ambition of the NDCs needs to be ratcheted up substantially, and that even then, the large-scale deployment of measures to extract CO_2 from the atmosphere is required.

Transparency and Global Stock-take

The Agreement establishes a process to review overall progress by the parties every five years, with an initial dialogue in 2018, and the first evaluation in 2023. The output of these evaluations is intended to feed into the revision process for each country’s NDC, which will also take place every five years. The Agreement sets the expectation that the participating countries will continually increase the scale of their planned emissions cuts with each revised NDC. Regarding transparency, the countries also agreed for the first time that all countries – not just developed countries – would report regularly (every two years for most parties) to each other and the public on their emissions and their progress toward implementing their NDCs.

Adaptation

Adaptation, in this context, is the steps taken to lessen the impact of climate change on human and natural systems. In the Paris Agreement, adaptation is given a significantly higher priority than under the Kyoto Protocol: the second key aim of the Agreement is to increase “the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production”.

As with mitigation, the parties to the Agreement are required to create and implement adaptation plans. Every five years, progress is to be reviewed, and methods and support evaluated, as part of the global stock-take.

Finance

The Agreement reaffirms the binding obligations of developed countries under the UNFCCC to support the efforts of developing countries, while for the first time encouraging voluntary contributions by developing countries as well. Furthermore, the Agreement holds that developed countries should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, to a greater extent than previous efforts.

In parallel with the Paris Agreement, the Conference of the Parties agreed to extend through 2025 the pre-existing goal of mobilizing USD100 billion per year in mitigation and adaptation support by 2020. After 2025, a new, higher funding target will be established (“from a floor of USD100 billion per year”).

Loss and Damage

The Loss and Damage concept recognises that not all climate change impacts can (or will) be avoided through mitigation or adaptation. The Agreement extends a pre-existing mechanism to address these unavoidable impacts, including sudden-onset events like extreme weather, and slow-onset events such as sea-level rise. Potential approaches include risk management efforts such as early warning systems and disaster preparedness, as well as risk insurance. It should be noted that the Conference of the Parties decision in parallel with the Paris Agreement stated that the loss and damage provision in the Agreement “does not involve or provide a basis for any liability or compensation”.

Roles of Non-State Stakeholders

The Paris Agreement is an agreement between national governments. However, many non-state stakeholders have displayed strong commitment to the climate agenda. These include sub-national governments such as states, provinces and cities, as well as private sector and civil society organisations. The Agreement recognises their role the global climate effort and encourages them to continue.

Two key UN-linked channels for this engagement are the Lima-Paris Action Agenda and the NAZCA Portal (Non-State Actor Zone for Climate Action), where non-state actors can register their commitments and action plans. There are currently over 12,500 commitments from over 5,500 cities, regions, companies, investors, and civil service organisations registered on the portal.

A third channel for engagement, the one-year Talanoa Dialogue, was launched in November 2017 at the 23rd Conference of the Parties (COP23), as part of the 5-year global stock-take cycle. It is a facilitative dialogue focused on the questions “Where are we?”, “Where do we want to go?”, and “How do we get there?”. The UNFCCC members as well as non-state actors are encouraged to submit input addressing these questions, particularly the third question. These responses will be synthesized into a report for COP24 in December 2018 and will inform the stock-take and NDC goal revision processes.

POLICY TYPES

There are two primary policy paths to encouraging emissions reductions: market-based approaches and regulatory approaches. Market-based approaches are generally broader and involve pricing carbon in some way, while regulatory approaches tend to be more sector-specific. Governments are using both approaches in their efforts to address climate change.

Pricing Carbon

Carbon pricing is generally favoured by economists as the most efficient way to reduce greenhouse gas emissions. A carbon price shifts the burden of paying for the negative externalities associated with carbon emissions back to those responsible for producing them and who can thus reduce them, or see demand for the product fall. An efficient carbon price level is aligned to the costs of damage from carbon, but in practice is generally established by the government, with lobbying input from relevant interests. There are two main types of carbon pricing systems: a carbon tax, or an emissions trading system (ETS).

In an ETS (also known as a cap-and-trade system), the price of carbon is established indirectly, whereby the quantity of total emissions is restricted and the scarcity causes a rise in price. The operator of an ETS, usually a government body, puts a cap on total GHG emissions and allocates permits to emit specific quantities of specific greenhouse gases over a given time period. The initial permits may be given freely, often based on historic emissions an approach called grand-fathering, sold at a fixed price, priced via auction, or some combination of these methods. Participants with lower than allocated emissions can sell their excess allowances to those who want to increase their emissions, establishing a market price for carbon (or other GHGs). The system also allows for financial derivatives of permits to be traded on secondary markets.

A carbon tax directly sets a price on carbon by defining a tax rate on greenhouse gas emissions, typically on the carbon content of fossil fuels. Although different fuels and different fuel uses may be taxed at quite different rates (or not at all), the resulting tax is still generally referred to as a carbon tax. In contrast to an ETS, the price of carbon is set explicitly, while the amount of emissions reduction is not predetermined. (World Bank 2017f)

Other methods that have an effect of increasing the relative price of carbon-containing fuels directly or indirectly include fuel taxes, the elimination or reduction of fuel subsidies, the provision of green subsidies (to reduce the price of non-carbon energy sources), and regulatory processes that include a "social cost of carbon" in cost/benefit analyses or even in electricity pricing in deregulated markets.

According to the World Bank, as of 2017, there are 47 carbon pricing initiatives implemented or scheduled for implementation, covering 42 countries and 25 cities, states and provinces. The active initiatives cover 8 $GtCO_2e$, representing 14.6% of global GHG emissions, at a value of USD52.21bn.

In Asia, there are 14 such initiatives operating, covering 4 countries (Australia, Japan, New Zealand, and South Korea) and 10 cities and provinces. These cover 3.2 $GtCO_2e$, or 5.8% of global GHG emissions, at a value of USD17.1b. Eight of these initiatives are pilot ETSs in China at the city or provincial level. These are slated to be merged into the forthcoming national-level Chinese ETS, launched in late 2017 but not yet operational. While Japan has already implemented a carbon tax, it is also considering a national ETS, as are Taiwan, Thailand and Vietnam.

Table 3: Active Asian Carbon Pricing Initiatives

Carbon Pricing Initiative	$MtCO_2e$ Covered	% Global GHG Emissions	Value (USD bn)
Australia ERF Safeguard Mechanism	381	0.71	N/A
NZ ETS	40	0.07	0.25
Korea ETS	453	0.84	10.17
Japan			
Japan carbon tax	999	1.81	2.34
Tokyo CaT	7	0.03	0.01
Saitama ETS	14	0.01	0.01
Japan subtotal	**1,020**	**1.85**	**2.36**
China			
Beijing pilot ETS	85	0.16	0.35
Chongqing pilot ETS	97	0.18	0.09
Fujian pilot ETS	200	0.37	1.00
Guangdong pilot ETS	366	0.68	0.94
Hubei pilot ETS	165	0.30	0.62
Shanghai pilot ETS	170	0.31	0.88
Shenzhen pilot ETS	61	0.11	0.16
Tianjin pilot ETS	118	0.22	0.32
China subtotal	**1,262**	**2.33**	**4.36**
Total	**3,156**	**5.80**	**17.13**

Source: World Bank (2017f)

Table 4: Asian Carbon Pricing Initiatives Under Consideration

Country	Type	Note
China	ETS	Official launch held in December 2017. Operational launch expected over 2018-2020. Pilot ETSs will be merged into it.
Japan	ETS	Considering ETS since 2008. Ministry of Environment is continuing to explore options and confer with stakeholders.
Taiwan	ETS	Launch schedule TBD. 2015 climate law sets an emission reduction target of 50 % below 2005 levels by 2050.
Thailand	Undecided	Assessing various types of carbon pricing initiatives. As part of this process, has started a voluntary ETS with 2 phases running from 2015-2020.
Vietnam	ETS	Plans to develop a carbon market by 2018.

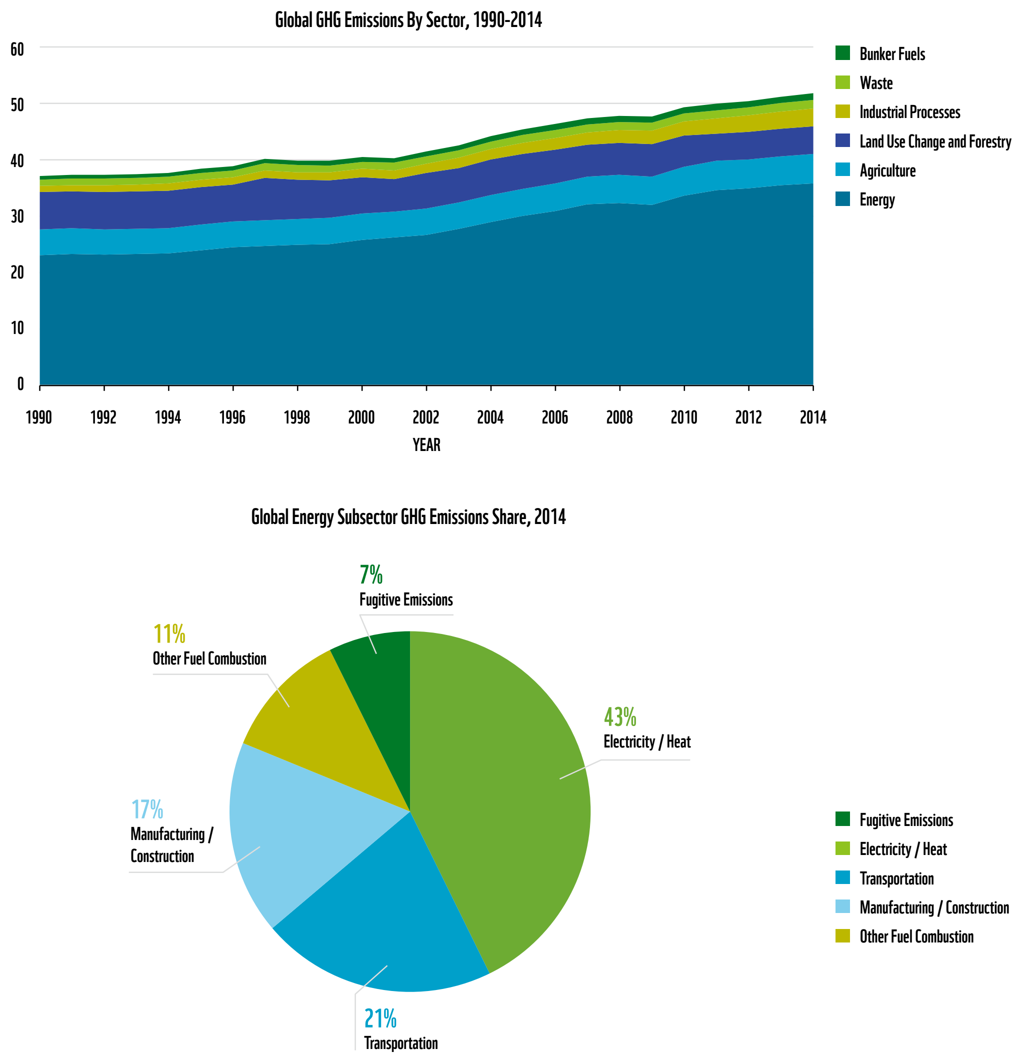
Source: World Bank (2017f)

Regulatory Standards, Incentives, and/or Prohibitions

Beyond pricing carbon, a variety of regulatory approaches may be used to address climate change issues in a given sector. Direct regulatory control policies used in pollution regulations can be directly applicable to GHG emissions regulation, such as emission performance standards for different fuel types, or requirements to use "best available control technology". Other options include demand-side policies to foster technological change, or quotas for clean or renewable energy in the power mix, and supply-side policies such as government procurement rules or technology investment programmes.

Regulatory approaches to climate change mitigation have tended to focus on the broad energy sector – emissions from energy used and fuel burned in power generation, heat, transport, manufacturing, buildings, and other sources – since the sector comprises over two-thirds of global GHG emissions.

Figure 24: Global GHG Emissions by Sector, 1990-2014 and 2014 Global Energy Subsector GHG Emissions Share



Note: To be clear, the Energy Subsector emissions pie chart does not include GHG emissions from the Agriculture, Land Use Change and Forestry, Industrial Processes, Waste, and Bunker Fuels sectors.
Source: CAIT (2015), FAO (2014), IEA (2014)

Table 5: Selected Regulatory Policies for Addressing GHG Emissions

SECTOR POLICY OPTION	COMMENT
Power Generation	
Feed-in tariffs and premiums for renewable energy	Market/regulatory blend. Getting the price level right has been challenging and will require ongoing adjustments as take-up increases
Renewable portfolio standards	Frequently paired with tradeable renewable energy certificate program to improve cost effectiveness
Tax rate adjustment	Differential taxation based on feedstock or carbon output
Capital subsidies / rebates	-
Investment / production tax credits	-
Cogeneration	Combined heat and power generation for higher thermal efficiency
Efficiency standards	-
Emission standards	When including CO_2, can be set at a level to accelerate phase-out of higher emission power plants using coal
Carbon Capture and Storage (CCS)	Cost-effectiveness unproven, particularly at the scale required. Storage component unproven over long time scales. Availability of economically-viable storage also lacking
Develop: nuclear	Not cost effective at scale and time needed, even leaving aside waste issues
Develop: large-scale hydro	Limited site options without severe human and environmental impact
Develop: large-scale renewables	Large scale projects at cost parity or better with fossil fuels, but that may change if cheap-money era ends
Buildings	
Energy efficiency standards for buildings and appliances	Obligations for efficiency and prohibitions on inefficient technologies; Potential time lag between enacting policy and GHG emissions reduction
Grants to promote efficiency / energy savings	Especially for heating and electrical use
Cogeneration	MicroCHP (combined heat and power) for homes and small businesses
Investment tax credits for renewables	-
Building integrated renewables	-
Transport	
Financial incentives for EVs	e.g., no registration tax, free toll policy, zero VAT
Fuel economy standards	Potential time lag between enacting policy and GHG emissions reduction
Emissions standards	Relatively straightforward to adjust existing pollution-related standards
Biofuel mandates	Food crop vs. fuel crop land use issue; carbon neutrality is not established

SECTOR POLICY OPTION	COMMENT
Industrial Processes	
Financial incentives for retrofits	-
Information programmes to promote energy efficiency	Including data collection systems & auditing/reporting requirements
Efficiency standards/tradable efficiency certificates	Can include energy consumption targets
Emissions standards	May include CCS
Ban polluting plants	e.g., close smaller/less efficient facilities
Prohibition on use of certain fluorinated gases in new equipment	-
Agriculture	
Livestock management	-
Energy efficiency standards for equipment	-
Alternative fuel use	Promotion or requirement
Manure management	-
Optimising nitrogen fertilisers	-
Land Use, Land Use Change, and Forestry (LULUCF)	
Effective policing of anti-deforestation policies	-
Reducing emissions from deforestation and forest degradation (REDD)	Results-based payments to developing countries for achieving reductions in deforestation relative to baseline
Sustainable forest mgmt. practices	-
Afforestation/reforestation	Lowered albedo may reduce temperature benefits of carbon sequestration
Waste	
Financial incentives such as landfill taxes	-
Waste prevention	-
Recycling and recovery	-
Landfill gas capture & combustion	Cleaner option than allowing the methane to be emitted freely
Product life-cycle policies	-

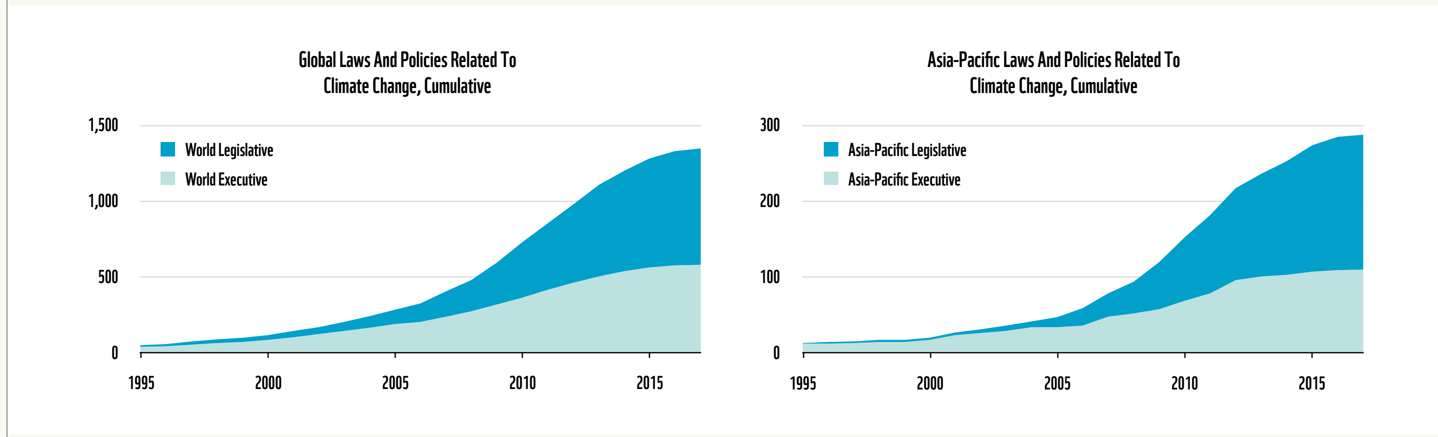
Source: OECD (2015)

POLICY OVERVIEW BY GEOGRAPHY

This section presents an overview of the Paris commitments of the top global emitters as well as those of the top 5 emitting countries in Asia-Pacific, and the legislative and executive actions these countries have emplaced to meet their commitments. The remaining countries in the region are covered in less detail in Table 6, as they generally constitute well below 1% share of global emissions each.

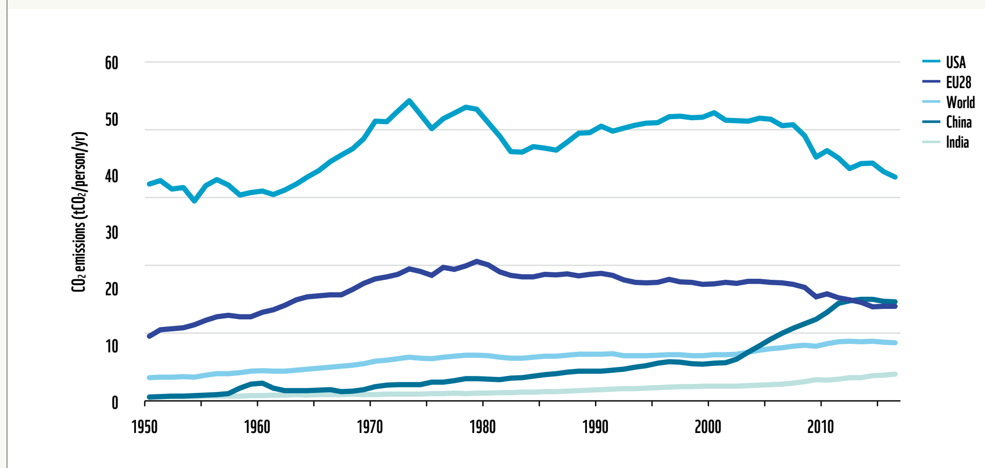
Worldwide, there are over 1,300 laws and policies either directly or indirectly related to climate change. This is 20 times more than were in place in 1997. In Asia-Pacific, the current total is almost 300, reflecting a similar increase over the past 20 years. Globally as well as in Asia-Pacific, activity on this front accelerated sharply from about 2006, but has tapered off in recent years, as the major policy frameworks are now generally place, although supplementary laws and policies are still being developed or updated. (Nachmany, et al. 2017)

Figure 25: Cumulative Total of Climate-Related Laws and Policies



Source: Grantham (2017). Chart based on Nachmany, et al (2017)

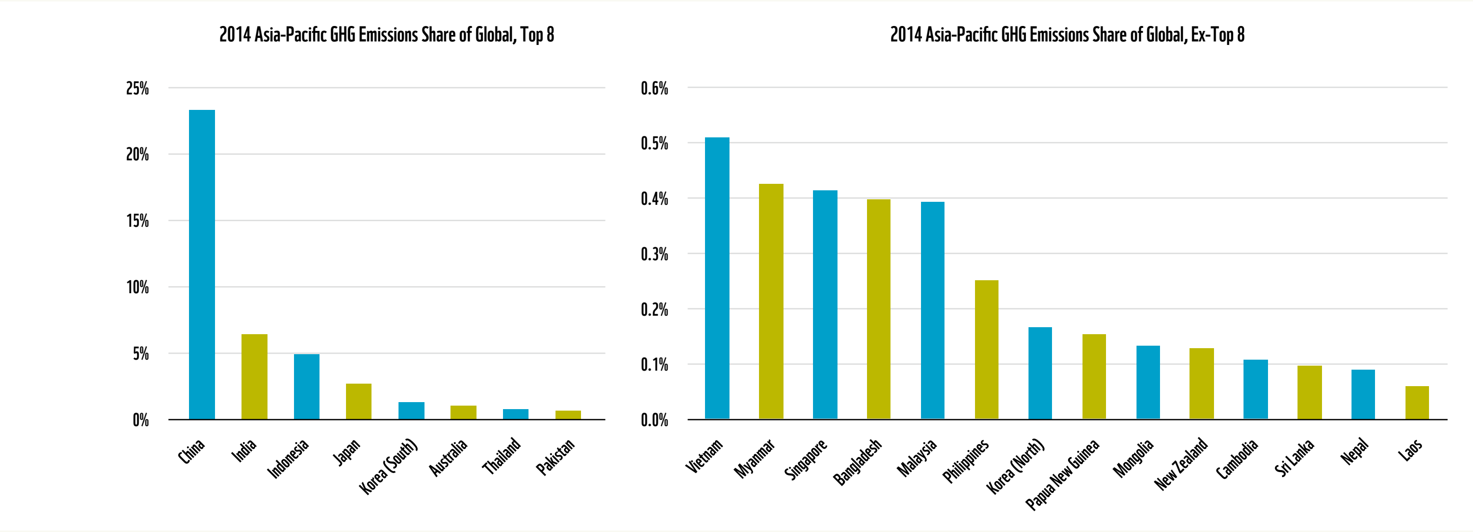
Figure 26: CO_2 Emissions Per Capita, Top 4 Emitters, 1950-2016



Source: Quéré, et al. (2017)

While GHG emissions have been dominated historically by Europe and North America, in recent decades Asia has been increasing emissions sharply. In particular, China has emerged as the top emitter of GHGs on an absolute basis: the top four absolute emitters are in order China, USA, EU28, and India. China also recently surpassed the EU28 on emissions per capita.

Figure 27: 2014 Asia/Oceania GHG Emissions Share of Global GHG Emissions



Source: CAIT (2015)

United States

The United States is the second-largest GHG emitter in absolute terms and the highest per-capita emitter amongst the top four. In 2014 total emissions were 6,432.4 $MtCO_2e$, accounting for about 13% of global emissions.

On June 1, 2017, President Trump announced that the US would withdraw from the Paris Agreement, and formally notified the UN of this intent on August 4. The withdrawal will become effective no earlier than November 4, 2020, according to Article 28 of the Agreement. That said, while from a signalling perspective the announced withdrawal is a clear negative for climate progress, it is unlikely that action toward reducing emissions will cease entirely in the United States. This is because of strong commitment at the state and local level to emissions reductions.

Indeed, within a week of the announcement, the governors of California, New York and Washington formed the US Climate Alliance, a coalition of states committed to the goal of reducing greenhouse gas emissions consistent with the goals of the Paris Agreement. By July 2017, the Alliance comprised 14 states plus Puerto Rico, representing over one-third of the US population and $7 trillion in GDP (USCA 2017).

An older study shows 20 states and over 130 local governments (WWF 2015) have adopted specific GHG emissions reduction targets, while 34 states have climate action plans which may or may not include such targets. Most states have policies that will contribute to emissions reductions even in the absence of specific GHG targets. These include carbon pricing, emission limits, energy efficiency mandates and incentives, and steps to promote cleaner transportation. (C2ES 2017)

In its NDC submission, the United States pledged to reduce its emissions by 26% from 2005 levels by 2025, and to make best efforts to achieve a 28% reduction. This pledge is unconditional. The US in its NDC stated that it expected to achieve this reduction via domestic efforts, without the use of international market mechanisms to offset some of its emissions (UNFCCC 2015). The US further submitted a longer-term emissions reduction target of 80% or more below 2005 levels in 2050 (CAT 2017).

The primary laws relevant to this target are the Clean Air Act, the Energy Policy Act, and the Energy Independence and Security Act. Recent regulatory actions under the Clean Air Act include an expansion of fuel economy standards to heavier types of vehicles, as well as the approval of alternatives to various F-gases in certain applications. The two Energy acts have implemented multiple measures regarding building sector emissions, including energy conservation standards and building codes. In addition, the federal government reduced GHG emissions from its operations by 17% from 2008 to 2016, and the executive order targeting a 40% reduction compared to 2005 levels by 2025 remains in effect. (UNFCCC 2015)

European Union-28

The European Union in aggregate is the third-largest GHG emitter in absolute terms, and also in per-capita terms amongst the top four emitters. In 2014 total emissions were 3,890.1 $MtCO_2e$, accounting for about 8% of global emissions.

In its NDC submission, made collectively on behalf of the 28 members, the European Union pledged to reduce its collective emissions by at least 40% from 1990 levels by 2030. This pledge is unconditional. The EU plans to achieve this reduction through domestic/regional efforts and does not expect to use international market mechanisms to offset some of its emissions (UNFCCC 2015). EU-level policies to achieve this include the EU ETS, the Effort Sharing Directive, the Energy Efficiency Directive, the Energy Performance Buildings Directive, and the Renewable Energy Directive. The EU's longer-term target for 2050 is for emissions reduction of 80-95% below 1990 levels (CAT 2017).

The NDC is in line with the EU's 2030 climate and energy framework, which was adopted in October 2014 and builds on its 2020 climate and energy package. The 2030 framework sets three key targets for the year 2030: the 40% cut in emissions articulated in the NDC, a 27% target share for renewable energy, and a 27% improvement in energy efficiency. These are all binding targets at the EU level.

The EU-level framework is being carried out and supported by legislative action at the national level. Examples include:

- Germany's Climate Action Programme 2020 and its Climate Action Plan 2050, which set out policies and measures that attempt to enable Germany to meet its emissions reduction targets in the specified year.
- France's Energy Transition Law of 2015 and the Climate Plan announced in July 2017. As part of the Climate Plan, France will end the sale of gasoline- and diesel-powered vehicles by 2040, progressively increase taxes on fossil fuels, close coal-fired power plants by 2022 and invest more in renewable energies. In September 2017, the government presented a bill that would end the exploration for and exploitation of fossil fuels by 2040.
- The United Kingdom's Climate Change Act of 2008, which commits the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050. It requires the government to establish and meet a series of five-yearly legally binding carbon budgets. In 2017, the UK also announced a ban on the sale of new petrol- or diesel-powered cars and vans, to take effect in 2040.
- Italy's Climate Change Action Plan of 2007, a comprehensive plan aimed at helping Italy meet its commitments under the Kyoto Protocol.

China

China is the largest GHG emitter in absolute terms and recently became the second-largest per-capita emitter amongst the top four absolute emitters. In 2014 total emissions were 11,645.2 $MtCO_2e$, accounting for about 23% of global emissions.

In its NDC submission, China unconditionally pledged to reduce its emissions intensity by 60-65% from 2005 levels by 2030, and to reach peak carbon emissions by the same year (and make best efforts to peak early). It also targets a 20% share of non-fossil fuels in primary energy consumption (2016 actual share: ~13% (BP 2017)), and to increase forest stock volume by 4.5b m^3 compared to 2005, both by 2030. These pledges build on its 2009 commitments for 2020, which targeted a 40-45% emissions intensity reduction, 15% share of non-fossil fuels, and 1.3b m^3 in forest stock increase, all relative to 2005 levels. As of 2014, China had achieved -38%, 11.3% and +2.2b m^3 respectively (UNFCCC 2015).

China's primary tool to meet its commitments is a reduction in the use of coal. The 13th Five-Year Plan caps coal usage in power generation at 58% by 2020, while the National Action Plan on Climate Change mentions increasing to 10% the share of gas in primary energy generation, and the Energy Strategy Development Action Plan aims to limit coal consumption to 4.2b tonnes by 2020 (CAT 2017). These targets are being translated into real action: in August 2017, the NDRC announced that through 2020 it is postponing or terminating the construction of 150 million kW of coal-fired generating capacity, eliminating a further 20 million kW of capacity, and upgrading 1 billion kW to reduce emissions (CSC 2017a). These policies are also consistent with China's ongoing efforts to address air pollution – Beijing's last large coal-fired power plant suspended operations in 2017 (CSC 2017b).

Other prominent actions by China include widespread expectations for a policy announcing a timetable for the elimination of 100% fossil fuel-powered vehicles (CSC 2017c). as well as a cap-and-trade program linked to new energy vehicles for car manufacturers and importers, slated for 2019 (CSC 2017d). Companies that manufacture or import over 30,000 vehicles annually will be required to obtain new energy vehicle credits equivalent to 10% of their production or face a steep fine; the quota percentage will rise over time. These credits can be earned by producing new energy vehicles or by purchasing them from other companies. As with its coal measures, these policies combine perceived action on climate goals with air pollution benefits, arguably a more urgent short-term issue.

In its NDC, China also pledged to implement a nationwide carbon emissions trading scheme. As mentioned above, China is running eight pilot ETSs at the city or provincial level (see Table 3). These are slated to be merged into the forthcoming national-level Chinese ETS, which was formally launched on December 19, 2017 and is expected to become operational over the course of 2018 to 2020.

India

India is the fourth-largest GHG emitter in absolute terms and the smallest of the top four absolute emitters on a per-capita basis. In 2014 total emissions were 3,219.0 $MtCO_2e$, accounting for about 6% of global emissions.

In its NDC submission, India pledged to reduce its emissions intensity by 33-35% from 2005 levels by 2030. It also commits to increase the share of non-fossil-based power generation capacity to 40% of installed electric power capacity by 2030, and to create an additional carbon sink of 2.5–3 $GtCO_2e$ through additional forest and tree cover by 2030. (UNFCCC 2015)

India has more than 10 policies and laws related to climate change (Grantham 2017), the most relevant of which are the National Environment Policy of 2006, and the National Action Plan on Climate Change, which together establish the policy framework and focus of the required interventions. These are supported by other policies and laws on electricity and renewables promotion, energy efficiency, and sustainable agriculture development, as well as various fiscal levers (taxes and subsidies) and market mechanisms. In addition, almost all Indian states and territories have developed climate change action plans, which translate the national action plan into state-level measures for mitigation and adaptation.

The most significant element of India's progress towards meeting its commitments is its ongoing work to improve the efficiency of its coal power plant fleet, and the parallel increase in renewable sources for electricity generation. Renewable power capacity increased over 900%

from 2002 to 2015, to 35 GW (13% of capacity), and is targeted at 175 GW by 2022. At the same time, coal is being de-emphasized – the Central Electricity Authority's (CEA) Draft National Electricity Plan states that aside from the 50 GW already under construction, no new coal capacity is needed at least for the 2022-2027 five-year period; it also plans for no new gas plants after that year. This has apparently led some private sector players in coal power to suspend further investment and development in India in favour of solar (CAT 2017).

However, there are some indications that this plan could be altered in favour of coal. In August 2017, the Three-Year Action Agenda released by the National Institute for Transforming India (Niti Aayog), a government planning body chaired by the Prime Minister, included a plan to boost domestic coal production in the name of energy security. It also asserted that coal's 75% share of electricity generation in India would not change significantly over the next few decades. Somewhat confusingly, the Niti Aayog report did not dispute the CEA's position on needing no new coal-fired electricity generation from 2022 (NITI 2017). This may be due to the subdued load factors of coal plants, which in August 2016 hit a record low of 52% on average (ICEA 2016). Boosting utilisation could create more demand for coal without new generating capacity.

Indonesia

Indonesia is a top-10 global emitter and the third-largest emitter of greenhouse gases in Asia-Pacific. In 2014 total emissions were 2,474.9 $MtCO_2e$ accounting for approximately 5% of global emissions. Unlike most leading GHG emitting countries, the vast majority of Indonesia's emissions (about two-thirds) stem from land use change and forestry[1].

In its NDC submission, Indonesia unconditionally pledged to reduce its emissions by 29% relative to its business as usual (BAU) scenario for 2030, defined in aggregate as 2,869 $MtCO_2e$. This is an incremental improvement on its 2010 voluntary pledge of a 26% reduction vs. its 2020 BAU scenario. In both cases, it pledged further reduction of up to 41% vs. BAU, conditional on international support. (UNFCCC 2015)

Indonesia's main targets for reducing emissions are the LUCF and energy sectors, which contribute over 97% of planned relative emissions reductions to 2030. In the land use and forestry sector, the country aims to sharply reduce emissions from unplanned deforestation by 2030, and to eliminate it thereafter. The country expects its participation in REDD+ (the UN's program for reducing emissions from deforestation and forest degradation) to be a significant component in meeting its NDC targets in this space. (UNFCCC 2015)

In the energy sector, Indonesia's 2014 National Energy Policy targets a 2025 primary energy supply that includes at least 23% from "new and renewable energy," up from 6.5% in 2016. However, these targets also stipulate a minimum 30% share from coal, and 22% from natural gas, essentially unchanged from 2016 levels; only oil's share is slated to decrease, to 25% from 40% in 2016 (CAT 2017).

Indonesia's policy framework with respect to climate change includes 4 laws and at least 17 executive/ministerial policies (Grantham 2017). In the LUCF sector, the country has instituted a moratorium on the clearing of primary forests and is working to improve forest and peatland governance as part of the country's National Forestry Plan 2011-2030. Numerous executive actions relating to the sector cover the country's REDD+ activities, which are housed within the Directorate General of Climate Change, within the Ministry of Forestry and Environment. The energy sector is guided by Indonesia's National Energy Policy of 2014 and the National Energy Plan of 2016, as well as by the periodically updated Electricity Supply Business Plan. While these plans envision significant contributions from renewable energy – particularly geothermal – over the medium term, in the near term the focus appears to be on expanding the role of coal, with 17GW of capacity expected to be added in the next five years.

[1] It should be noted that the emissions totals included here across countries come from the WRI's CAIT database, which in the case of Indonesia are substantially larger than what the country cites in its NDC submission. This is due in part to the high degree of uncertainty and variability with respect to LUCF emission estimates.

Japan

Japan is a top-10 global emitter and is the fourth-largest source of greenhouse gases in Asia-Pacific. In 2014 total emissions were 1,352.7 $MtCO_2e$ accounting for approximately 3% of global emissions.

In its NDC submission, Japan unconditionally pledged to reduce its emissions by 26% from 2013 levels by 2030. Japan plans to achieve the majority of this reduction via efficiency and process improvements in the various fuel-combusting sectors – primarily energy and industry. Japan also expects to count improvements to its net CO_2 sink position in the LUCF sector, as well as the results of any approved overseas emissions reductions investments via whatever Kyoto-like international emissions-offset market mechanism emerges out of the Paris Agreement (UNFCCC 2015). Japan's longer-term target for 2050 is for emissions reduction of 80% below 2013 levels.

The primary Japanese policies and legislation to achieve this include the Act on Promotion of Global Warming Countermeasures, which mandates the introduction of ETSs in Japan, and also requires the national and local governments to develop and implement GHG emission reductions plans. The Act was passed in 1998 and came into effect in 2005. Under its auspices, the national government adopted the Plan for Global Warming Countermeasures in 2016, which essentially turns its NDC into official policy targets. Another key piece of climate-related legislation includes the Energy Conservation Act of 1979, which was passed in response to the oil shocks of the 1970s. This law promotes energy efficiency in sectors using fossil fuel energy, in particular by requiring the reporting of and incremental reduction in the amount of energy used across much of the industrial, transport, commercial, and residential sectors. (Grantham 2017)

With respect to the energy sector, Japan aims for generation from renewables to make up 22-24% of the power sector by 2030, of which non-hydropower renewables will be 14%. This is up from a share of approximately 15% in 2016, which itself represents strong growth post-Fukushima (CAT 2017). Japan also targets a 20-22% share for nuclear power generation by 2030; achieving this will depend on how many of its shuttered plants it is able to restart. Any missing nuclear capacity (due to legal, technical or political issues) will likely be made up by coal, but renewables could also see some incremental benefit.

South Korea

South Korea is a top-15 global emitter and is the fifth-largest source of greenhouse gases in Asia-Pacific. In 2014 total emissions were 671.8 $MtCO_2e$ accounting for approximately 1% of global emissions.

In its NDC submission, South Korea pledged to reduce its emissions by 37% relative to its business as usual (BAU) scenario for 2030, which it estimated as 850.6 $MtCO_2e$. This pledge currently excludes any impact from the land use and forestry sector; the country will decide later whether or not to include the net effect from this sector (UNFCCC 2015). South Korea plans to use carbon credits from international market mechanisms to offset some of its emissions – the Ministry of Environment clarified that of the 37% pledge, 25.7% would come from domestic efforts, and the remaining 11.3% would come from international market mechanisms (CAT 2017). On a straight-line basis, this target essentially represents a weakening of its 2009 voluntary pledge of a 30% reduction vs. its 2020 BAU scenario of 782.5 $MtCO_2e$, as the emission levels in 2030 assuming a fully realised pledge for that year are almost identical to the 2020 levels.

The primary legislative policy regarding climate change in South Korea is the Framework Act on Low Carbon Green Growth, which came into effect in 2010. The Act creates the legislative framework for emissions reporting and reduction targets, the Korea ETS, carbon taxes, carbon labelling and disclosure, and renewable energy expansion (Grantham 2017). In its original formulation, the Act included South Korea's 2020 pledge as the country's target; in its 2016 update, the Act replaced the 2020 pledge with the weaker 2030 pledge (CAT 2017).

Other climate policies related to this framework cover most sectors of the economy. They include renewable portfolio standards for power companies (10% renewable share requirement by 2024, up from 2% in 2012), increasingly stringent CO_2 emissions standards for light vehicles, the various enabling policies with respect to the Korea ETS, and green building standards (UNFCCC 2015).

Other Asia-Pacific

The policy themes seen in top emitters broadly apply to the rest of Asia and the Pacific: a framework climate-focused policy in place, with supplemental laws and policies either in place, under development, or already being updated. As the energy sector (and electricity generation within it) is typically the largest single emissions source in most countries, this is where a significant portion of the policy effort is focused.

That said, the circumstances of each country are unique, and may differ from this broad profile. In particular, in almost all of the countries in the region, agricultural emissions feature much more prominently than the 3% share they contribute to global emissions. As mentioned above, Indonesia's emissions are dominated by the Land Use Change & Forestry sector, a result of the clearing (frequently by fire) of its forests for agriculture; while in Singapore, maritime bunker fuels are the overwhelming source of GHGs (see Figure 29 next chapter).

Table 6 below presents an overview of most Asia and Pacific countries' recent emissions, global share, and 2030 emissions reduction targets.

Table 6: (Intended) Nationally Determined Contributions – US, EU28, Asia & Oceania

Country	2014 GHG Emissions ($MtCO_2e$)	% of Global Emissions	Initial (Intended) Nationally Determined Contribution			
			Metric	Headline Number	Base Year	End Year
Top 5						
China	11,645.2	23.3%	Carbon intensity	60-65% carbon intensity reduction	2005	2030
			Absolute emissions	Peak CO_2 emissions by 2030, best efforts to peak earlier		2030
			Policies / actions	20% share of non-fossil fuels in primary energy consumption		2030
			Policies / actions	Increase forest stock volume by ~4.5b m^3	2005	2030
United States	6,432.4	12.9%	Absolute emissions	26-28% reduction (best efforts to get to -28%), unconditional	2005	2025
EU28	3,890.1	7.8%	Absolute emissions	At least 40% reduction (without using international credits)	1990	2030
India	3,219.0	6.4%	Carbon intensity	33-35% carbon intensity reduction	2005	2030
			Policies / actions	40% share of non-fossil fuels in electricity generation (conditional)		2030
			Policies / actions	Increase forest/tree cover to create sink for 2.5-3b $MtCO_2e$		2030
Indonesia	2,474.9	5.0%	Relative emissions	29% unconditional reduction, 41% conditional; BAU defined as 2,869 $MtCO_2e$	BAU	2030
Asia						
Bangladesh	198.3	0.4%	Relative emissions	5-15% reduction in power, transport, industry; BAU defined as 240 $MtCO_2e$	BAU	2030
Cambodia	52.8	0.1%	Absolute emissions	27% reduction; BAU defined as 11.6 $MtCO_2e$	BAU	2030
Japan	1,352.7	2.7%	Absolute emissions	26% unconditional	2013	2030
Korea, Dem. Rep. (North)	83.0	0.2%	Relative emissions	8% unconditional, 40.25% conditional	BAU	2030
Korea, Rep. (South)	671.8	1.3%	Relative emissions	37% reduction; BAU defined as 850.6 $MtCO_2e$	BAU	2030
Laos	29.6	0.1%	Policies / actions	30% share of renewable energy in energy consumption	1990	2020/2025
			Policies / actions	Increase forest cover to 70% of land area		2020
			Policies / actions	Reach 90% electricity penetration in rural households		2020
Malaysia	196.1	0.4%	Carbon intensity	35% unconditional plus 10% conditional	2005	2030
Mongolia	65.5	0.1%	Relative emissions	14% reduction (excluding LULUCF), conditional; BAU defined as 51 $MtCO_2e$	BAU	2030
			Policies / actions	30% share of renewables in electricity generation (conditional)	2014	2030
Myanmar	212.6	0.4%	Policies / actions	38% share of large-scale hydro in electricity generation (9.4 GW)		2030
			Policies / actions	30% share of renewables in rural electricity penetration expansion		2030
Nepal	44.4	0.1%	Policies / actions	50% reduction in dependency on fossil fuels		2050
			Policies / actions	80% share of renewables in electricity generation		2050
Pakistan	362.9	0.7%	Relative emissions	20% conditional reduction; BAU defined as 1,603 $MtCO_2e$	BAU	2030
Philippines	124.7	0.3%	Relative emissions	70% conditional reduction	BAU	2030
Singapore	206.1	0.4%	Carbon intensity	36% unconditional; target peak at 2030	2005	2030
Sri Lanka	48.0	0.1%	Relative emissions	Energy sector 4% unconditional, 16% conditional	BAU	2030
			Relative emissions	Other sectors 3% unconditional, 7% conditional	BAU	2030
			Policies / actions	60% share of renewables in electricity generation (up from 50%)	2010	2020
			Policies / actions	32% forest cover (up from 29%)	2010	2030
Thailand	389.3	0.8%	Relative emissions	20% unconditional, 25% conditional; BAU defined as 555 $MtCO_2e$	BAU	2030
			Policies / actions	20% share of renewables in electricity generation		2036
			Policies / actions	30% share of renewables in electricity consumption		2036
Vietnam	254.7	0.5%	Relative emissions	8% unconditional, 25% conditional; BAU defined as 787.4 $MtCO_2e$	BAU	2030
			Carbon intensity	20% unconditional reduction, 30% conditional	2010	2030
			Policies / actions	45% forest cover, unconditional increase		2030
Oceania						
Australia	537.3	1.07%	Absolute emissions	26 to 28% unconditional	2005	2030
New Zealand	63.8	0.13%	Absolute emissions	30% unconditional	2005	2030
Papua New Guinea	76.0	0.15%	Absolute emissions	Carbon neutrality	2010	2030

Source: IGES (2017), UNFCCC (2015), CAIT (2015)

IMPLICATIONS FOR INVESTORS

RISK IMPLICATIONS

There are several kinds of risk investors face from policy actions that fall broadly into the public sphere. The most relevant to this chapter is regulatory risk, followed by liability or litigation risk, and finally, reputational risk. These risks are interlinked and interdependent, and may also encompass the physical risk discussed in the previous chapter.

Regulatory Risk

The global policy response to climate change in large part necessitates significant changes in the energy sector, including energy transformation: refineries/electricity/heat generation, transport, manufacturing & construction, other fuel combustion, and fugitive emissions from fuels. Of these, the first three sub-sectors make up over 80% of energy sector emissions (see Figure 24 above) and are the primary targets for carbon taxes and other carbon-related policies.

As existing policy commitments are insufficient to get the world on the path to the 2°C target, let alone the 1.5°C target, investors and asset owners with or considering exposure to these sub-sectors should be cognizant of the fact that the sub-sectors remain the likeliest targets for further regulatory activity. Indeed, the potential for stranded assets increases over time, as clean substitutes such as renewable energy and zero-emission vehicles gain market traction (with or without regulatory help). Other potential consequences include declines in asset values, declines in asset yields, and long-term erosion of stock value. Companies who fail to account for the regulatory risks discussed above may be exposed to shareholder lawsuits, while asset managers may be exposed to investor litigation.

Litigation Risk

That litigation risk is a potential consequence of climate change action seems fairly obvious, particularly as part of the transition to clean energy. However, the prospect (or reality) of litigation is also a potential driver of climate change action at the corporate as well as the governmental level. Regulators or investors may file claims against corporations and their directors for issues such as climate damages or regulatory compliance, while citizens or communities might sue state or national governments to enforce/improve existing climate policies or develop new ones.

In its Carbon Boomerang report for the 2 Degrees Investing Initiative, the law firm MinterEllison aggregates eight categories of claim into three classes of litigation (ME/2Dii 2017):

- Failure to mitigate – claims seeking to establish liability for emissions and/or associated climate change impacts;
- Failure to adapt (including failure to report or disclose) – claims deriving from commercial failures to risks associated with climate change into account, and/or to accurately disclose related exposures; and
- Energy transition-specific regulatory compliance – claims arising from laws and standards introduced to implement energy transition policies, and related consumer protection law claims.

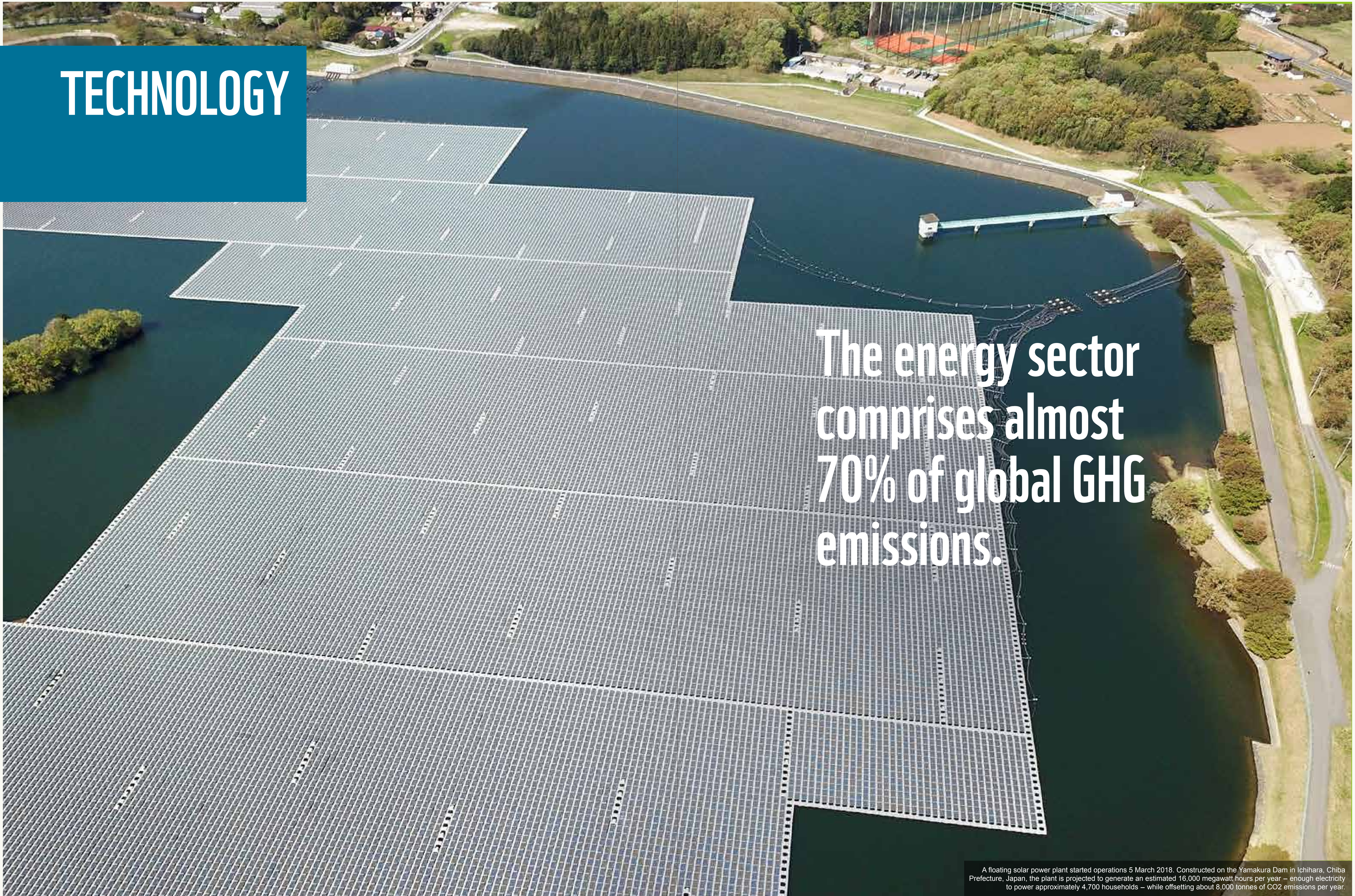
The financial consequences of these kinds of claims are wide-ranging, including legal costs, fines or penalties, creditworthiness impacts, restitution costs, valuation impacts, distracted management, and reputational damage.

Reputational Risk

Beyond the fiduciary aspects of accounting for climate risk, investment managers and asset owners face an increasing exposure to climate-related reputational risk. This may initially be closely linked with related litigation, but as climate change impacts become more evident, and more attached to human stories of lost livelihoods or negative health outcomes, the reputational risks to the parties involved in generating these impacts increases.

The seedling nursery in Huong Thuy Town, Vietnam. Here seedlings are produced from plant tissue culture through micropropagation. Hundreds of smallholders are joining forces to produce sustainable Acacia used in outdoor furniture around the world – with most of the country's 2.7 million hectares of plantation forest owned by individual households, expanding the approach and making the business case for sustainability may be the best chance for saving forests in the Greater Mekong.

TECHNOLOGY



The energy sector comprises almost 70% of global GHG emissions.

A floating solar power plant started operations 5 March 2018. Constructed on the Yamakura Dam in Ichihara, Chiba Prefecture, Japan, the plant is projected to generate an estimated 16,000 megawatt hours per year – enough electricity to power approximately 4,700 households – while offsetting about 8,000 tonnes of CO_2 emissions per year.

The investment required to address climate change is enormous, regardless of approach taken – and multiple approaches are required. An updated calculation from Galiana & Green (2009) provides an illustration of the magnitude of the endeavour: In order to reduce global CO_2 emissions by 50% from 2016 levels by 2050, the average annual rate of decarbonisation of global output – i.e., the rate of decline in carbon intensity of GDP – must rise from the 45-year average of 1.46% to at least 4.0%, assuming a 2% annual growth rate for global GDP (Galiana 2009). Mitigating and adapting to climate change will require investments in human capabilities, communities, systems, and, most importantly, technology. This chapter provides a broad overview of some of the key technologies and investment themes related to this effort, with a greater focus on those technologies that are relatively more investable from the perspective of mainstream institutional investors.

MITIGATION

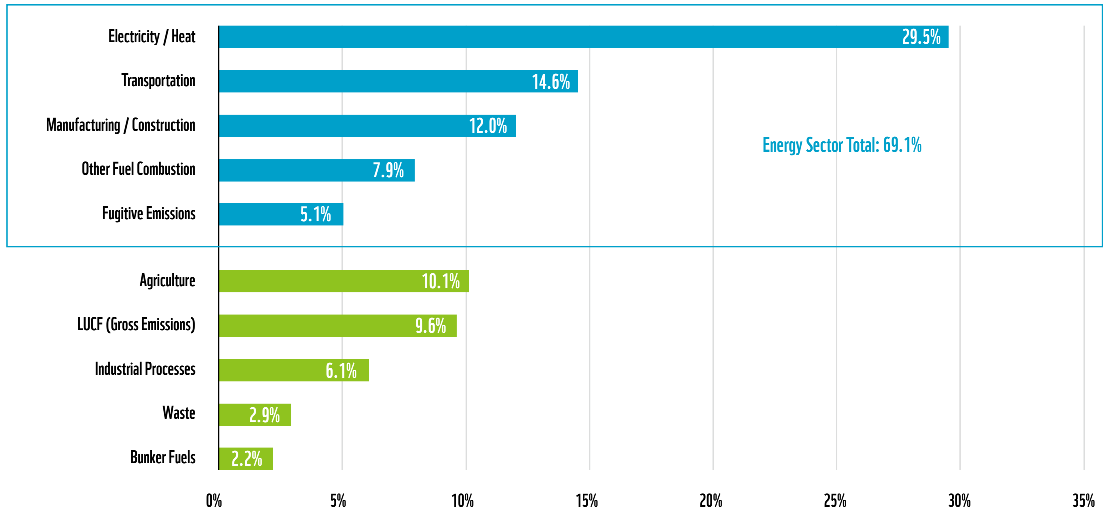
In the context of climate change, mitigation is defined as action taken either to reduce GHG emissions, or to increase the rate at which GHGs are removed from the atmosphere. The outline for mitigating climate change is fairly clear:

1. Reduce energy and resource demand while aggressively decarbonising the energy supply;
2. Minimise emissions via clean electrification of non-power work processes to the extent possible;
3. Sequester atmospheric carbon at a rate higher than it is being emitted;
4. All at a price that the world is willing to pay.

While these steps are simply stated, each of them contains significant challenges.

Greenhouse gas emissions can be categorized into six primary sectors: energy (from fuel combustion), agriculture, land use change & forestry, industrial processes, waste, and international bunker fuels for shipping and aviation. The energy sector dwarfs the rest, comprising almost 70% of global emissions, and is thus the primary focus of mitigation efforts.

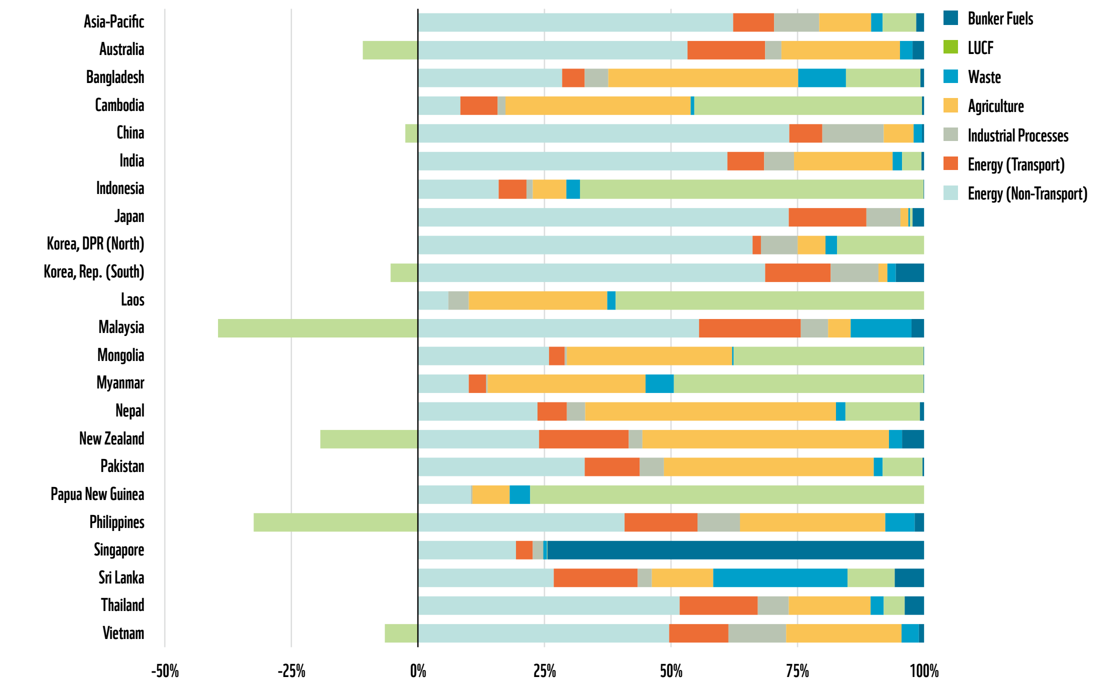
Figure 28: Global GHG Emissions Share by Sector and Energy Sub-Sector, 2014



Source: CAIT (2015), FAO (2014), IEA, (2014)

In Asia-Pacific, the energy sector's emissions share of 70% is similar to the global level, and is driven mainly by the largest emitters, China and India. Beyond these countries, however, there is significant variation in emission profiles (see Figure 29). In particular, emissions from land use change and forestry (LUCF) comprise a significant share (over 25%) of emissions in a quarter of the countries in the region, including Indonesia, a top-10 global emitter. Agricultural emissions are significant in about half of the region's countries, while Singapore's emissions are dominated by bunker fuel emissions from the shipping industry.

Figure 29: Asia-Pacific GHG Emissions Share by Sector, 2014



Note 1: For countries where Land Use Change & Forestry (LUCF) is a net CO_2 sink, sector percentages are based on emissions totals excluding LUCF.
Note 2: Energy (non-transport) includes electricity/heat generation, manufacturing & construction, other fuel combustion, and fugitive emissions from fuels. Due to data limitations, transport emissions are not separated from energy for Laos and Papua New Guinea.
Source: CAIT (2015), IEA (2014)

This variety of emissions profiles implies that investments in mitigation efforts cannot follow a one-size-fits-all strategy for the region, but rather must be appropriate for a country's local context. That said, a focus on the energy sector, and in particular on electricity generation, is appropriate in most cases. This is because the low share of energy sector emissions in some regional countries is due in part to limited electrification; the share is expected to increase as these countries develop their power infrastructure.

Table 7 below presents an abbreviated selection of the kinds of mitigation technologies public and private investors are pursuing today. In many cases, these investments involve public sector leadership and/or financing, with corporate or project finance covering much of the rest. This is especially the case for non-energy sector mitigation technologies. In the energy sector, secondary market investors have greater scope for equity participation in these technologies, either through a listed pure-play or embedded in a larger corporate. As such, the balance of this section on mitigation technologies will focus on the energy sector.

Table 7: Selected Roster of Potential Mitigation Technology Investments by Sector

Emissions Sector / Sub-Sector	Technology Category	Description	Mitigation Potential / Effect	Potential Investment Modes
Energy: Electricity / Heat Generation	Renewable Power	Hydro / wind / solar / geothermal / biomass energy	No / low carbon emissions	Equity / debt; project finance; PPP
	Carbon Capture & Storage	Remove carbon post-combustion from point sources such as fossil fuel power plants	Significant emissions reduction potential	Co-invest alongside public finance; project finance

Emissions Sector / Sub-Sector	Technology Category	Description	Mitigation Potential / Effect	Potential Investment Modes
	Nuclear Power	Nuclear energy	No carbon emissions	Equity / debt
	Fossil Fuel Power	Fuel switching	Emissions reduction	Equity / debt; project finance
	Energy Storage	Store surplus variable renewable energy	Facilitates penetration of renewable power	Equity / debt; project finance
	Smart Grid	Suite of technologies enabling multiway flows of power and information, allowing for distributed electricity generation	Facilitates penetration of renewable power	Equity / debt; project finance
	Cogeneration	Heat from power generation is captured and used	Significantly higher efficiency	Equity / debt; project finance
	District Energy	Centralised heating and / or cooling provided by pipeline network	Reduced incremental energy demand; deferred investment in new electricity / heat generation	Co-invest alongside public finance; equity / debt; PPP
	Energy Efficiency – Buildings	Improved building envelopes; HVAC equipment; appliances; space heating / cooling; retrofit or new build	Reduced incremental energy demand; deferred investment in new electricity / heat generation	Co-invest alongside public finance; project finance; debt / equity; green banks / bonds
Energy: Transportation	Urban Rail	Mass transit in and near cities via rail	Lowest emissions intensity mode of passenger transit	Co-invest alongside public finance; project finance; PPP; debt / equity
	Electric Vehicles	Battery electric vehicles / plug-in hybrid vehicles	Eliminate or reduce emissions from fossil fuel combustion	Equity / debt; venture capital
	Electrical Charging	Publicly available charge points for electric vehicles	Facilitates penetration of electric vehicles	Venture capital / private equity; equity / debt; project finance; PPP
	Fuel Cell Vehicles	Hydrogen-powered vehicles	No carbon emissions	Venture capital; equity / debt
	Energy Efficiency – Transport	Fuel economy	Reduced fuel demand	Embedded equity
Energy: Manufacturing / Construction	Energy Efficiency – Industry	Wide variety of efficiency measures possible – industry-specific	Reduced incremental energy demand; deferred investment in new electricity / heat generation	Screen for energy management system use via indicators such as ISO 50001 certification; debt / equity issuance; asset sales; green banks / bonds

Emissions Sector / Sub-Sector	Technology Category	Description	Mitigation Potential / Effect	Potential Investment Modes
Agriculture	Fertiliser	Precision fertiliser deployment; low-nitrogen fertiliser	N_2O mitigation	Co-invest alongside public finance
	Livestock	Change livestock feeding practices, manure management strategies	CH_4 mitigation	Co-invest alongside public finance
Land Use Change & Forestry	Landscape Restoration	Multiple innovative tree planting business models with varied approaches	CO_2 mitigation / sequestration	Co-invest alongside public finance; venture capital/ private equity; debt/ green bonds
Industrial Processes	Reduce Energy Intensity	Wide variety of efficiency measures possible – industry-specific	Reduced incremental energy demand; deferred investment in new electricity/ heat generation	Equity / debt; project finance
	Increase Recycling / Scrap Usage	Generally lower energy required to process scrap/recycled material	Reduced incremental energy demand; deferred investment in new electricity/ heat generation	Equity / debt; project finance
Waste	Waste to Energy	Use captured landfill gas for heat / power	CH_4 mitigation, reduced fuel usage	Co-invest alongside public finance; project finance; PPP; debt/equity
Bunker Fuels	Fuel Efficiency / Fuel Switching	Multiple potential approaches, including engines, ship design, and wind power	Reduced fuel usage / emissions reduction	Equity / debt in equipment/engine manufacturers, shipbuilders

Source: IEA (2017a), Faruqi, et al. (2018), Helfre & Boot (2013), WWF

A view from Hijiri Bridge, in Ochanomizu, Tokyo. Three lines are crossing each other: Marunouchi Subway Line for Ikebukuro (red), Chuo Line rapid service for Tokyo (orange), and Chuo-Sobu Line local service (yellow). Japan has been a global pioneer and leader in rail investment and infrastructure.

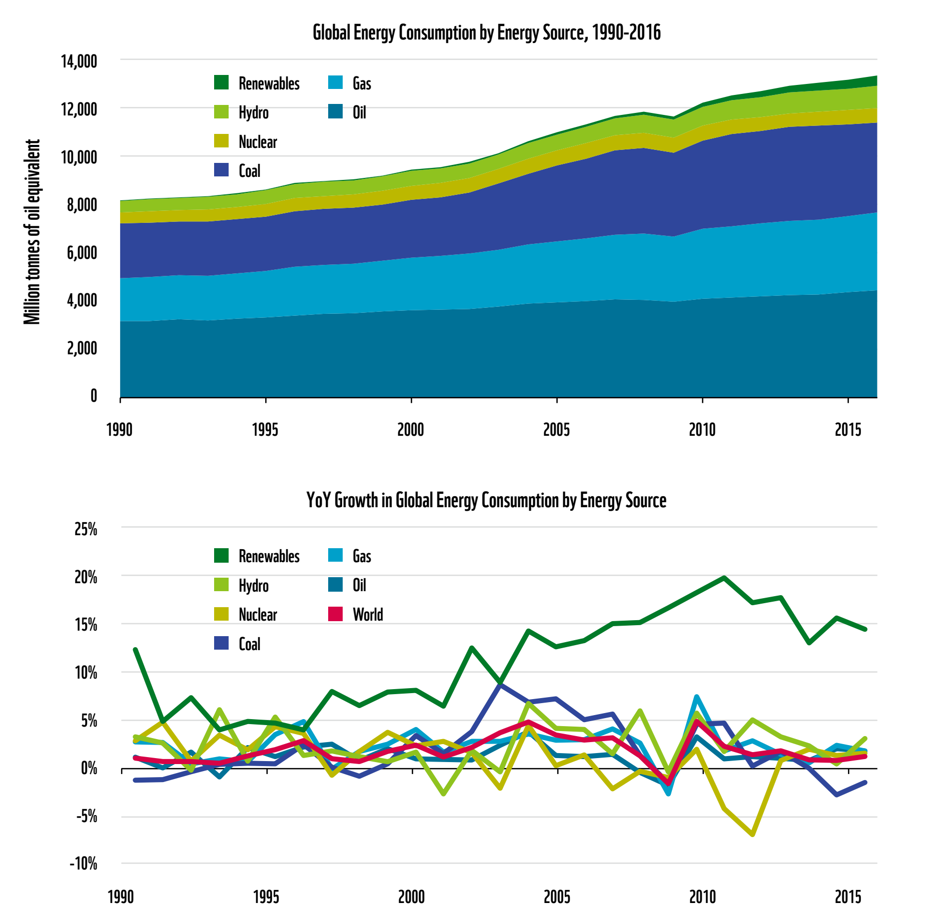
Energy

Energy sector emissions stem from fossil fuel combustion in the five sub-sectors of electricity/heat generation, transportation, manufacturing/construction, other fuel combustion and fugitive emissions from fuel combustion. Within the energy sector, the electricity/heat generation sub-sector is the largest component, at almost 30% of global emissions, and is almost as large as the remaining non-energy sectors combined. This prominence makes it the natural primary target for emissions reduction efforts.

Electricity Generation

The technologies involved in mitigating emissions from electricity generation range from speculative to fully mature. These include renewables, combustible fuels (fossil or otherwise) with carbon capture & storage or alone, and nuclear power.

Figure 30: Trends in Global Energy Consumption by Energy Source



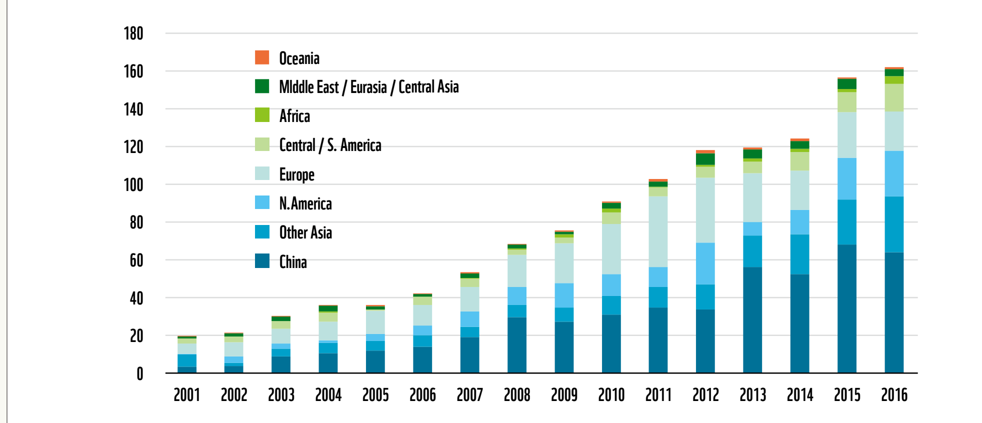
Source: BP (2017)

Renewable Power

Renewable power is one of only two energy sources that does not release greenhouse gases as part of the electricity generation process (with some potential exceptions involving biomass energy). As such, its rapid expansion within the global power supply is one of the primary vectors for bringing down emissions from electricity generation – the more renewable energy can substitute for fossil fuel energy, the greater the volume of emissions avoided. By definition, the use of renewable energy does not involve the consumption of exhaustible resources such as fossil fuels or uranium. Renewable resources include hydropower, wind energy, solar energy, geothermal heat, ocean energy (tides, waves, and thermal energy), and biomass.

Renewables comprised an estimated 24% of electricity generation in 2016, of which over 7% was non-hydro. In growth terms, the 162 GW of renewable capacity added in 2016 renewable energy was over 60% of net growth in global power generation for the second year in a row (REN21 2017). While the share of consumption of renewable energy of 10% lags its capacity share, the growth story is similar – in 2016, hydro and other renewable energy consumption grew 6%, compared to total global energy consumption growth of 1%. This growth was driven by non-hydro renewables (14% growth in 2016), particularly solar photovoltaic (30% growth in 2016) (BP 2017).

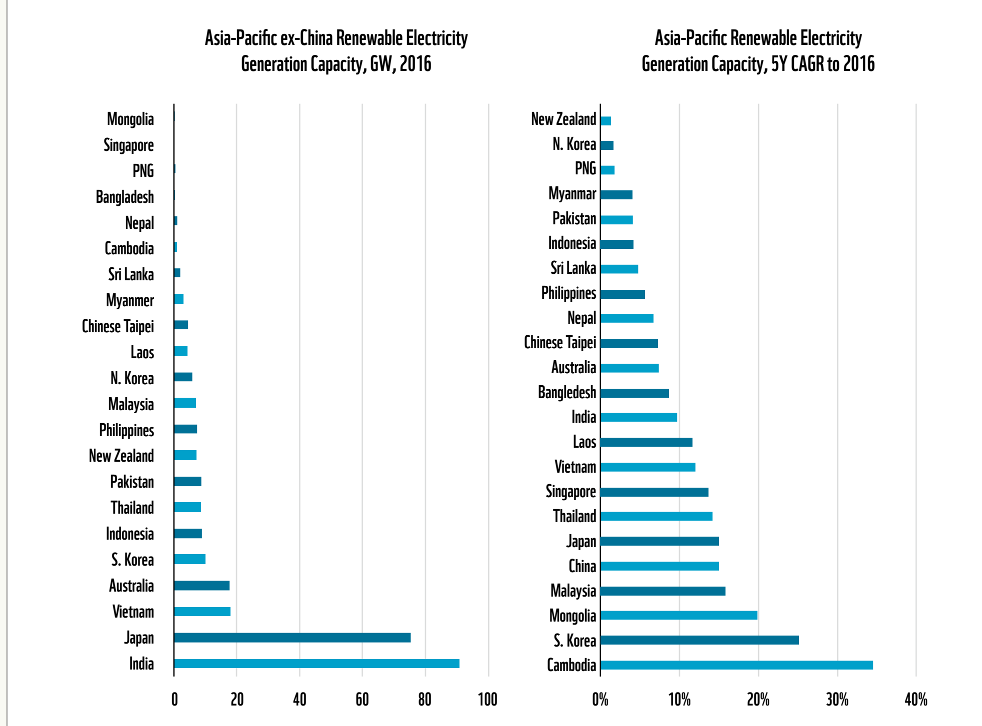
Figure 31: Annual Net Additions to Renewable Generation Capacity (GW) by Geography, 2001-2016



Source: IRENA (2017a)

China has dominated net additions to renewable electricity generation capacity, adding more capacity than any other region in almost every year since at least 2003. Globally, 1,256 GW of renewable capacity (large-scale hydropower as well as modern renewables) has been added since 2001, of which China added 470 GW.

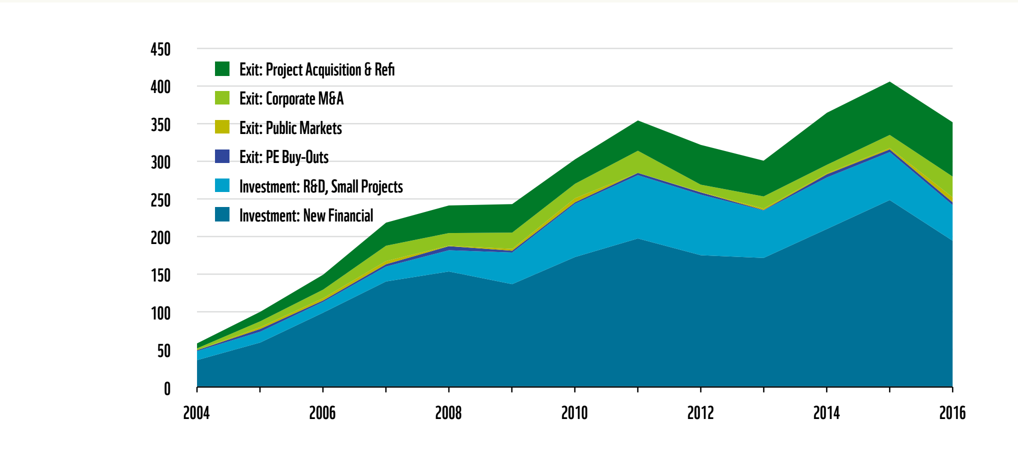
Figure 32: Asia-Pacific Renewable Electricity Generation Capacity and Growth



Source: IRENA (2017a)

China's 546 GW of renewable electricity generation capacity in 2016 was 66% of total Asia-Pacific capacity in that year. India and Japan have the next-highest shares, at 11% and 9.1% respectively. The rest of the countries in the region have significantly lower capacity, with only Vietnam and Australia exceeding the 2% share threshold. Capacity growth has been strong, with a 5-year CAGR of 13% for the region, and over two-thirds of countries achieving a CAGR of at least 5% over the period.

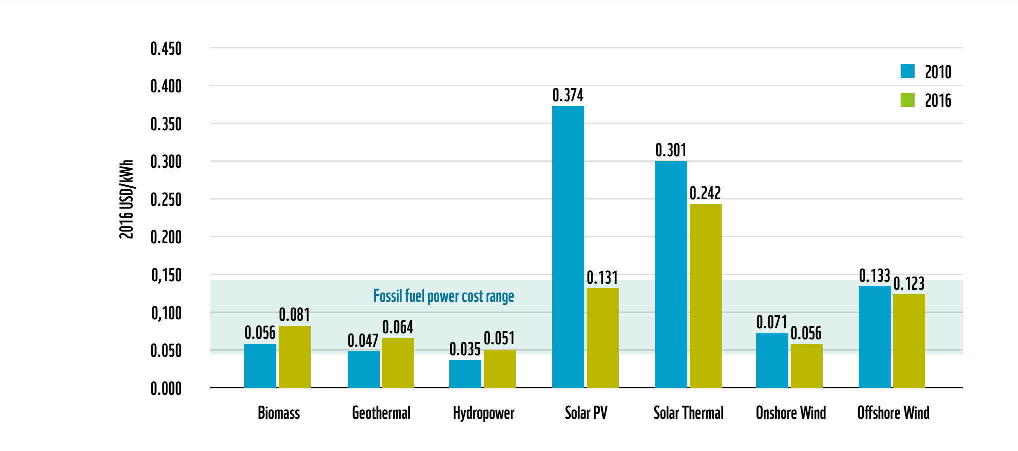
Figure 33: Trends in Global Renewable Energy Investment, 2004-2016, USD bn



Source: IRENA (2017a)

Investment flows into renewable energy have been strong for over a decade, with total new investment in 2016 of USD242bn representing a compound annual growth rate of 15% since 2004. Exit prospects for investors are also well-established, with aggregate M&A transactions reaching USD110bn in 2016, up 10 times from 2004. Most exits (by dollar value) are via project acquisition/refinancing or through corporate M&A, although public markets and private equity buyouts also play a role. (Frankfurt School-UNEP Centre/BNEF 2017)

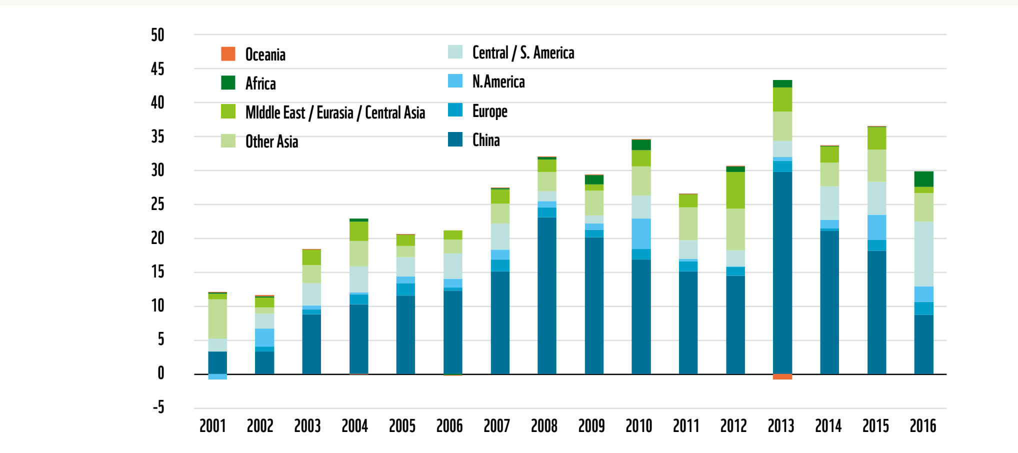
Figure 34: Trends in Levelized Cost of Energy, Primary Renewable Technologies



Source: IRENA (2017a)

The cost of renewable energy, on average, is declining, driven by a sharp fall in solar PV costs as the technology continues to gain scale. With the exception of solar thermal power, the average levelized cost of energy (LCOE) of all major renewable technologies is now within the cost range of fossil fuels. Indeed, the LCOE of hydro, geothermal and onshore wind is at the bottom end of the fossil fuel cost range (IRENA 2017a).

Figure 35: Annual Net Additions to Hydroelectric Generation Capacity (GW) by Geography, 2001-2016



Note: Excludes pumped storage.
Source: IRENA (2017a)

Hydropower

Hydropower is the most mature and most prevalent form of renewable energy worldwide. In 2016, it contributed approximately 16% of global electricity generation, a share that has remained fairly stable since at least 2000. This represented 69% of total renewable electricity generation, down from over 90% in 2000 (IRENA 2017a) (BP 2017). Hydropower via pumped storage is also the most common form of energy storage at the grid level. Most discussions of renewable energy consider hydropower separately from other renewable energy technologies, as its large share of the total can obscure trends in the other technologies.

Hydropower plants comes in three main classes:

- Large-scale hydropower (over 10 MW of capacity)
- Small-scale hydropower (1 to 10 MW)
- Mini-hydro (under 1 MW)

Global large-scale hydropower installed capacity of 936 GW in 2016 was 83% of total hydro capacity excluding pumped storage and has been growing at an average of 3% annually since 2000 (IRENA 2017a). It is traditionally installed as a low-cost source of base load power, although it has the flexibility to respond quickly to sudden peaks in demand. The maturity of the technology, long life of the asset, stability of revenue flow, and cleanliness of the power generated combine to make large-scale hydro projects attractive to both development finance and climate finance providers. Undeveloped technical potential for hydropower (leaving aside political, economic, or sustainability issues) is estimated at 10,000 TWh/year globally, with over 70% of that in Asia (WEC 2016).

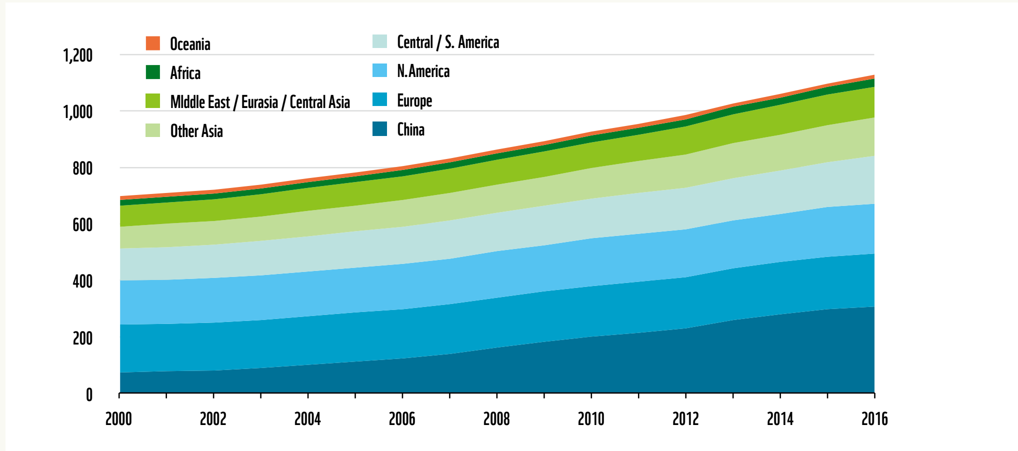
However, large-scale hydropower is somewhat controversial as a renewable technology in the sustainability community, as it almost invariably involves the creation of a reservoir. This generally has significant effects on the natural environment upstream and downstream, as well as on human communities. In addition, such reservoirs may be significant sources of methane emissions, released as the flooded vegetation rots in anaerobic conditions. The scale of these emissions is not yet well understood and varies significantly with local conditions (Scherer and Pfister 2016).

Global small-scale hydropower installed capacity of 117 GW in 2016 was 10% of total hydro capacity excluding pumped storage and has been growing at an average of almost 6% annually since 2000. Small-scale hydropower is less likely to involve a storage reservoir and may instead use run-of-river technology, which typically does not involve the storage of large amounts of water.

This implies a significantly higher variability in power output on a daily, monthly, or seasonal basis. Small-scale hydropower plants are faster to construct and generally have a smaller environmental footprint.

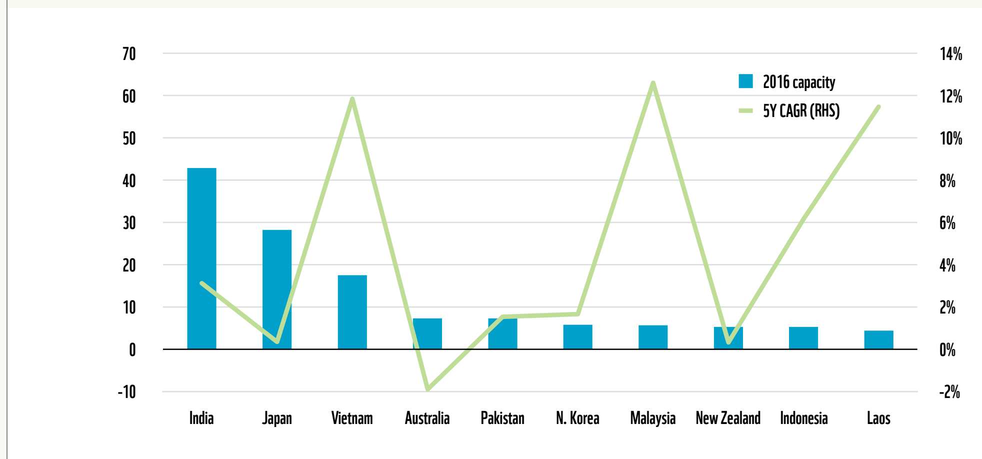
China has dominated net additions to hydroelectricity generation capacity, adding more capacity than any other region in almost every year since 2002. Globally, the cumulative hydroelectricity capacity added since 2001 is 430 GW, of which China added 233 GW (IRENA 2017a).

Figure 36: Hydroelectric Generation Capacity (GW) by Geography, 2001-2016



Note: Excludes pumped storage.
Source: IRENA (2017a)

Figure 37: 2016 Asia-Pacific ex-China Top 10 Hydropower Generation Capacity and 5Y CAGR, GW & Percent



Source: IRENA (2017a)

China's 307 GW of hydropower generation capacity in 2016 was 67% of total Asia-Pacific capacity in that year. India and Japan have the next-highest shares, at 9% and 6% respectively. The rest of the countries in the region have significantly lower capacity, with only Vietnam's 4% exceeding the 2% share threshold. Capacity growth has been modest compared to modern renewables, with a 5-year CAGR of 3.3% for the region ex-China (6.0% including China), and just over a third of countries exceeding that growth rate over the period. Only four countries – Cambodia, Malaysia, Vietnam, and Laos – managed a 5-year CAGR in double-digits, while capacity in Australia declined by 740 MW over the period.

Wind

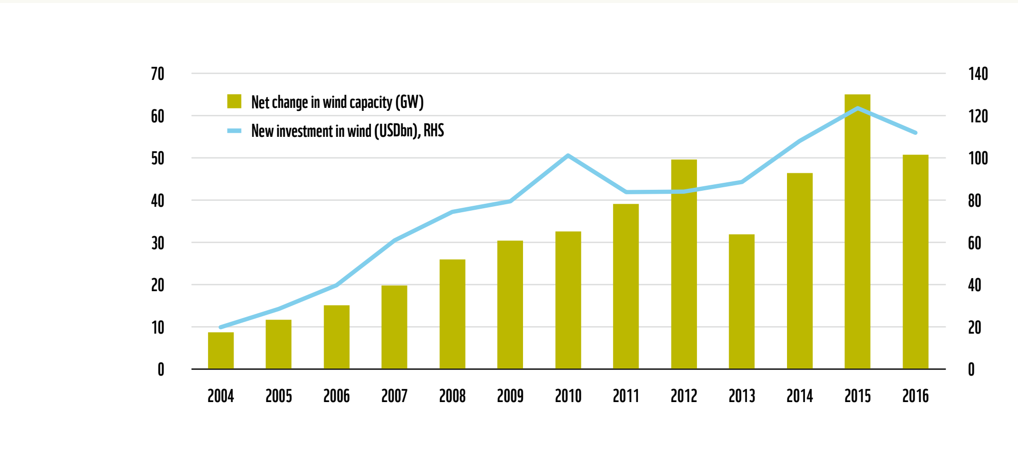
In absolute numbers, wind power capacity has increased more than any other form of renewable energy this century. In 2016, it contributed approximately 4% of global electricity generation, and its share of generation has increased every year for over 15 years. This represented almost 16% of total renewable electricity generation, up from just over 1% in 2000 (IRENA 2017a) (BP 2017).

Wind facilities are installed either onshore or offshore, with the former vastly outstripping the latter by capacity. Global onshore wind power installed capacity of 453 GW in 2016 was 97% of total wind power capacity and has been growing at an average of almost 23% since 2000 (IRENA 2017a). As seen in Figure 34 above, onshore wind is one of the cheapest sources of renewable energy with the average levelized cost of energy coming in at 5.6 US cents per kWh, which is competitive on an unsubsidised basis with fossil fuel plants in some locations. According to estimates from the US Energy Information Administration, overnight construction costs for onshore wind have fallen 25% over the past 3 years, to USD1,877/kW, which is lower than all other renewables as well as most types of coal power plants (EIA 2016a). While onshore wind components are at a fairly mature stage of development, the global weighted average LCOE of onshore wind could fall another 20-30% by 2025, according to the World Energy Council. Key risks to that estimate include the cost of capital, and the pace of incremental technological progress (WEC 2016).

The offshore wind sector is still in infancy but is growing rapidly. Global installed capacity for the sector was 14 GW in 2016 and represented 3% of total wind power capacity. Its compound annual growth rate from 2001 is almost 40% (IRENA 2017a). Offshore wind costs are more than double onshore wind, due to additional construction requirements for foundations and grid connections, but this is partially offset by the ability to install larger turbines and gain access to stronger winds. Costs are expected to come down as construction and project management techniques are refined and turbine size continues to scale up, with time estimates for a 40% reduction in costs ranging from 2023 to 2030.

Because wind is an intermittent and variable resource, the fluctuation of wind turbine output presents challenges for its integration into the broader electricity grid. Specialised

Figure 38: Trends in Global Wind Energy Investment and Capacity, 2004-2016

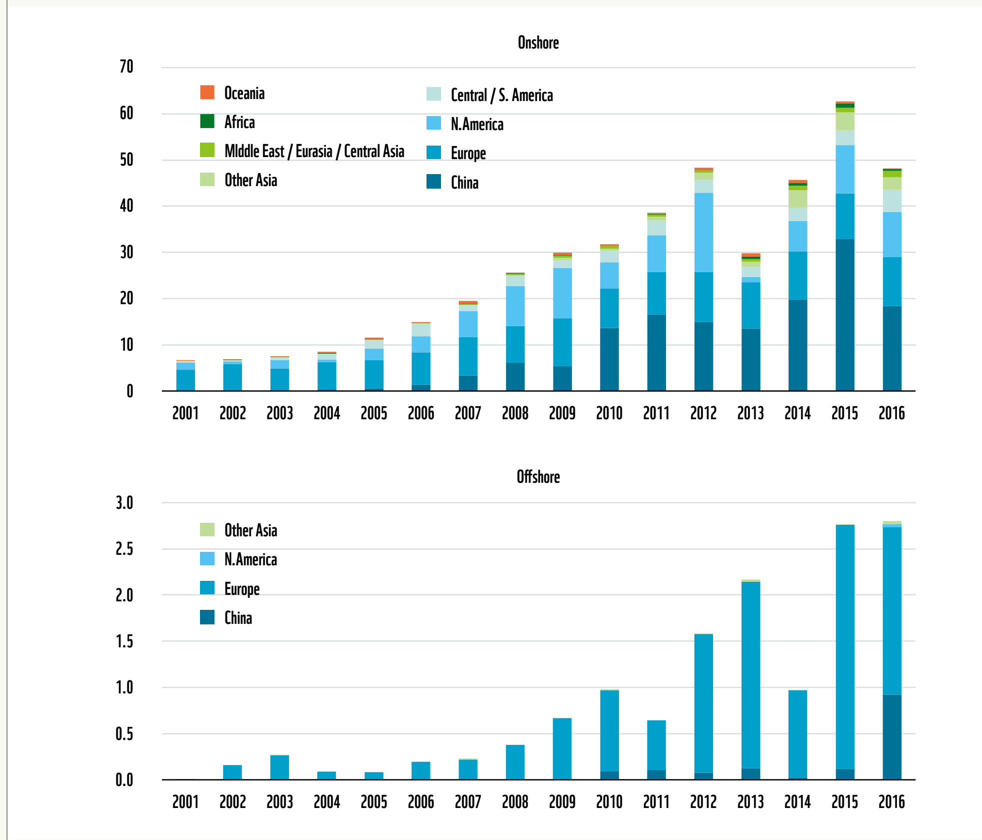


Source: IRENA (2017a), Frankfurt School-UNEP Centre/BNEF (2017)

wind forecasting software has been developed to this end, and the aggregation of multiple wind farms in a given region can help reduce average intermittency across the portfolio (WEC 2016). Incorporating energy storage at the grid or site level is another option for addressing intermittency, although the latter case may present prohibitive cost challenges for the present.

Thanks to a lengthy track record (the first modern wind farms were established in the early 1980s), investors are familiar with wind projects, and both onshore and offshore wind power projects are generally now seen as low-risk investments. Sources of investment include utilities, project finance, development agencies, institutional investors, public equity, debt, and bank lending (WEC 2016). Investment flows into wind energy have been broadly rising for over a decade, with total new investment in 2016 of USD113bn representing a compound annual growth rate of 16% since 2004 (Frankfurt School-UNEP Centre/BNEF 2017). This has supported a net cumulative 429 GW of wind capacity over the period.

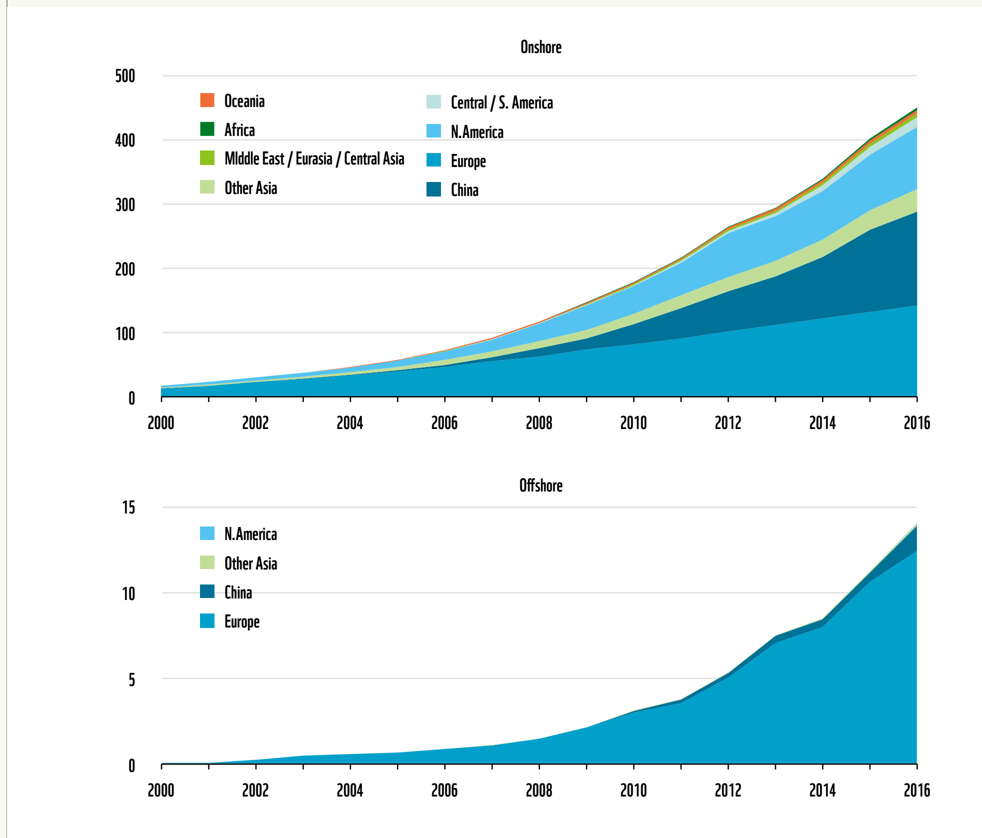
Figure 39: Annual Net Additions to Wind Generation Capacity (GW) by Geography, 2001-2016



Source: IRENA (2017a)

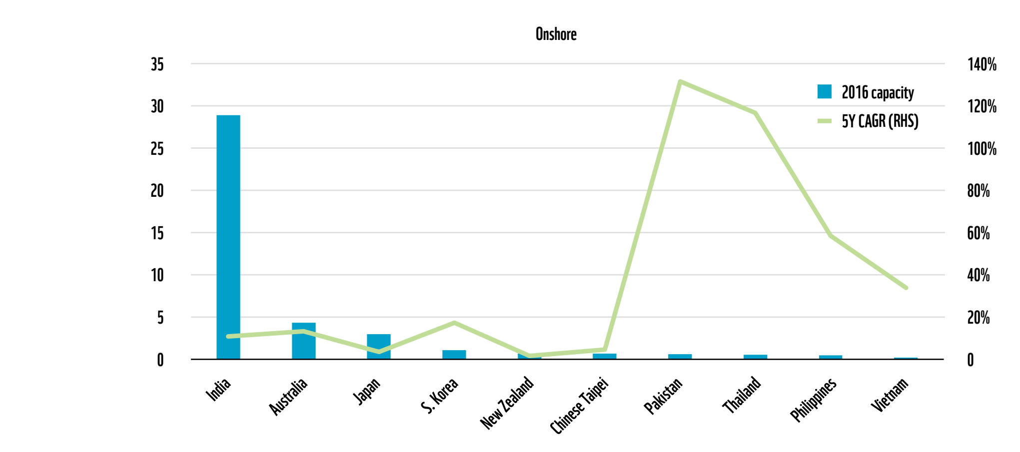
Net additions to onshore wind capacity have come mainly from Europe, North America and China since 2000. Europe is also the dominant source of capacity in offshore wind. Globally, the cumulative onshore and offshore wind capacity added since 2001 is 436 GW and 14 GW, respectively. Across both categories over the period, China added a net 149 GW, Europe added 143 GW, and North America added 94 GW (IRENA 2017a).

Figure 40: Wind Capacity (GW) by Geography, 2000-2016



Source: IRENA (2017a)

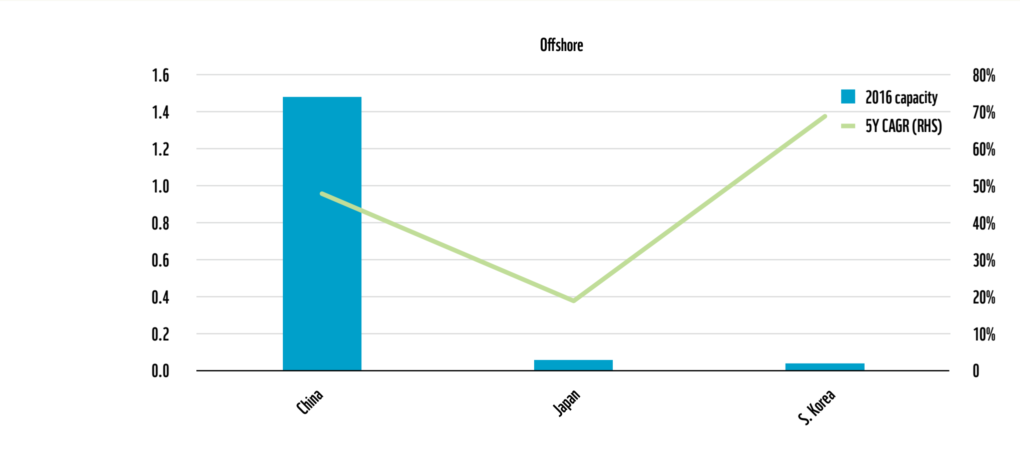
Figure 41: 2016 Asia-Pacific ex-China Top 10 Onshore Wind Generation Capacity and 5Y CAGR, GW & Percent



Source: IRENA (2017a)

China's 148 GW of onshore wind generation capacity in 2016 was 78% of total Asia-Pacific capacity in that year. India ranks second in the region, with 15% (29 GW), followed by Australia and Japan with about 2% share each. None of the remaining 17 countries in the region with onshore wind capacity exceed the 1% share threshold. Capacity growth has been solid, with a 5-year CAGR of 12.6% for the region ex-China (21.1% including China's 25.2%), and just under half of countries exceeding that growth rate over the period. Notably, Pakistan and Thailand have registered 5-year CAGRs of well over 100%, albeit from a low base.

Figure 42: 2016 Asia-Pacific Offshore Wind Generation Capacity and 5Y CAGR, GW & Percent



Source: IRENA (2017a)

In contrast to the onshore variety, offshore wind generating capacity in Asia-Pacific is much more limited, with installations limited to China, Japan, and South Korea. For these three countries, offshore capacity is 1-4% the level of their respective onshore capacity, although growth rates are significantly higher.

China is investing heavily in renewable energy like this wind farm built on the coastal flats in Jiangsu, China, as part of its ongoing efforts to address air pollution.

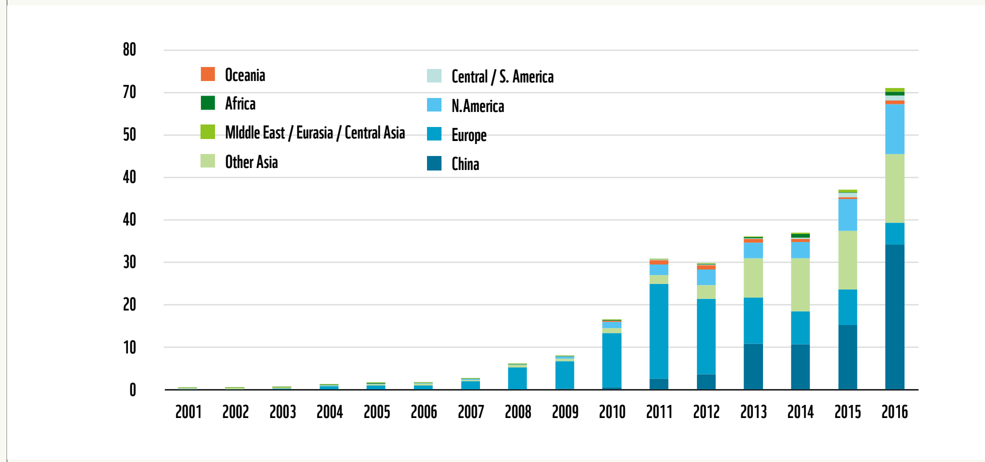
Solar

Solar power has become the fastest-growing form of electricity generation, with its initial acceleration starting from 2008. In 2016, solar contributed approximately 1.4% of global electricity generation, after reaching 1% for the first time the previous year. This represented almost 6% of total renewable electricity generation, up from just 0.3% in 2008 (IRENA 2017a) (BP 2017).

Solar electricity generation comes in two basic forms: solar photovoltaic (PV) and solar thermal, also known as concentrated solar power (CSP). With solar PV, a semiconductor converts incident sunlight directly into electricity, whereas in CSP solar radiation is focused onto a fluid-filled container to heat it. The heat collected is then used to power a generator. CSP technologies may also be used in heating and cooling applications.

Thanks to rapidly falling costs, solar PV has entered a phase of exponential growth. Indeed, the 71 GW of solar PV capacity installed in 2016 is greater than the entire global installed capacity base in 2011. Global solar PV installed capacity of 291 GW in 2016 was over 98% of total solar power capacity and has enjoyed a CAGR of 47% over the past 10 years (IRENA 2017a). Lazard estimates that in a number of usage scenarios, the unsubsidised levelized cost of energy for utility-scale solar PV without storage is lower than almost all conventional electricity generation sources; even with battery storage to ease intermittency issues, it is competitive with fossil fuels (Lazard 2017a). Similarly, the USEIA estimates that overnight construction costs for solar PV have fallen 67% since 2013 to US$2,671/kW, lower than most types of coal power plants and a little over twice the cost of natural gas plants (EIA 2016a). The rapid expansion and fall in cost of solar PV is expected to continue but may lead to a reduction in government support for higher solar PV penetration, such as reduction in levels of feed-in tariffs or tax credits for installation. As the market matures, grid integration and the cost of capital are expected to be key risks to further growth (WEC 2016). That said, Bloomberg New Energy Finance expects the levelized cost of energy for solar PV to drop another 66% by 2040 (BNEF 2017).

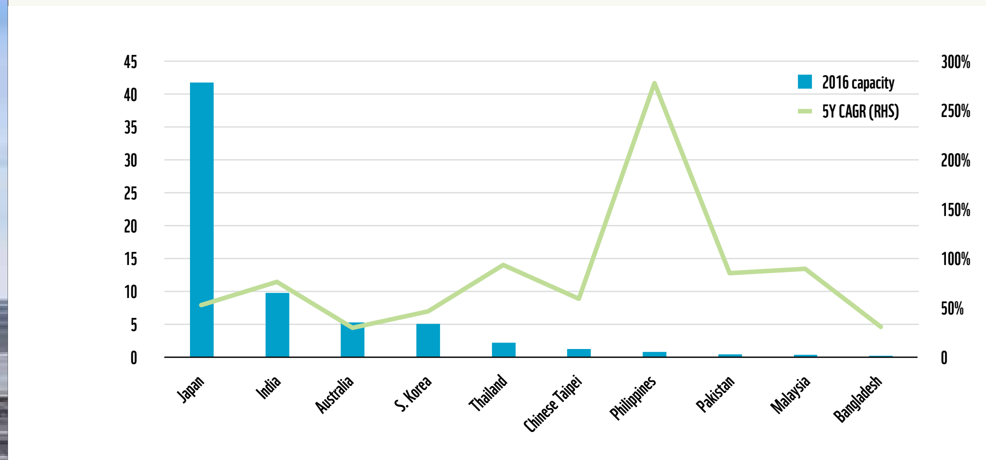
Figure 43: Annual Net Additions to Solar PV Capacity (GW) by Geography, 2001-2016



Source: IRENA (2017a)

Through 2012, Europe was the primary driver of solar PV growth. Since then, China has dominated net additions to solar PV capacity, and in 2016 added almost as much as the rest of the world combined. Japan has also added significant capacity, with over 35 GW installed since the Fukushima Daiichi nuclear disaster in 2011 and subsequent shuttering of much of its nuclear capacity. Globally, the cumulative solar PV capacity added since 2001 is 290 GW, of which Europe added 102 GW and China added 78 GW.

Figure 45: 2016 Asia-Pacific ex-China Top 10 Solar PV Generation Capacity and 5Y CAGR, GW & Percent

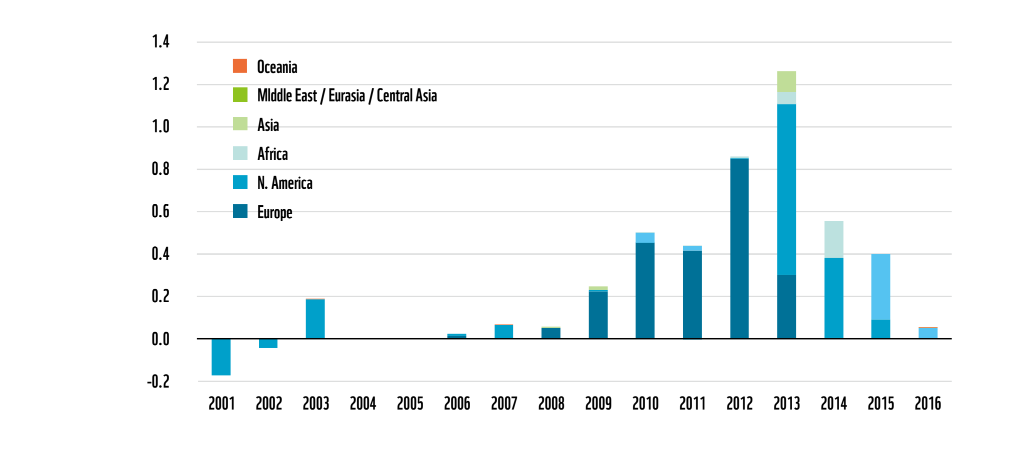


Source: IRENA (2017a)

China's 78 GW of solar PV generation capacity in 2016 was 54% of total Asia-Pacific capacity in that year. Japan ranks second in the region, with 29% (42 GW), followed by India, Australia, and South Korea, with shares ranging from 3.5%-6.7%. The only other country to cross the 1% share threshold is Thailand, with 1.5% of regional solar PV capacity.

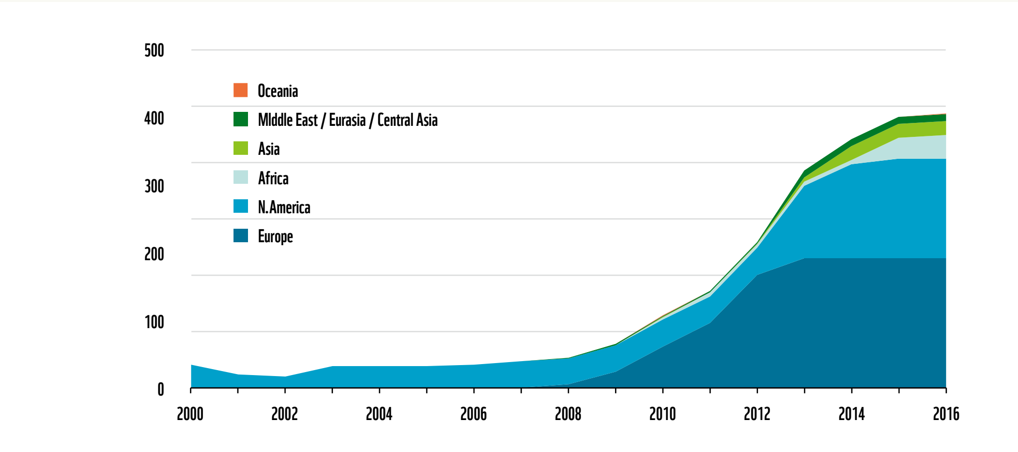
Capacity growth has been extremely robust, with a 5-year CAGR of 53.1% for the region ex-China (66.2% including China's 86.2%), and just over half of countries exceeding that growth rate over the period. The Philippines leads in recent growth terms, registering a 5-year CAGR of 277%, driven by an almost 6-fold increase in capacity from 2015 to 2016, to 765 MW.

Figure 46: Annual Net Additions to CSP Capacity (GW) by Geography, 2001-2016



Source: IRENA (2017a)

Figure 47: CSP Capacity (GW) by Geography, 2000-2016



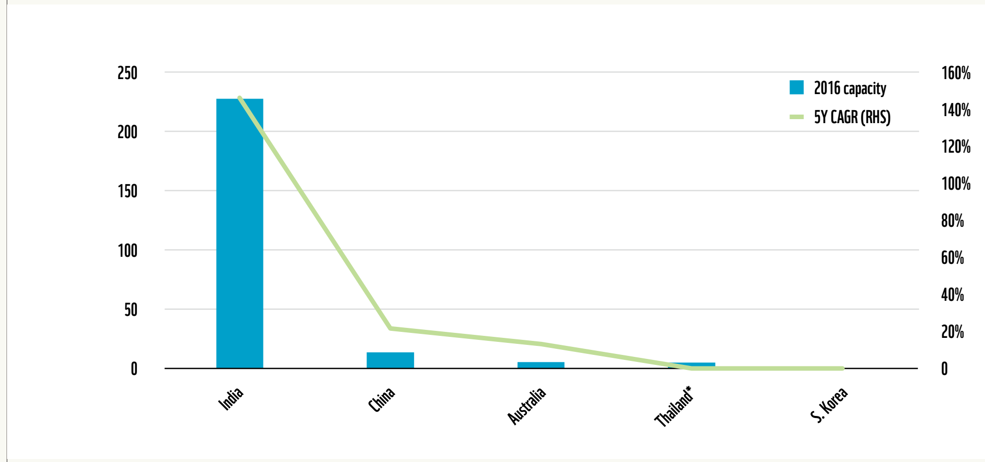
Source: IRENA (2017a)

Growth in concentrated solar power has tapered off since peaking in 2013. Global installed capacity for the sector was just under 5 GW in 2016 and represented less than 2% of total solar capacity. While its compound annual growth rate from 2001 is over 16%, since 2013 growth has averaged 8% (IRENA 2017a). This is largely because the technology is still undergoing development and has not yet reached cost competitiveness with conventionally fuelled power plants.

CSP is typically deployed with integral thermal storage, which allows for continued power generation for as many as 10 hours after sunset. This makes it more attractive as a potential base load power source than solar PV. One key issue with CSP plants is their water footprint. While some water is turned into steam to turn the generator, most is used for cooling. For wet-cooled CSP, water usage is estimated at 3,573 L/MWh, higher than the amount required for coal (~3,123 L/MWh), nuclear (3,055 L/MWh) and combined-cycle gas (570-1,100 L/MWh). Given the arid locations most suitable for CSP, ensuring a sufficient water supply may be challenging and/or costly. Dry-cooled CSP uses about 10% of the water of wet-cooled, but has higher capital costs, is less efficient, and loses effectiveness at ambient temperatures over 38°C (WEC 2016).

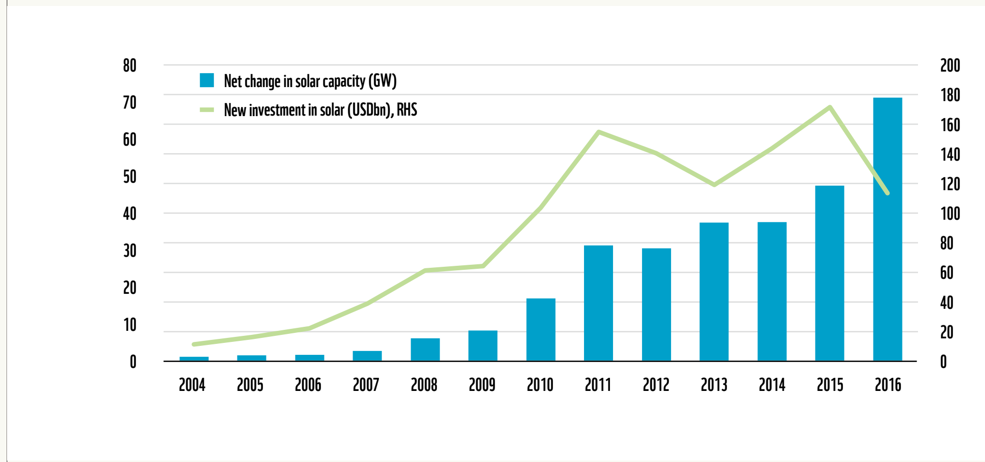
Spain and the United States have been the primary markets for CSP, although Morocco and South Africa both recently started adding capacity. China has deployed a limited amount of CSP to date, and in 2016 announced that it would build up to 20 pilot CSP facilities to develop the technology's potential in China. Globally, the cumulative CSP capacity added since 2003 is 4.7 GW, of which Spain added 2.3 GW and the United States added 1.6 GW.

Figure 48: 2016 Asia-Pacific Solar CSP Generation Capacity and 5Y CAGR, MW & Percent



Note: * Thailand CAGR is 4Y.
Source: IRENA (2017a)

Figure 49: Trends in Global Solar Investment and Capacity, 2004-2016



Source: IRENA (2017a)

In contrast to solar PV, CSP generating capacity in Asia-Pacific is much more limited, with country capacity measured in MW instead of GW. India is the clear leader in the region, whose 229 MW is over 9 times the capacity of the rest of the region. Aside from India, only four other regional countries have CSP installations: China, Australia, Thailand, and South Korea. Of these countries, only India, China and Australia have expanded CSP capacity over the past 5 years, with the regional 5-year CAGR of 88% driven primarily by India. That said, growth rates can be somewhat misleading, due to the lumpy nature of capacity deployment – India's 5-year CAGR of 147% mainly reflects an increase in capacity from 54 MW to 229 MW in 2014, with no further expansion through 2016.

Investment in solar is almost entirely in PV. The past few years of rapid growth and falling costs have transformed solar PV into a mainstream investment, which has fed back into the sector with lower financing costs. As a result, despite a 34% decline in solar investment in dollar terms in 2016, capacity continued to increase. Investment flows into solar have risen tenfold since 2004, reaching USD114bn in 2016 (Frankfurt School-UNEP Centre/BNEF 2017). This has supported a net cumulative 294 GW of solar capacity over the period.

Solar panels in Gujarat Solar Park, in Gujarat, India. It has an installed capacity of 1 GW. India looks to generate 175 GW through renewable sources by 2022, of which 100 GW is to come from solar power. Furthermore, India aims to generate 40% of its total energy requirement from renewable sources by 2030.

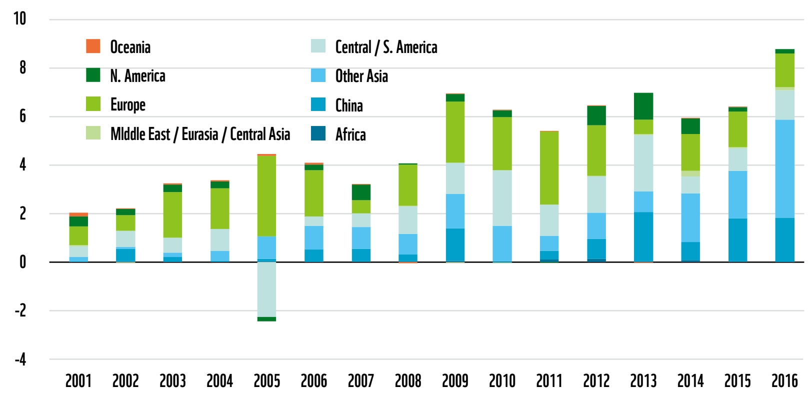
Biomass / Geothermal / Marine

Of the remaining renewable energy technologies, biomass is the most prevalent, comprising approximately 2% of electricity generated in 2016. The category is an aggregate of a variety of different types of biologically sourced fuels, in solid, liquid or gaseous form. These fuels are then burned to provide heat to power a generator. Solid biomass is the most common fuel used, powering over 80% of bioenergy generated in 2015; biogas powered most of the rest. Liquid biomass is more commonly used as fuel for transportation. Biomass is also used extensively for heating applications. Most climate models that have the world successfully achieving the 2 Degree Scenario goals assume extensive use of bioenergy with carbon capture and storage in the latter half of this century.

The basic rationale for treating biomass as a carbon-neutral renewable energy source is that the carbon released on its combustion is offset by the carbon sequestered while the biomass was grown. This is true to a point – but much depends on the type of biomass used and how it is obtained. Biomass sourced from organic residues and waste (including agriculture and forestry residues as well as industrial and municipal waste) is more likely to be carbon-neutral than biomass that is sourced from the forestry or agriculture sectors. This is because waste-derived biomass is less likely to involve emissions from direct or indirect changes in land use, as compared to forestry or agriculture biomass.

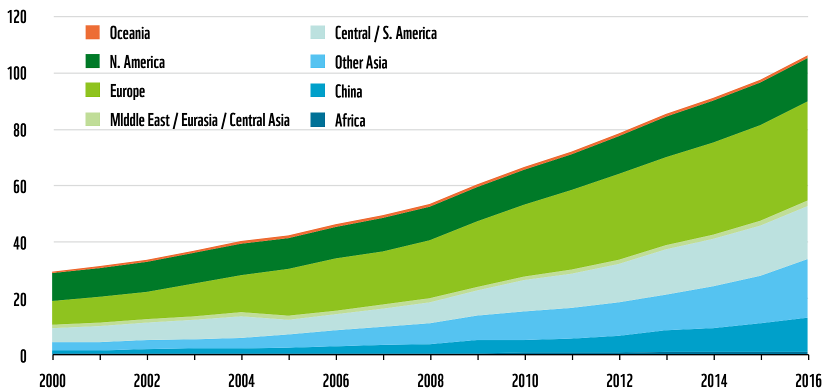
Total biomass electricity generation capacity has grown at a CAGR of over 8% since 2000, reaching 107 GW of installed capacity by 2016. Bioenergy is most developed in Europe, although capacity is increasing rapidly in China and the rest of Asia. Cumulative net capacity additions from 2001 totalled 77 GW, with Europe providing 27 GW, China 11 GW, Asia ex-China 18 GW, and Central/South America 14 GW.

Figure 50: Annual Net Additions to Bioenergy Capacity (GW) by Geography, 2001-2016



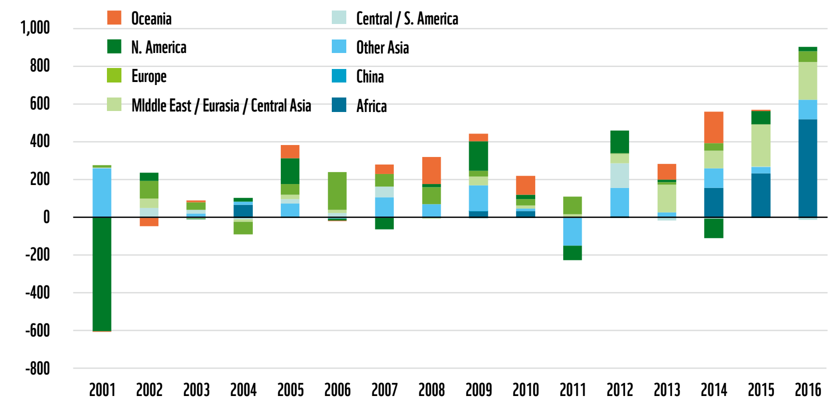
Source: IRENA (2017a)

Figure 51: Bioenergy Capacity (GW) by Geography, 2000-2016



Source: IRENA (2017a)

Figure 52: Annual Net Additions to Geothermal Electricity Generation Capacity (MW) by Geography, 2001-2016



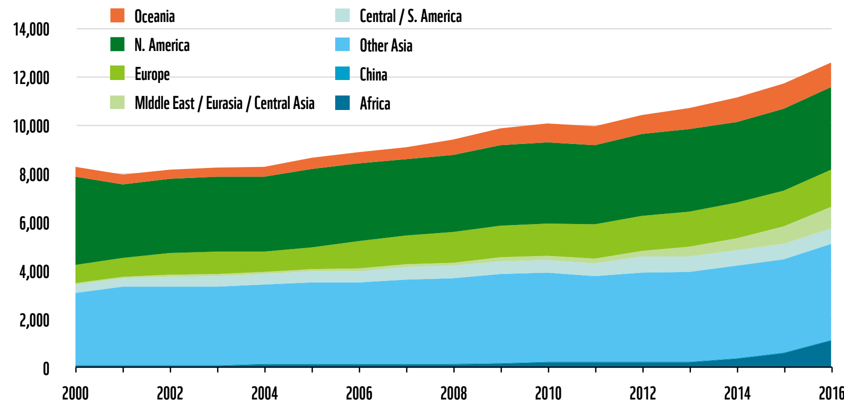
Source: IRENA (2017a)

Geothermal power makes use of heat energy generated and stored within the earth. This heat energy, usually in the form of steam or hot water, is collected from underground reservoirs and used directly for heating applications or converted to electricity via a thermal power plant.

Geothermal power is a fairly niche market globally, supplying about 0.3% of electricity generated annually since 2000. This is because it requires geothermal resources with a temperature of at least 100-150°C – typically found in areas with elevated levels of seismic and/or volcanic activity. In addition, because each suitable geothermal site is geologically distinct, generation systems must be optimized for each location, which limits the opportunities for economies of scale to drive cost reductions through standardisation of components. As a result, growth in the geothermal power sector has lagged behind wind and solar PV.

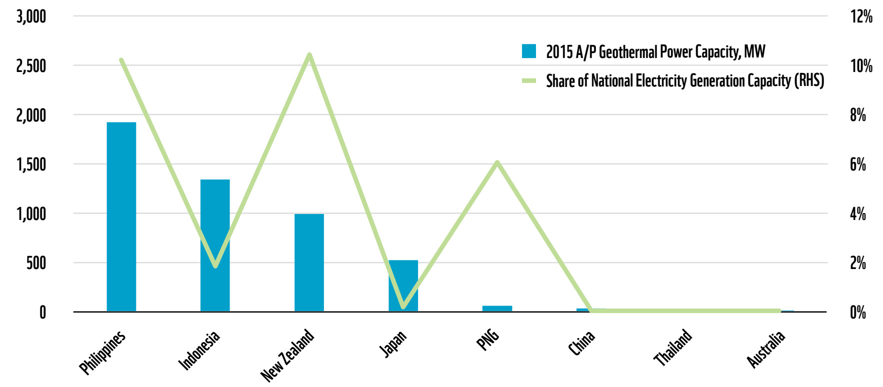
Total geothermal electricity generation capacity has grown at a CAGR of over 2.6% since 2000, reaching 12.6 GW of installed capacity by 2016. Cumulative net capacity additions from 2001 totalled 77 GW. Over 90% of geothermal power generating capacity comes from just 10 countries: Iceland, Indonesia, Italy, Japan, Kenya, Mexico, New Zealand, the Philippines, Turkey, and the United States (IRENA 2017a).

Figure 53: Geothermal Electricity Generation Capacity (MW) by Geography, 2000-2016



Source: IRENA (2017a)

Figure 54: Asia-Pacific Geothermal Power Capacity & Share of National Electricity Generation Capacity, 2015



Source: IRENA (2017a), UNdata (2018)

In Asia-Pacific, just eight countries had any amount of deployed geothermal power generation capacity as of 2016. For the Philippines and New Zealand, both top-5 countries with respect to installed capacity, geothermal power comprises over 10% of national installed electricity generation capacity. Although growth has been low compared to other renewable energy technologies, many regional countries include targets for geothermal power in their mid-term energy strategies. In particular, if Indonesia is able to deliver on its target of 12.6 GW installed capacity by 2025, regional geothermal power generation capacity would triple.

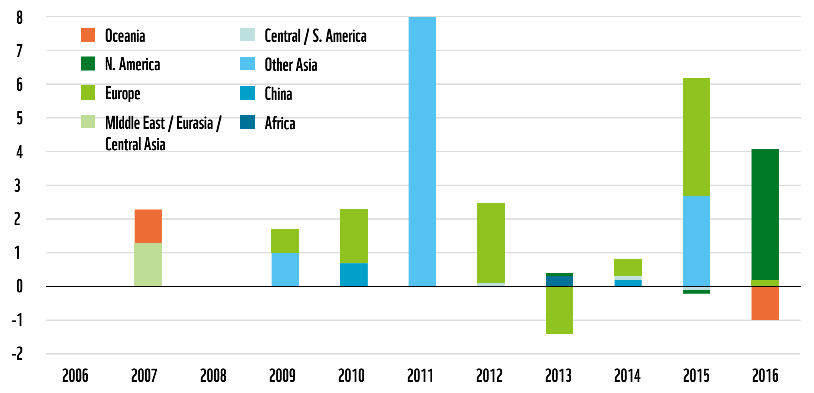
Table 8: Asia-Pacific Geothermal Power Capacity Target / Resource Potential, Where Available

Country	Geothermal Power Target / Resource Potential
China	Incremental 500 MW by 2020, up from 27 MW in 2016
India	Estimated 10 GW of resource potential
Indonesia	12.6 GW installed capacity by 2025; estimated 29 GW of resource potential
S. Korea	2,046 GWh per year by 2030
Philippines	Incremental 1.5 GW added from 2010-2030
Taiwan	10 MW installed capacity by 2020; 150 MW by 2025; 200 MW by 2030
Thailand	1 MW installed capacity by 2021
Vietnam	Estimated 340 MW of resource potential

Source: REN21 (2017), WEC (2016)

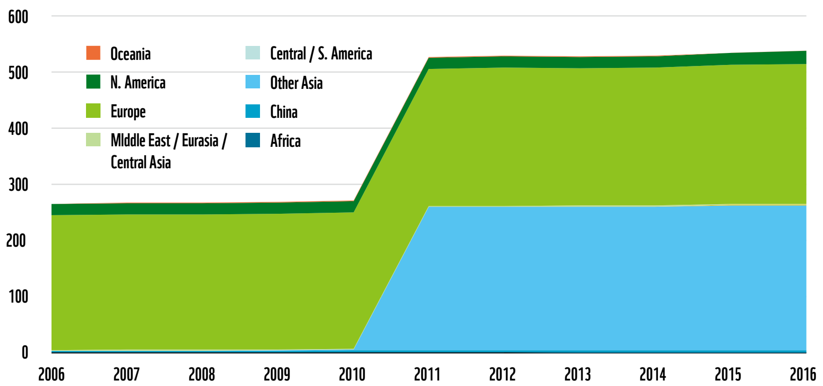
Direct geothermal use for heating and cooling applications can make use of lower-temperature geothermal resources, which are more geographically dispersed than high-temperature resources. Despite this, its global use for heating is also fairly concentrated, with 8 countries comprising 80% of global capacity, reflecting the intersection of resource availability with countries where district heating is prevalent. China is the leader in geothermal heating, with 6.1 GW_{th} of capacity (approximately 30% of global capacity) covering over 100mn m^2 of heated space. As part of its pollution control and water conservation measures, China is targeting the installation of another 400mn m^2 covered by 2020. (REN21 2017)

Figure 55: Annual Net Additions to Marine Energy Capacity (MW) by Geography, 2006-2016



Source: IRENA (2017a)

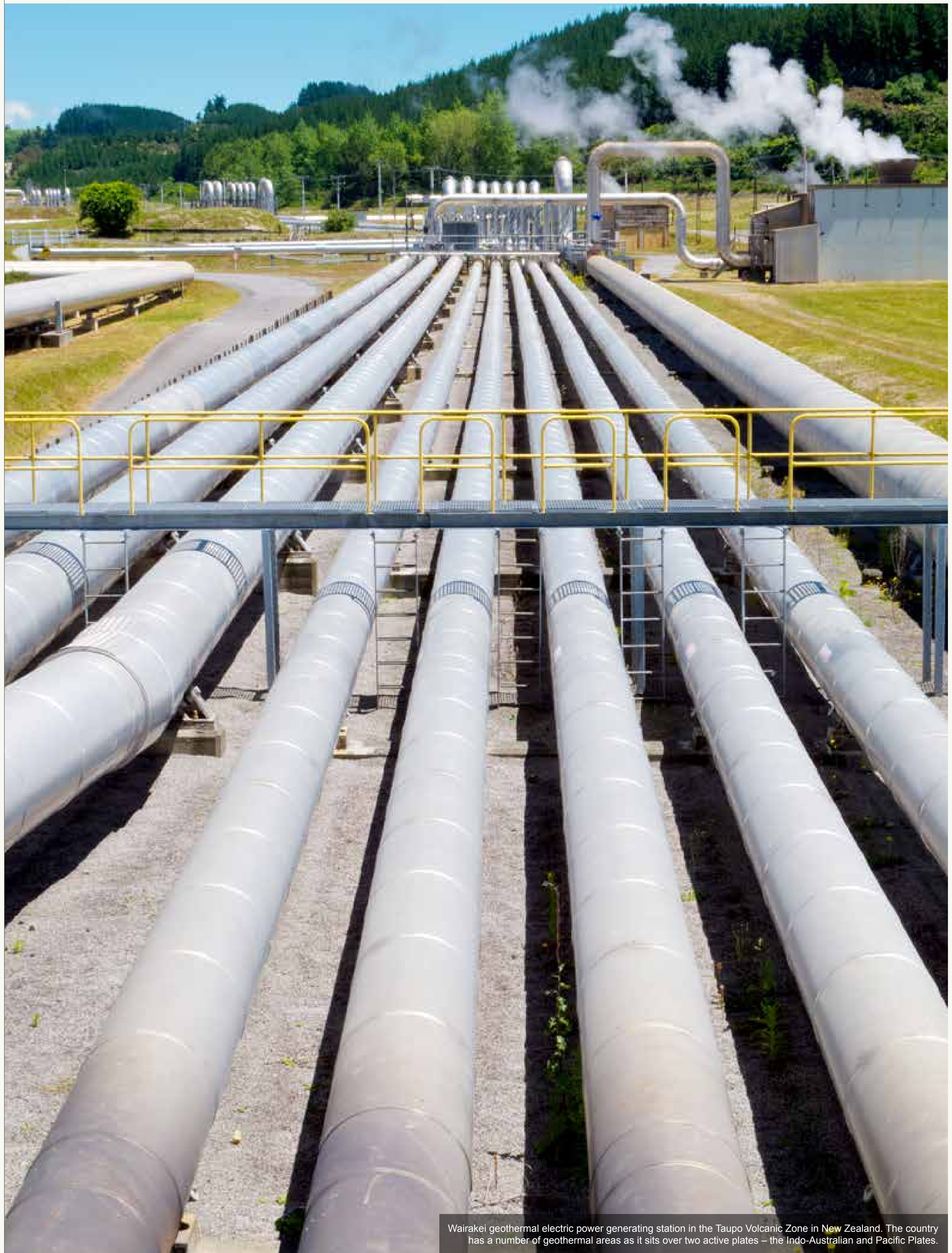
Figure 56: Marine Energy Capacity (MW) by Geography, 2006-2016



Source: IRENA (2017a)

Marine energy is still in its infancy as a source of electricity generation capacity. There are four main categories of marine energy technology: tidal range, tidal stream, wave energy, and ocean thermal energy conversion (OTEC). Tidal range accounts for substantially all of installed capacity and commercial capacity under development. Given the relative youth and pre-commercial nature of the technologies involved, costs are high, and not yet close to being competitive with other renewables or fossil fuels.

Installed capacity globally is just 536 MW globally, 90% of which comes from 2 projects in South Korea and France; another 1.7 GW is under construction. However, the given the scale of potential energy available in the ocean – the theoretical potential of wave energy alone was estimated to be almost double the global energy supply in 2008 – R&D into marine energy continues to expand. Although projects with actual permissions are fairly rare, there is over 850 GW of marine energy projects at various stages of the development process, with most of this at the early concept stage (WEC 2016). Investment into the sector has averaged USD300m annually for the past decade (Frankfurt School-UNEP Centre/ BNEF 2017).



Wairakei geothermal electric power generating station in the Taupo Volcanic Zone in New Zealand. The country has a number of geothermal areas as it sits over two active plates – the Indo-Australian and Pacific Plates.

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Carbon Capture & Storage (CCS)

CCS is a combination of technologies that aim to mitigate the CO_2 emissions from the combustion of fossil fuels or from industrial processes by capturing the CO_2 emitted, transporting it, and storing it underground permanently. Each part of the process involves technologies that were developed for other sectors, and are considered to be at least relatively mature with respect to those applications: Carbon separation is an established element of natural gas processing and fertiliser production; CO_2 pipeline networks have been operated for decades in the oil and gas sector; and the injection of CO_2 underground is a standard practice as part of enhanced oil recovery (EOR) operations in the oil sector (WEC 2016).

However, as applied to the power sector, this combination of technologies is still at an early stage, with first-of-a-kind commercial-scale CCS power plants only starting to be deployed from 2014. As a result, costs are high: the Global CCS Institute (GCI) estimates that levelized costs/MWh for early CCS-equipped coal and natural gas power plants in the US are 45-70% higher than unabated plants, implying a range of USD 66-97 per tonne of avoided CO_2, with broadly similar but generally somewhat higher CO_2 costs in other countries. For later iterations of these first-generation plants ("Nth-of-a-kind"), GCI models a drop to USD 43-55 per tonne of CO_2 avoided (Irlam 2017). This is far above the current market price for CO_2, which reduces the attractiveness of CCS in purely commercial terms.

Table 9: Costs of CCS Technologies at Reference Location (USA) – First-of-a-Kind (FOAK) vs. Nth-of-a-Kind (NOAK)

	PC super-critical	Oxy-comb. Super-critical	IGCC	NGCC	Iron and steel	Cement	Natural gas	Fertiliser	Biomass to ethanol
Levelised cost	USD/MWh	USD/MWh	USD/MWh	USD/MWh	USD/tonne	USD/tonne	USD/GJ	USD/tonne	USD/litre
Without CCS	75-77	-	95	49	280-370	101	3.75	400-450	0.40-0.45
With CCS - FOAK	124-133	118-129	141	78	114	69	0.061	13	0.018
With CCS - NOAK	108	107	102	62	95	58	0.058	12	0.017
Increase for FOAK w. CCS	60-70%	51-64%	45%	57%	30-41%	68%	2%	3-4%	4-5%
% decrease FOAK to NOAK	-13 to -19%	-9 to -16%	-28%	-21%	-17%	-16%	-5%	-8%	-6%
Cost of CO_2 avoided (USD/tonne CO_2)									
FOAK	74-83	66-75	97	89	77	124	21.5	25.4	21.5
NOAK	55	52	46	43	65	103	20.4	23.8	20.4

Notes: For industrial processes, levelised costs are expressed on an incremental basis relative to current market commodity prices which have been used as an analogue for the cost of production without CCS. Ranges are presented for technologies that represent a family of multiple reference plants. This includes the variability in market price identified for industrial commodities (such as iron and steel). The transport and storage costs applied are between 7 and 12 USD/tonne CO_2 for all power generation technologies. A combined 11 USD/tonne CO_2 is included for the industrial case transport and storage costs.
Source: Irlam (2017)

Regarding storage, monitoring for CO_2 leakage is particularly important, as models show that a leakage rate above 0.1% per year will invalidate the effectiveness of CCS in global warming control (Enting, Etheridge and Fielding 2008). This limited fault tolerance may have the effect of raising costs for the storage component of CCS, to ensure as complete a site characterisation as possible for a given location.

Because of these cost issues, when combined with the level of CCS deployment required to make a meaningful impact on GHG emissions, CCS is somewhat controversial from a resource allocation perspective. As of late 2016, there were 21 CCS projects in operation, with a combined carbon capture capacity of 40 million tonnes per annum (Mtpa), whereas the IEA's 2 Degree Scenario requires 400 Mtpa of CO_2 to be captured and stored by 2025, and 4,000 Mtpa by 2040 (IEA 2017a). The scale of investment required for CCS to reach that level of capacity is measured in the trillions of dollars.

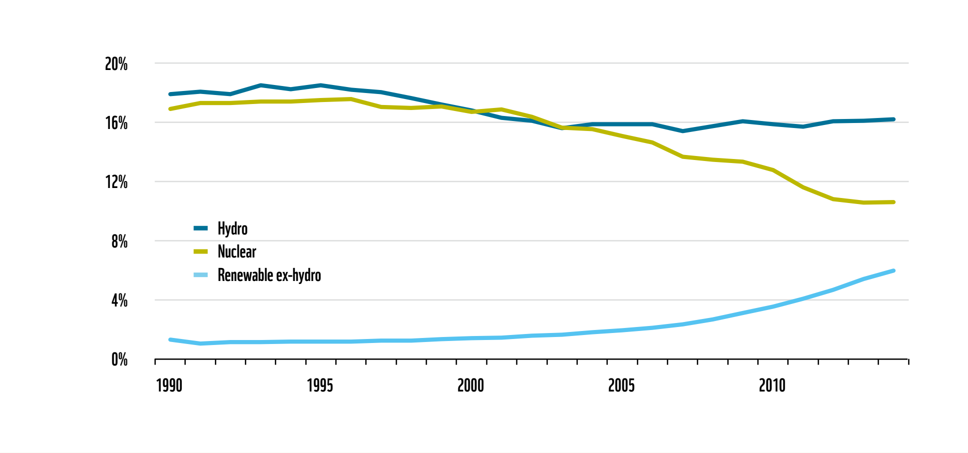
The argument against this level of investment is that at least some of that quantum could be put to better use in renewable energy development and energy efficiency improvements, rather than in prolonging the life of fossil fuel combustion as an energy source. However, conventional power is likely to be required for baseline generation until the intermittency associated with modern renewables is addressed successfully and cost-effectively, and the deployment of renewable capacity has reached sufficient scale to begin replacing conventional power.

Nuclear Power

At the operating level, generating nuclear power does not release greenhouse gases. Nuclear plants are characterised by extremely high capital costs paired with low operating costs, if the undefined costs associated with the storage and monitoring of disposed nuclear waste on millennial timescales is not counted. There is as yet no long-term disposal solution for nuclear waste that is in operation. Deep geological disposal is the consensus international solution, but only one pilot site, the Waste Isolation Pilot Plant in the US, is operational; it reopened in early 2017 after a 3-year clean-up period following an explosion at the site that released trace levels of americium and plutonium above ground as far as 800 meters from the site. Other deep disposal sites are under discussion or under construction, primarily in Europe.

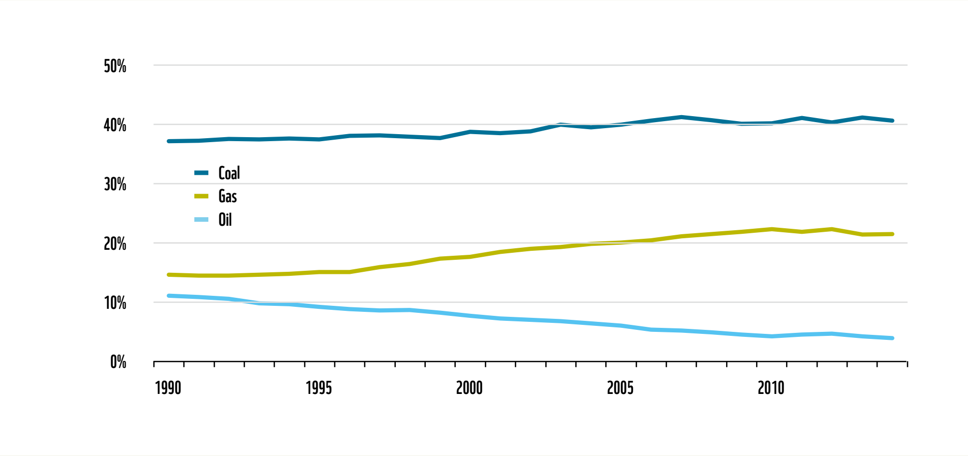
Nuclear power's share of global electricity production was under 11% in 2015, having fallen steadily from the high teens in the 1990s, with the decline accelerating in the wake of the Fukushima Daiichi disaster in Japan in 2011. Global installed capacity was 390 GW at the end of 2015. Investment in nuclear energy has increased sharply since 2012, more than tripling to USD26bn in 2016. As of the end of 2015, 65 reactors were under construction, representing an additional 64 GW of capacity, mostly in China, India, Russia and South Korea. These capacity additions come at a time when nuclear capacity is expected to fall or remain flat in North America and Western Europe. In those locations, permission for new reactors is frequently politically difficult to secure, so capacity is being maintained by securing extensions to the operating life of existing plants to 80 years or more from the 50-60 years that is the norm (WEC 2016).

Figure 57: Global Share of Electricity Production by Low-Carbon Source, 1990-2014



Source: World Bank (2017a)

Figure 58: Global Share of Electricity Production by Fossil Fuel, 1990-2014

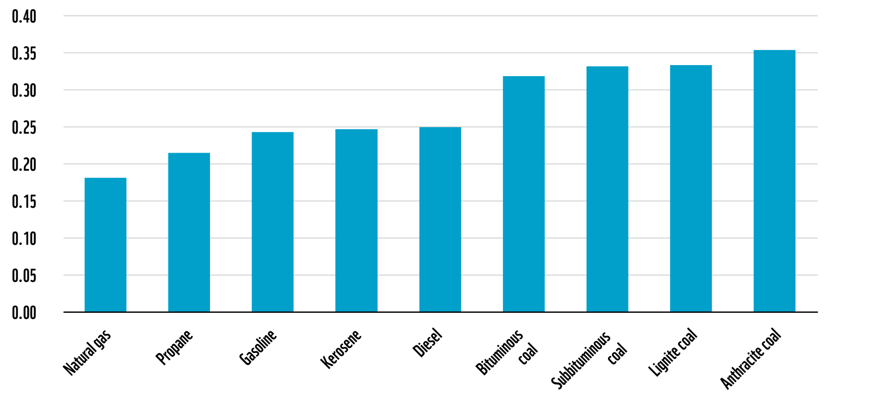


Source: World Bank (2017a)

Fossil Fuel Power

Fossil fuel electricity comes from coal, natural gas and oil, but mostly coal, which accounts for over 40% of global electricity generation. The share of natural gas has been rising since the mid-1990s, averaging 22% in recent years; this has come mainly at the expense of oil, whose share fell from over 10% in 1990 to 4% in 2014 (World Bank 2017a).

Figure 59: CO_2 Emissions from Combustion by Fuel Type, kg CO_2 per KWh



Source: EIA (2016b)

Coal is the most carbon-intensive fossil fuel, releasing over 300 grams of CO_2 per kilowatt-hour, almost double the level of natural gas and 35-40% higher than oil products (EIA 2016a). As a result, CO_2 emissions from coal combustion comprise over 70% of emissions from the power generation subsector (IEA 2015).

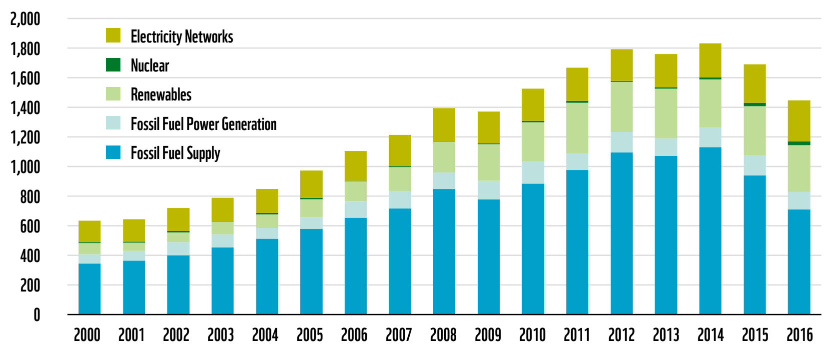
Efforts to mitigate emissions in the fossil fuel energy sector have thus focused on reducing coal usage or reducing its emissions. Emissions reduction can come from CCS (discussed above), or from increasing efficiency, or both. Three-quarters of coal plants use subcritical technology, with an efficiency of around 30%. Upgrading these plants to supercritical or beyond would yield efficiencies of 40% or more, which could cut emissions by 1.7 $GtCO_2$ per year, according to the World Energy Council (WEC 2016). However, that would be costly (subcritical plants are prevalent because they are relatively inexpensive), and until CCS is widely deployable as a retrofit option, would still leave well over 10 $GtCO_2$ in annual emissions from coal.

Reducing coal usage essentially requires the replacement of its base load capacity with energy from another source with lower emissions, ideally a renewable source. However, as modern renewables with storage are not yet able to be deployed cost-competitively as base load capacity, natural gas has been the primary replacement for coal, particularly in areas where the price of natural gas is low. Given the long life of a commercial thermal power plant (well over 40 years, typically), for new plants this runs the risk of locking in natural gas emissions well beyond 2050. As renewable energy's share continues to expand, advances in areas such as storage, grid management, and energy portfolio management could allow gas plants to be relegated to a backup rather than a primary generation role.

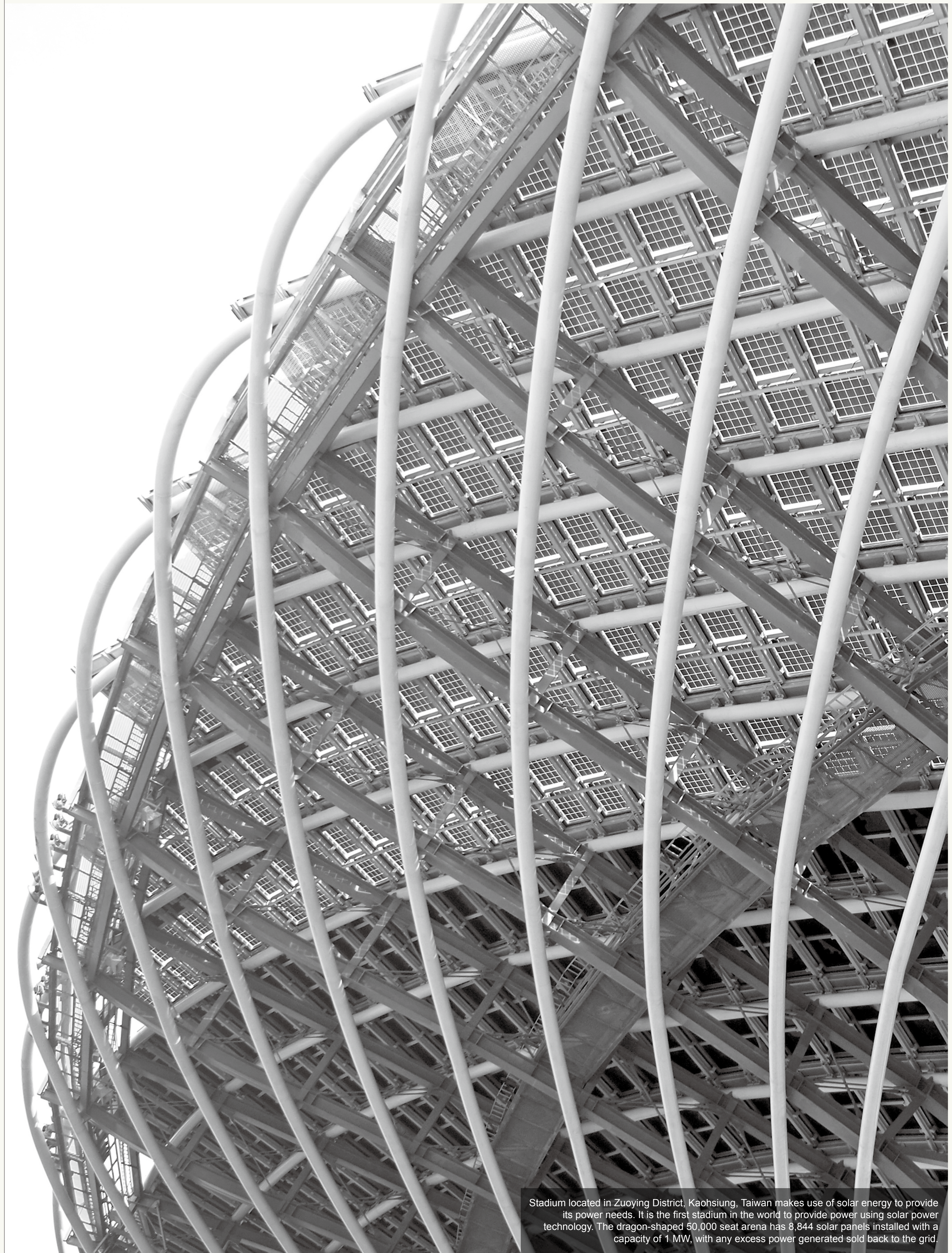
To a certain extent, this usage reduction is already happening: policy shifts in 2016 in China and India, two of the largest coal power markets, have led to significant drops in global pre-construction activity figures (-48%, to 570 GW in the 12 months to January 2017) and to a sharp increase in frozen construction (607 GW, up 164%) (Shearer, et al. 2017). These changes have come amidst significant increases in renewable energy targets in both countries.

The lion's share of investment in energy supply goes towards securing additional quantities of fossil fuels. The USD708bn invested in fossil fuel supply in 2016 was 49% of global investment in energy supply, the first time its share was below 50% in living memory. The combination of fossil fuel power generation and supply has historically combined to secure about two-thirds of the annual investment in energy supply, but declined to 57% in 2016, with grid and renewables enjoying increased relative share of investment (IEA 2017b). Both sides of this trend are expected to continue, as the energy sector decarbonises.

Figure 60: Global Investment in Energy Supply, 2000-2016, USD bn (2016 Dollars)



Note: Renewables includes investments in electricity, transport and heat.
Source: IEA (2017b)



Stadium located in Zuoying District, Kaohsiung, Taiwan makes use of solar energy to provide its power needs. It is the first stadium in the world to provide power using solar power technology. The dragon-shaped 50,000 seat arena has 8,844 solar panels installed with a capacity of 1 MW, with any excess power generated sold back to the grid.

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Accompanying Electricity-related Technologies

The prominent role expected of renewable power generation requires additional investments in supporting technologies. This is due to the variability and intermittency of modern renewables (known as variable renewable energy, or VRE) – in many cases, the grid and/or the regulatory regime have difficulty integrating their power in a cost-effective and sustainable manner. Key areas for investment to support this transition include energy storage, smart grids, demand-side management, monitoring and sensors. Such integration may also require adjustments to or a redesign of the regulatory regime under which electricity is delivered.

Energy Storage

Energy storage, particularly at utility-scale, has a number of potential applications in electricity delivery. Most prominently, it makes it possible to time-shift surplus power from when it is cheaper to periods when it is more expensive. Depending on the situation, these characteristics can help with issues including frequency modulation, load balancing, and peaking capacity, among many others. In particular, as VRE's share of overall electricity generation increases, storage will likely be required over periods ranging from days to months. The International Renewable Energy Agency projects a tripling of electricity storage capacity by 2030, assuming a doubling of the share of VRE (IRENA 2017b).

Figure 61: Services Providable By Energy Storage

Bulk energy services	Ancillary services	Transmission infrastructure services	Distribution infrastructure services	Customer energy management services	Off-grid	Transport sector
Electric energy time shift (arbitrage)	Regulation	Transmission upgrade deferral	Distribution upgrade deferral	Power quality	Solar home systems	Electric 2/3 wheelers, buses, cars and commercial vehicles
Electric supply capacity	Spinning, non-spinning and supplemental reserves	Transmission congestion relief	Voltage support	Power reliability	Mini-grids: System stability services	
	Voltage support			Retail electric energy time shift	Mini-grids: Facilitating high share of VRE	
	Black start			Demand charge management		
				Increased self-consumption of solar PV		

Note: Boxes in green are energy storage services directly supporting the integration of variable renewable energy.
Source: IRENA (2017b)

Srinagarind Dam located on the Khwae Yai River in Si Sawat District of Kanchanaburi Province, Thailand. A hydroelectric power generation facility, the dam's power station has a capacity of 720 MW of which 360 MW is pumped storage.

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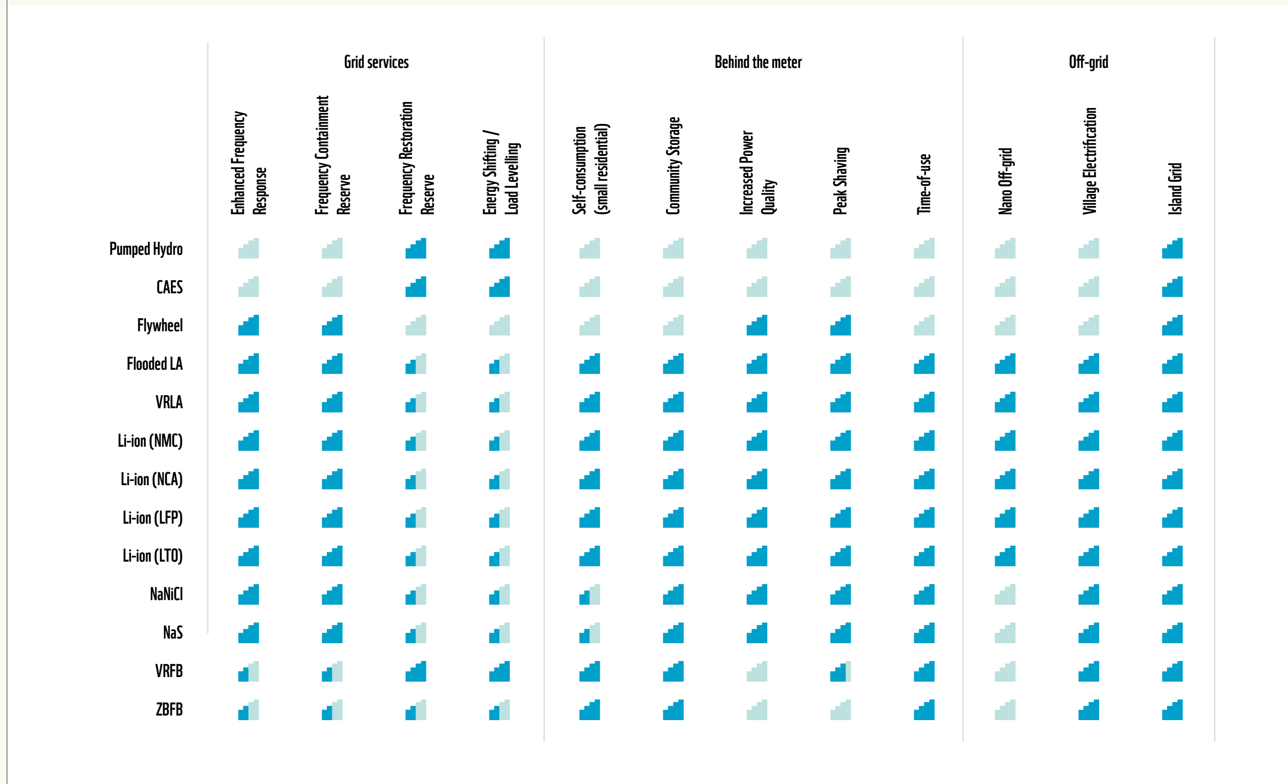
There is a wide variety of storage options under development and commercially deployed, generally using electro-mechanical, electro-chemical, thermal, electrical, or chemical processes, sometimes in hybrid combinations. Performance and cost characteristics vary across types as well as within them. Multiple types of storage may thus be deployed at various points across a given grid, according to the performance characteristics required, be it response time, discharge time, or other desired feature(s).

Figure 62: Suitability of Storage Technologies for Different Applications



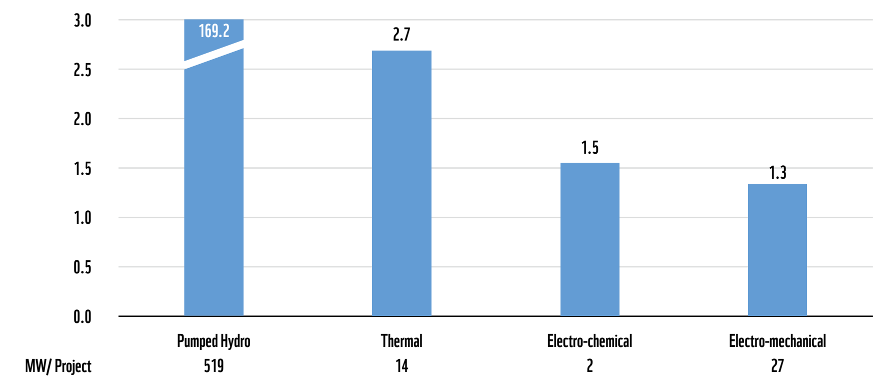
Note: CAES = compressed air energy storage; LA = lead-acid; VRLA = valve-regulated lead-acid; NMC = nickel manganese cobalt oxide; NCA = nickel cobalt aluminium oxide; LFP = lithium iron phosphate; LTO = lithium titanate; NaNiCl = sodium nickel chloride; NaS = sodium sulphur; VRFB = vanadium redox flow battery; ZBFB = zinc bromine flow battery.
Source: IRENA (2017b)

Table 10: Key Characteristics of Selected Types of Energy Storage Technologies

Technology	Type	Stage	Power rating (MW)	Discharge time	Cycles / lifetime	Self-discharge	Energy density (Wh/L)	Power density (W/L)	Efficiency	Response time
Pumped Hydro	Electro-mechanical	Commercial	100-2500	4-16h	30-60 years	~ 0	0.2-2	0.1-0.2	70-85%	10 s-min
Li-ion battery	Electro-chemical	Commercial	0.05-100	1 min-8h	1k-10k	0.1-0.3%	200-400	1300-10000	85-95%	< sec
Lead-acid battery	Electro-chemical	Commercial	0.001-100	1 min-8h	6-40 years	0.1-0.3%	50-80	90-700	80-90%	< sec
Sodium-Sulphur battery	Electro-chemical	Commercial	10-100	1 min-8h	2.5k-4.5k	0.05-20%	150-300	120-160	70-90%	< sec
Molten Salt	Thermal	Demo/ Pilot / Deploying	1-150	hours	30 years	n/a	70-210	n/a	80-90%	min
Compressed Air	Electro-mechanical	Demo/ Pilot / Deploying	10-1000	2-30h	20-40 years	~ 0	2-6	0.2-0.6	40-70%	min
Flywheels	Electro-mechanical	Demo/ Pilot / Deploying	0.001-20	sec-min	20k-100k	1.3-100%	20-80	5000	70-95%	< sec
Flow battery	Electro-chemical	Demo/ Pilot / Deploying	0.1-100	hours	12k-14k	0.002	20-70	0.5-2	60-85%	< sec
Super-conducting Magnetic	Electric	R&D	0.1-1	ms-sec	100k	10-15%	~ 6	~ 2600	80-95%	< sec
Super-capacitor	Electric	R&D	0.01-1	ms-min	10k-100k	20-40%	10-20	40000-120000	80-95%	< sec
Hydrogen	Chemical	R&D	0.01-100	min-week	5-30 years	0-4%	600 (200 bar)	0.2-20	25-45%	sec-min
Synthetic Natural Gas	Chemical	R&D	1-100	hour-week	30 years	Negligible	1800 (200 bar)	0.2-2	25-50%	sec-min

Source: WEC (2016)

Figure 63: Energy Storage Capacity in Operation by Type as of 3Q17 (GW)



Note: Database includes project entries yet to be validated. Pumped storage includes mixed hydro/pumped storage. Includes demonstration and pilot projects.
Source: US DOE (2017)

Pumped storage plants are the predominant form of operational energy storage in capacity terms, comprising over 96% of storage capacity (see Figure 63). Thermal storage comes in second with 2.7 GW of capacity, a result of its deployment in combination with concentrated solar power plants. Electro-chemical storage (i.e., batteries) are next, with 1.5 GW in operation. (This figure excludes home storage solutions and batteries in electric vehicles.) Battery storage has the highest number of installations and lowest average capacity, a reflection of the more modular nature of Li-ion batteries, which predominate in the category. Electro-mechanical storage (excluding pumped storage) rounds out the primary deployed technology categories and consists mainly of compressed air energy storage (CAES) and flywheels.

Pumped Hydro Storage (PHS)

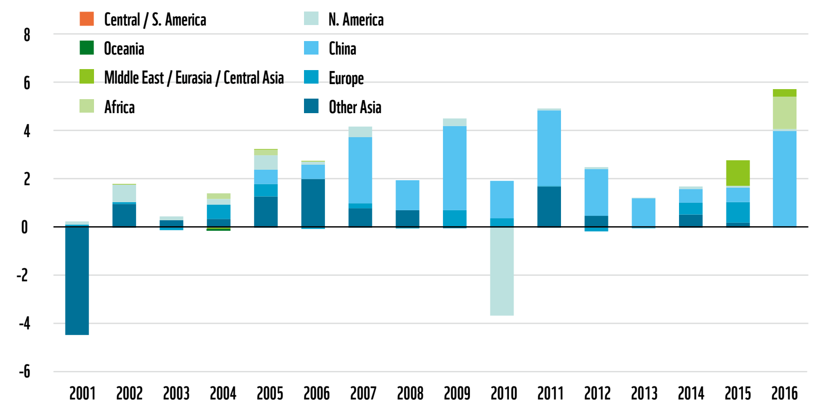
Pumped hydro storage installations transfer water between an upper and a lower reservoir, generating electricity on the way down and consuming it on the way up. Pumped hydro is a mature technology with over a century of commercial history and shares many characteristics with large-scale hydropower. The primary difference is that unlike regular hydro, pumped storage is a net consumer of electricity.

Table 11: Advantages and Disadvantages of Pumped Storage Systems

Advantages	Disadvantages
Established technology with high technical maturity and extensive operational experience	Geographic restrictions, since a suitable site with large land use is needed
Very low self-discharge	Typically, only 1 cycle per day
Reasonable round-trip efficiency	Low energy density (large footprint)
Large volume storage and long storage periods are possible	High initial investment costs
Low energy installation costs	Long construction period
Good start/stop flexibility	Long time to recover investment
Long life and low costs of storage	Environmental concerns

Source: IRENA (2017b)

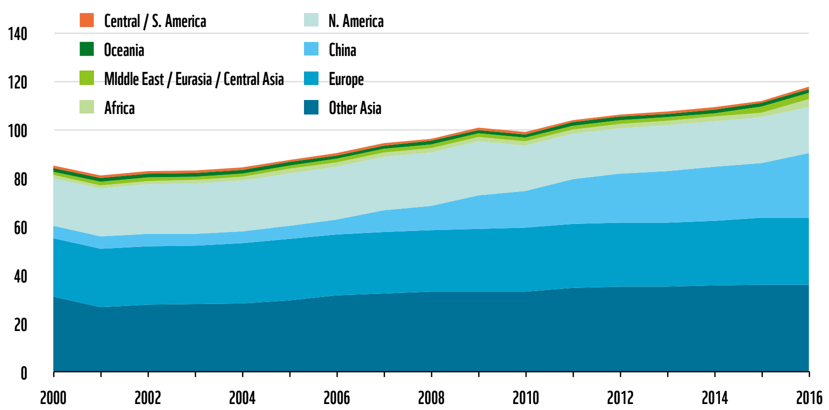
Figure 64: Annual Net Additions to Pumped Storage Capacity (GW) by Geography, 2001-2016



Note: Excludes mixed hydro/pumped storage.
Source: IRENA (2017a)

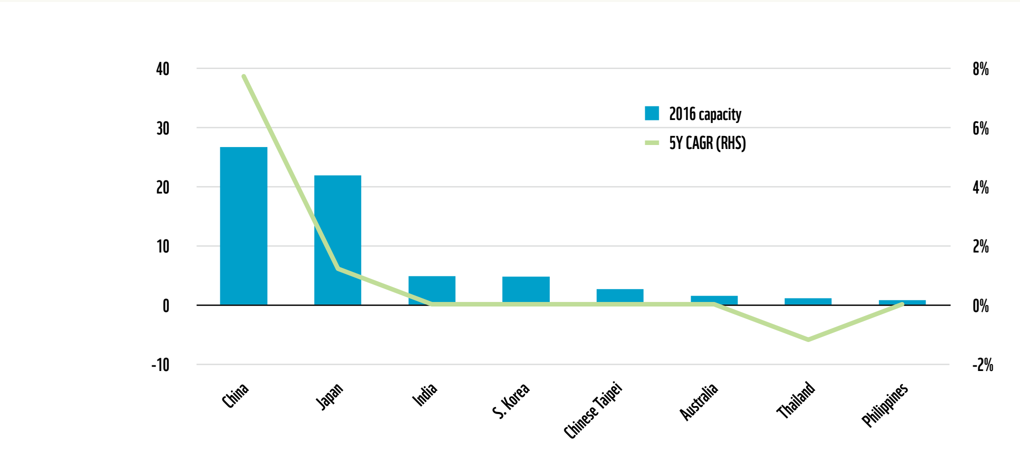
Global PHS electricity generation capacity reached 118 GW in 2016 (excluding mixed hydro/pumped storage facilities) and has been growing at an average of 2% annually since 2000. China has dominated net additions to pumped hydro capacity, adding more capacity than the rest of the world combined in most years since 2007. Globally, the cumulative PHS capacity added since 2001 is 33 GW, of which China added 25 GW. China, Japan and the USA are the top 3 countries using PHS, with about 57% of global installed capacity (IRENA 2017a).

Figure 65: Pumped Storage Capacity (GW) by Geography, 2001-2016



Note: Excludes mixed hydro/pumped storage.
Source: IRENA (2017a)

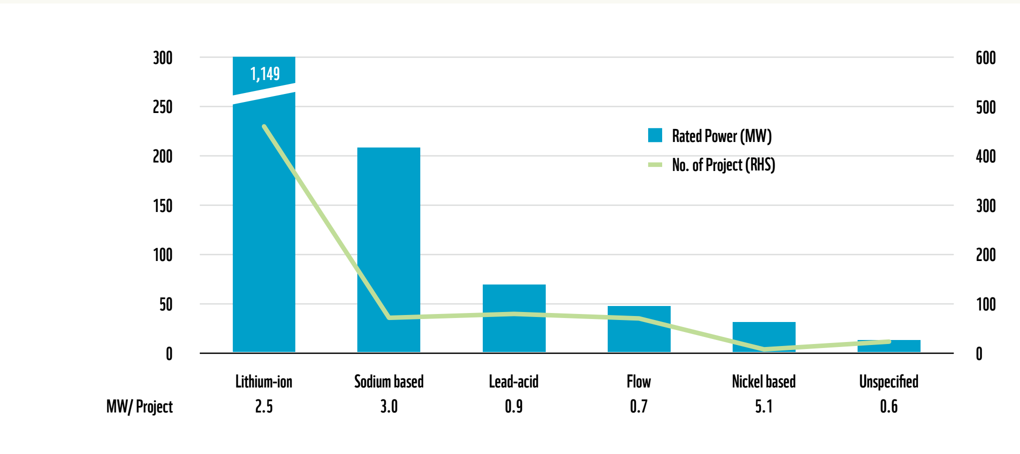
Figure 66: 2016 Asia-Pacific Pumped Hydro Storage Capacity and 5Y CAGR, (GW & Percent)



Source: IRENA (2017a)

In Asia-Pacific, a total of eight countries have any pumped hydro capacity. As mentioned, China and Japan are the regional (and global) leaders, and account for over three-quarters of installed capacity. Most of the remaining capacity is held by India and South Korea, who together account for the next 15% share of capacity, with Taiwan, Australia, Thailand and the Philippines holding the rest. Regional capacity growth is driven almost exclusively by China, which expanded its storage capacity by 8.3 GW (45% increase) between 2011 and 2016. Japan added another 1.3 GW (6% increase) over the same period, while capacity in the rest of the region stayed flat or dropped slightly.

Figure 67: Battery Energy Storage Capacity in Operation by Type as of 3Q17



Note: Includes demonstration and pilot projects. Excludes vehicles and most residential installations. Some database entries are yet to be validated.
Source: US DOE (2017)

Batteries

There are many different possible chemistries in commercial service or in development. In aggregate capacity terms, the primary technologies deployed at the moment are lithium-ion, sodium-based and lead-acid batteries. Many battery technologies have fairly lengthy histories and are well understood; from a utility-scale deployment perspective, the issue has been cost per unit of performance, combined with limited reason to deploy them. The growing scale of VRE has changed this calculation, as have recent cost decreases, which have been driven in large part by the battery needs of the electric vehicles sector.

Lithium-ion batteries were introduced by the Sony Corporation of Japan in the early 1990s, and are now the most prominent battery technology globally, thanks to their omnipresence in portable consumer electronics. Their development has been given a further boost by the demands of the electric vehicle sector, as Li-ion batteries are lightweight and yet have higher energy and power density relative to other battery technologies. Thermal stability is the biggest issue with these batteries, and if left unmanaged can lead to the cells catching fire. As costs continue to decrease for mobility applications, stationary systems are becoming more cost-competitive. They are already a viable choice in situations where non-cost characteristics like volume, weight, cycling performance, energy efficiency and/or remote monitoring have more relative importance for a given installation. There are numerous Li-ion battery chemistries in commercial operation, each with their own strengths and weaknesses within the context of the overall Li-ion performance envelope (IRENA 2017b).

Sodium-based batteries are high-temperature batteries and were the leading deployed battery technology for stationary applications in the 2000s before the rise of lithium batteries (WEC 2016). Sodium-based batteries have a higher energy density than other non-lithium batteries and are at the low end of the range vs. lithium. There are two main types in commercial operation – sodium-sulphur (NaS) batteries, which were developed for stationary applications, and sodium nickel chloride ($NaNiCl_2$) batteries, which were originally developed for mobile applications. The operating temperature of NaS batteries is 300-350°C, while $NaNiCl_2$ batteries run slightly cooler, at about 250°C. R&D in this battery category is continuing – experimental cells have demonstrated good performance at temperatures as low as 90°C. NaS batteries were initially mainly used in Japan, where over 300 MW of capacity is installed at 170 projects around the country; operational experience with the technology has since spread more broadly (IRENA 2017b).

Lead-acid batteries are a mature technology with over 100 years of industrial history. Approximately 80% of the total installed capacity of industrial batteries across all applications involve lead-acid battery technology (EUROBAT 2013). While lead-acid batteries generally suffer in comparison with Li-ion batteries along performance metrics, their low cost, proven reliability, high recyclability and depth of operational experience make them a compelling choice for many applications. They are already widely used for renewables deployment for home systems and off-grid. For example, over 3 million 12V lead-acid batteries have been distributed as an integral part of solar home systems sold by Rahimafrooz Renewable Energy Ltd. In Bangladesh, Nepal and India (ARE 2013).

Nickel-based batteries are the second-most widely used battery technology after lead-acid, with a particular niche in extreme climate conditions or where fast charging is required. The primary commercial chemistries used are nickel-cadmium and nickel-metal hydride, both of which use alkaline cells. They are somewhat more expensive than lead-acid batteries, with slightly higher energy density and cycle and calendar life. (EUROBAT 2013)

Flow batteries produce electricity in a similar manner as the other battery types discussed, with two chemical components dissolved in liquids contained within a system, typically separated by a membrane. The fundamental difference is that in a flow battery, the energy is stored in the electrolyte, rather than in the electrode material. The electrolyte is not contained in the cell, but is rather stored in external tanks, which allows for essentially instant recharging by refilling the tanks, akin to a fuel cell. Another key difference from conventional batteries is that because power (W) is a function of the surface area of the membrane, while energy (Wh) is determined by the size of the storage tanks, they are independently scalable. In recent years, the technology has moved beyond the R&D phase, and is now in the early stages of commercialisation, with vanadium redox and zinc bromide the two most developed chemistries. (IRENA 2017b)

Table 12: Advantages and Disadvantages of Selected Battery Types

Battery Type	Advantages	Disadvantages
Lithium-ion	High specific energy (Wh/kg)	Cost
	High discharge capabilities	Potential for thermal runaway requires integrated thermal mgmt. & monitoring
	High round-trip efficiency	Performance lifetime sensitive to operating temperatures
	Low self-discharge rate	Potential issue with sustainable cobalt
	Relatively long lifetime	End-of-life recycling path is complex due to multiple Li chemistries
	Benefit from EV R&D, scale deployment	
Sodium based	Extensive commercial deployment in Japan	High operating temperature (250-350°C)
	Relatively high energy density	High operating cost
	Compact, low maintenance	Corrosion issues (NaS)
	Long discharge duration, high pulse power available	Limited number of suppliers may be an innovation handicap
	Very low self-discharge rates	
	Low cost non-toxic materials, high recyclability	
	High cycle lifetime ~5k	

Battery Type	Advantages	Disadvantages
Lead-acid	Very mature	Low energy density, cycling times
	Good cost-performance ratio over wide range of applications	Potential for restrictions due to lead toxicity
	Large existing recycling market	Very heavy
	Low lifecycle cost	Performance issues with deep discharge
		Poor performance at low or high ambient temperatures
Nickel based	High power output, good deep discharge performance (NiCd)	Low energy density (NiCd)
	Good low temp performance (NiCd)	Environmental concerns (NiCd)
	High energy density (NiMH)	Memory effect performance issue (NiMH)
	Almost 100% recyclability	Poor high temp performance (NiMH)
Flow	Can operate at close to ambient temperatures	Complex system architecture – sensors, pumps, flow management
	Energy and power characteristics are independently scalable	Potential for high maintenance/repair cost
	Over 10k cycle lifetime	Acidic electrolytes – leak risk
	Very deep discharge with limited lifecycle issues, long duration of discharge	Limited commercial deployment; early stage of cost learning curve
	Relatively high efficiency, but lower than Li-ion	
	No risk of thermal runaway	
	Particularly suitable for large-scale stationary applications	

Source: IRENA (2017b), Lazard (2017b), EUROBAT (2013)

Li-ion batteries remain the most prevalent technology for upcoming deployments of battery electricity storage (BES), with almost 65% of global BES capacity that has been announced, contracted, or is under construction. When complete the 1 GW of capacity this represents will almost double the global deployed Li-ion BES. It should be noted that these figures are low, as they do not generally include vehicles or storage capacity paired with home solar PV systems in single-family residences. This will understate the deployment figures for Li-ion and lead-acid batteries in particular.

Table 13: Announced, Contracted and Under Construction Electro-Chemical Storage Capacity by Type

Country	Electro-chemical (unspecified)	Electro-chemical Capacitor	Flow Battery	Lead-acid Battery	Lithium-ion Battery	Metal Air Battery	Nickel based Battery	Sodium based Battery	Total (kW)
United States	177,963		3,408	21,500	363,296	14,250			580,417
Australia	10		400		292,250			30	292,690
China		1,000	200,000		17,600				218,600
Germany			410		122,000				122,410
India	100,000				10,125				110,125
S. Korea					48,500				48,500
Canada	5,000		9,000		33,960				47,960
Egypt					30,000				30,000
Italy		1,920	1,950		20,000			4,000	27,870
Kazakhstan			25,000						25,000
Top 10	**282,973**	**2,920**	**240,168**	**21,500**	**937,731**	**14,250**	**0**	**4,030**	**1,503,572**
World	**286,723**	**2,920**	**240,943**	**21,500**	**1,017,231**	**19,588**	**2,000**	**4,830**	**1,595,735**
% of Total	18%	0%	15%	1%	64%	1%	0%	0%	

Source: US DOE (2017) after IRENA (2017b)


Rows of batteries in industrial standby power system, Thailand.

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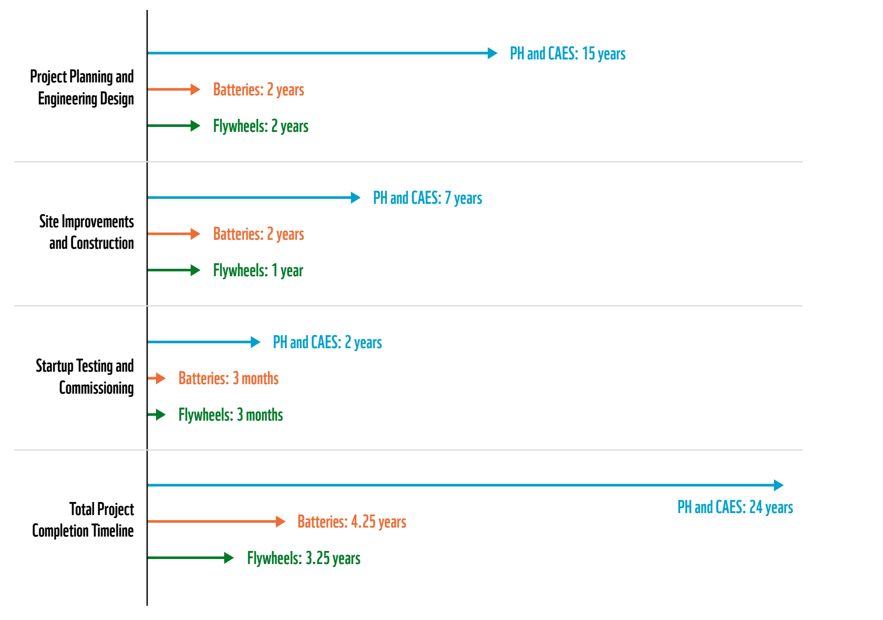
Compressed Air Energy Storage (CAES)

Compressed air storage uses off-peak electricity to compress air and store it in a reservoir, typically an underground cavern. Above-ground tanks may also be used, although this increases the cost of the system. To discharge the stored energy, the compressed air is heated, expanded, and directed to a conventional natural gas turbine to produce electricity (US DOE/EPRI 2015). Emissions are substantially lower than a natural gas plant, as in a conventional plant, as much as two-thirds of the turbine capacity is used to compress the air mixed with the natural gas. This is independently supplied in a CAES plant, so the turbine can generate 3 times the output for the same natural gas input (ESA 2017a).

Figure 68: Typical Project Timelines



Source: US DOE/EPRI (2015)

CAES systems are roughly equivalent to pumped hydro in terms of capacity and duration of storage. They are typically used to provide bulk power management and are suitable for long-term or seasonal storage (IRENA 2017b). Like pumped hydro, CAES also faces geographical constraints, as using a natural cavern is significantly cheaper than excavating one or installing storage tanks. Large-scale CAES projects can take a very long time to come to fruition – the US DOE has posited typical project timelines for CAES (and PHS) of 24 years from conception to completion (see Figure 68) (US DOE/EPRI 2015).

Globally, there are only two large-scale CAES plants in operation – one in the United States (110 MW), and one in Germany (290 MW) (US DOE 2017). One more 317 MW system in the US is fully permitted but contracting and construction has been delayed due to lack of financing (Seltzer 2017).

Flywheel Energy Storage (FES)

Flywheels store kinetic energy via the angular momentum of a spinning rotor. When connected to a power conversion system, the flywheel's kinetic energy is transformed into electricity, and vice versa, by accelerating or braking the rotor. FES systems come in two broad classes: low-speed (under 10k RPM) and high-speed (up to 100k RPM). Low-speed FES rotors are typically made of steel or another metal, while high-speed FES rotors are more likely to be made of lightweight composite materials. In either case, the flywheels are normally completely enclosed in a housing designed to contain any catastrophic failure of the rotor. These enclosures may also be placed under vacuum to reduce friction losses (IRENA 2017b).

Advantages of FES systems include a high number of full charge/discharge cycles (100k+ is frequently cited), very limited degradation of capacity over the lifecycle, rapid discharging and recharging, high power density, low maintenance and wide operational experience. Disadvantages include low energy density vs. batteries, high self-discharge rates, and sensitivity to external shocks.

Because of the high power / low energy density nature of flywheels, at the utility or grid level they are generally used for short duration applications like frequency stabilisation. Of the 37 operational FES systems listed in the US DOE energy storage database, the typical duration of discharge was 15 minutes, delivering under 1 MW of power[2] (US DOE 2017). The total installed capacity of these systems is about 73 MW, of which 58 MW is in the United States. In Asia-Pacific, Australia is the sole country represented, with 3 installations totalling 2 MW.

[2] This excludes 3 FES systems installed at high-energy physics laboratories with significantly higher power capacity.

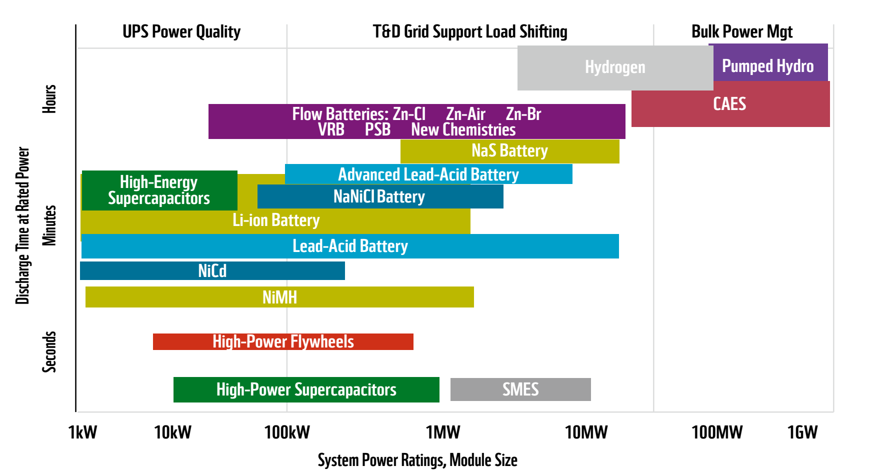
Hydrogen Energy Storage

Hydrogen energy storage (HES) is still in the pre-commercial stages of development. In HES, surplus electricity from a renewable source such as wind or solar is used to generate hydrogen from water via electrolysis. Hydrogen is a portable fuel, which means that its point of use is not necessarily linked to its point of production in space or time, assuming appropriate storage. As such, once it is generated, there are numerous options for its use in energy storage applications. These include using it directly as a feedstock for a fuel cell plant or combining it with CO_2 to create synthetic natural gas (SNG). Costs are currently high and roundtrip efficiencies are low (under 50% for the electricity-to-gas-to-electricity cycle), although this can be improved somewhat with cogeneration[3]. Because of the cost and low efficiency of these options at the moment, at existing projects it is currently more common for the hydrogen to be directly injected into the natural gas grid, although this is subject to hydrogen concentration limits and must be monitored closely. (ESA 2017b)

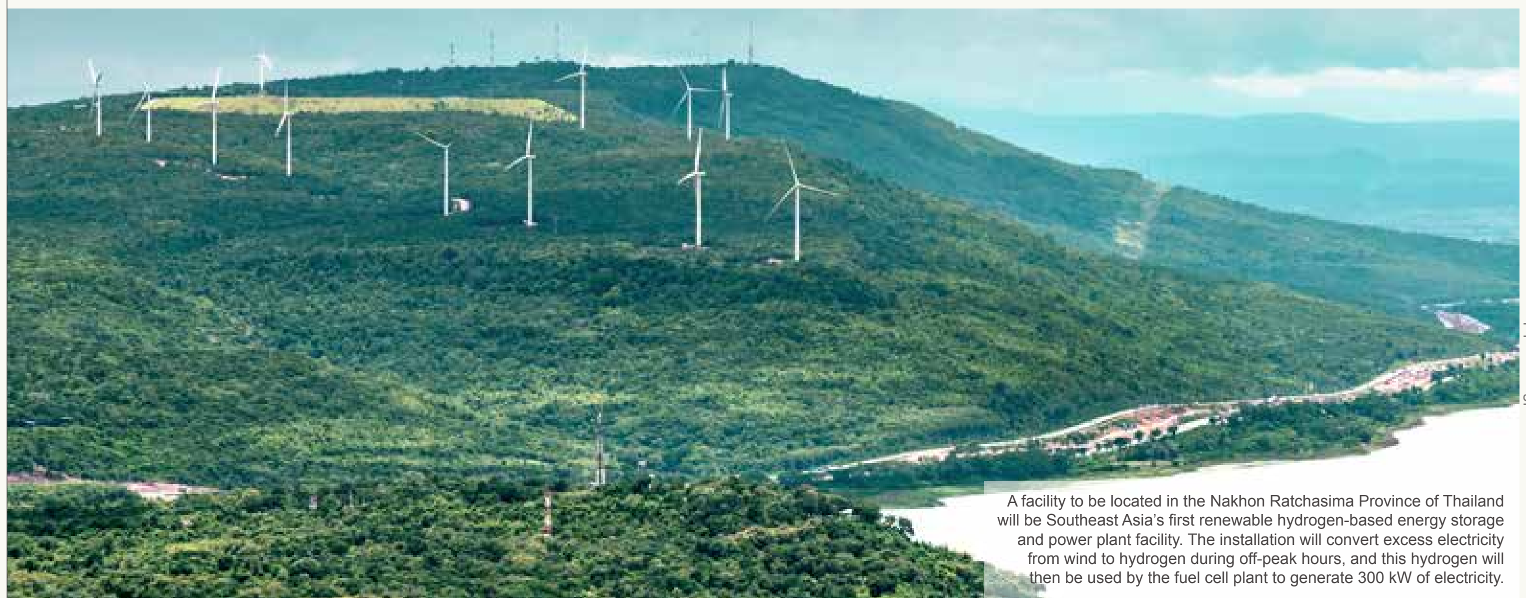
Globally, there are only 9 hydrogen projects listed as being in operation in the US DOE's energy storage database (US DOE 2017), and all of them are test/pilot/demonstration facilities. Two-thirds of these are in Germany, and the rest are also in Europe. Three more projects have been contracted, including a 300 kW storage facility in Thailand, where hydrogen generated from surplus wind power will be used in fuel cells to help power an energy neutral building. This is the first HES project in Asia, announced in June 2016.

[3] In cogeneration, waste heat from electricity generation is captured and used to drive a turbine generator, and then further used for water or space heating.

Figure 69: Positioning of Energy Storage Technologies



Note: UPS= Uninterruptible power supply; T&D= Transmission & distribution.
Source: US DOE/EPRI (2015)



A facility to be located in the Nakhon Ratchasima Province of Thailand will be Southeast Asia's first renewable hydrogen-based energy storage and power plant facility. The installation will convert excess electricity from wind to hydrogen during off-peak hours, and this hydrogen will then be used by the fuel cell plant to generate 300 kW of electricity.

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Electricity pylons march across northern China.

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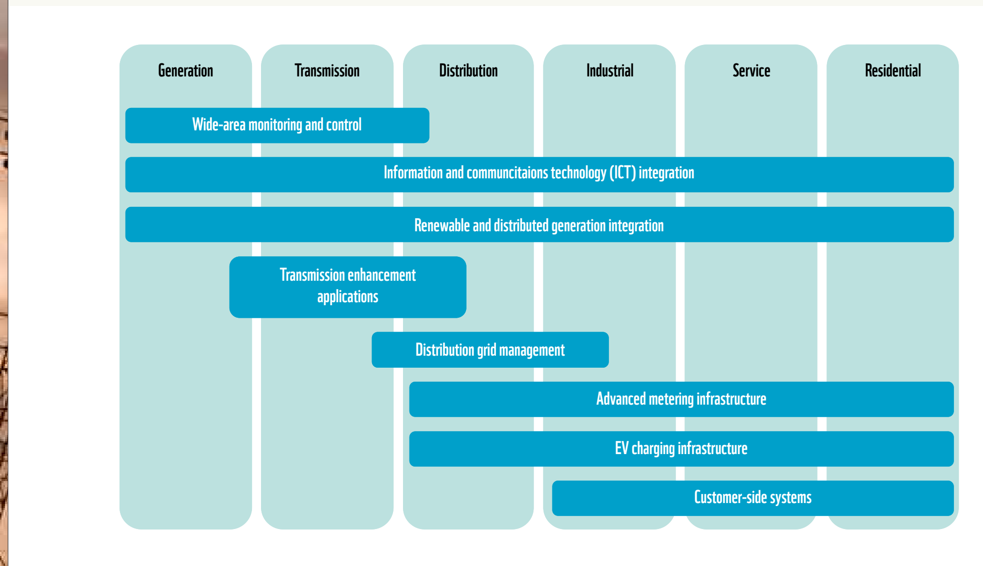
Smart Grid Technologies

The term "smart grid" is shorthand for the concept of two- or multi-way flow of information and power between all participants in an electricity network, allowing what were formerly end-users to become distributed sources of generation. Along with relevant changes to the regulatory and market structure environments, smart grids in principle aim to maximise efficiency, stability and reliability of the network while minimising costs and environmental impacts. There is no single smart grid product – rather, the term encompasses an evolving set of technologies that enable this communication and transmission. These technologies come in multiple varieties, as electricity market contexts vary across and within countries. (IEA 2011)

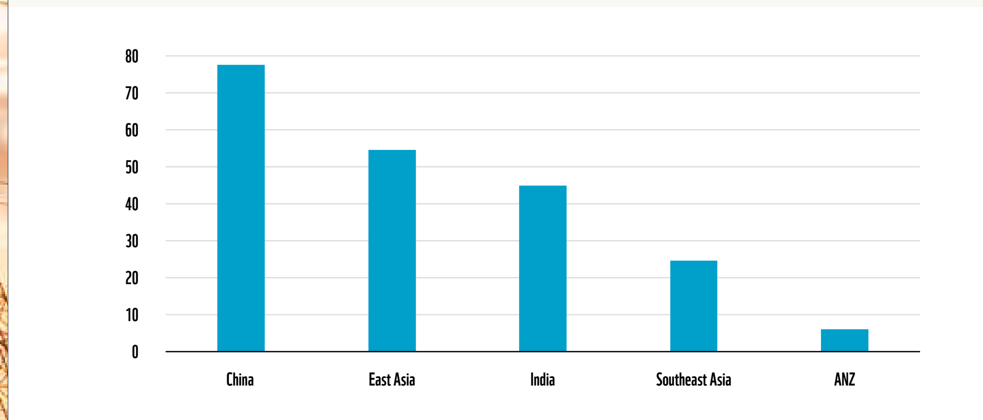
Aspects of the technology are a prerequisite for integrating commercial-scale variable renewable energy, particularly at higher shares of generation. Smart grid technology is also needed to handle trade between network participants that are both producers and consumers of electricity, such as energy storage facilities, residential PV systems, or municipal and building-level grids. Figure 70 shows the broad spectrum of areas where smart grid technologies can be applied.

Figure 70: Smart Grid Technology Areas



Source: US DOE/EPRI (2015)

Figure 71: Asia-Pacific Smart Grid Investment Forecast, 2017-2027, USD bn



Note: East Asia forecast is 2015-2025; China & SE Asia forecast is 2016-2026.
Source: Northeast Group via MSEI (2016a,b,c; 2017a,b)

Because they facilitate distributed generation, smart grid technologies can act as enablers for private sector investment into electricity systems, which are frequently constrained by capital limitations. This investment can be into relatively capital-intensive areas such as generating assets or storage-generation combinations, or into more capital-light services such as virtual power plants (VPPs). A VPP is a new business model for electricity delivery which aggregates a collection of distributed energy resources and coordinates them so they can be treated as a single resource by the grid operator. These distributed resources can include all types of power sources, from conventional and renewable generation to energy storage and demand response. While not yet common, VPPs are commercially available and being developed in Asia-Pacific. Australia is the site for the world's largest VPP (5 MW / 7 MWh), announced in 2016 (AGL 2016), while the Japanese government is subsidising the development of 7 VPP projects totalling 19.1 MW (Mesina 2017).

Rolling out smart grid technologies will require significant investments into equipment and software from utilities, governments and private investors. In particular, upgrading to advanced metering infrastructure (AMI) requires vast quantities of smart meters. In Asia, China has installed 50 million smart meters a year since at least 2014 (MSEI 2016c), while Malaysian utility Tenaga Nasional Bhd. is in the process of rolling out AMI to its 9 million customers (Buntz 2017). Asia-Pacific investment into the development and deployment of smart grid technologies is expected to exceed USD200bn through 2027, according to forecasts from market research firm Northeast Group.

The specifics of these investments will differ by country and region, depending on the status of the grid(s) involved. For less advanced markets, the focus may be on rolling out smart meters and smart inverters, while more advanced markets may look into virtual power plants and renewable resource forecasting. A summary of the different types of technologies involved is presented in Table 14 below.

Table 14: Smart Grid Technology Summary

Technology	Problems mitigated	Maturity	Availability / Market penetration	Capital and O&M costs (USD)	Typical payback	Risks / Disadvantages	Depends on existence of	Synergistic with
Advanced metering infrastructure (AMI)	Lack of distribution monitoring; outage detection and location; energy conservation; energy theft	Commercial; advanced AMI in R&D, demo	Widespread; >10% penetration (U.S.)	$50–$250 / meter; up to $500/meter incl. communications and IT; O&M $1 / meter / month	3- to 10-year payback; depends on existing and new systems	PR/education issues can be touchy	Standardisation; interoperability	DR; advanced pricing; DA
Advanced electricity pricing	High peak loads; load shedding; outage frequency	Some methods mature; others R&D, demo	TOU, CPP becoming common; RTP pilot/ demo	Depends on programme; generally low if AMI already exists	Depends on pricing scheme and electric system specifics; a few years	PR/education issues can be touchy	AMI	Smart inverters; forecasting
Demand response (DR)	High peak loads/prices; load shedding; outage frequency	Basic DR mature; automated DR demo / early commercial	Widespread for basic functions; 10% penetration	$240/kW capacity (vs.$400/kW for gas peaking plant); O&M costs low	<3 years	PR/education issues can be touchy; trade-off with user comfort	Comms, e.g. AMI; smart equip. / thermostats; favourable reg. env.	Smart inverters; AMI; advanced pricing; microgrids / VPPs
Distribution automation (DA)	Inefficiency; voltage regulation; outage frequency and duration; distribution maintenance costs	Some techs approaching mature; others in R&D, demo	Many techs commercial, becoming common; others in R&D	Depends on specific tech; IVVC / FLISR demo ~$150,000/ feeder	Depends on tech and on grid characteristics	Optimal tech / communications choices depend on future conditions	Standardisation, interoperability	AMI; DR; distributed storage; smart inverters; PV forecasting; microgrids
Renewable resource forecasting	Reliability issues and cost of solar / wind variability; voltage and frequency regulation	Wind commercial; PV early comm.; R&D improvements	Wind widespread; PV becoming widely available; penetration depends on reg. structure	Wind forecasting service $2,500 / month / plant; PV expected to be similar	<1 year if renewable penetration is above 10%	Wind low risk; solar may have initial bugs	Local service availability	Microgrids & VPPs; DA; advanced pricing; storage
Smart inverters	Power quality; voltage / frequency regulation; undesired inverter tripping offline	Commercial; becoming standard for larger inverters	Widespread availability over 100 kW; wind market penetration high, PV low in most regions	<5% more than conventional inverter; O&M same as conventional inverter	Depends on tech and payment structure	Low risk; unintentional islanding; potential stability	Favourable regulatory environment	DR; AMI; advanced pricing; microgrids; VPPs
Distributed storage	Voltage / frequency regulation; power ramps	Demo, R&D	Some techs commercial; others in R&D; not common	Tech-dependent; typically, higher than other energy / power production methods	Depends on market structure and value of reliability	High capital costs; traditional market / regulatory structures don't value distributed ancillary services	Not applicable	AMI; advanced pricing; DA; microgrids; VPPs; forecasting
Virtual power plants (VPPs)	Solar / wind variability; high peak loads / prices	Demo, R&D	Commercially available; not common	Low	Situation dependent	Limited field experience	Favourable regulatory environment	Smart inverters; distributed storage; advanced pricing; DA; forecasting
Microgrids	Power outages; power quality; solar/wind variability; high peak loads/prices	Demo, R&D	Commercially available; not common	Tech-dependent; ~$5/ Watt capacity	Tech dependent; may not be justified unless reliability valued highly	Limited field experience	Favourable regulatory environment	Smart inverters; distributed storage; advanced pricing; DA; forecasting

Note: O&M=Operation & Maintenance; TOU=Time Of Use; CPP=Critical Peak Pricing; RTP=Real-Time Pricing. All technologies depend to some extent on the regulatory environment and on standardisation and interoperability issues. These dependencies are only listed here if they may be particularly problematic for the technology in question.
Source: IRENA (2013)

New Infrastructure

Investment in appropriate infrastructure also has the potential to mitigate energy-related emissions. In particular, district energy, light rail, and electrical charging networks have significant potential to facilitate emissions reductions, both directly and indirectly.

District Energy

District energy, or district heating and cooling (DHC) is the centralised provision of heating and/or cooling to end-users, typically via an insulated water or steam pipe network. The primary nonindustrial application is space heating or cooling, although hot water provision is also common. Heat sources include geothermal energy, waste-to-energy incineration, waste heat recovery, heat from combined heat and power (CHP) plants, boilers, heat pumps and solar thermal plants. Cooling sources include electric chillers, free cooling from cold water sources or waste cool from LNG terminals, and absorption chillers driven from surplus heat or renewables. (UNEP 2015)

Mitigation Potential and Other Benefits

DHC can result in a 30-50% reduction in primary energy consumption relative to distributed heating and cooling. This reduction is in part due to the economies of scale available to a centralised source of heat or cold, which allows for the provision of heating/cooling services more efficiently and cheaply than on-site sources, particularly when using waste heat or heat from CHP plants. Where heating or cooling is originally produced from electricity, district energy can reduce overall electricity usage and ease the burden on the grid. As fossil fuels are the predominant source of fuel used to generate heat, district heating can lower the amount of fuel consumed and thus emissions generated. This reduction in fossil fuel use can lead directly to lower air pollution levels, both indoors and outdoors. When paired with thermal storage, DHC can also help integrate renewable energy sources into the electricity system by using excess renewable electricity during periods of oversupply. (UNEP 2015)

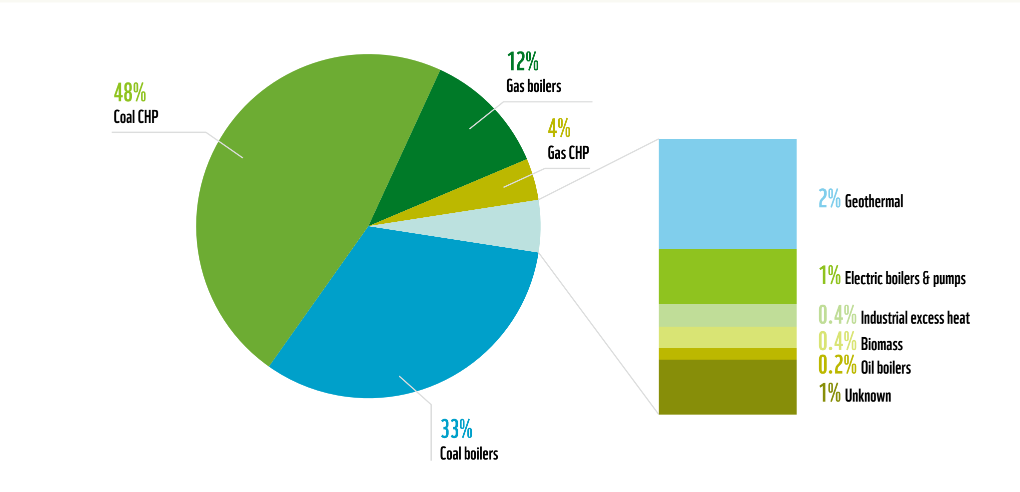
Global Context

Because of transmission losses, district energy is most cost-effective in locations with high population density, which keeps the transport network short. District heat is most prevalent in the colder urban regions of China, Russia, North America, OECD Europe, non-OECD Europe and Eurasia, Japan and South Korea (EIA 2017). District cooling is less common that district heat, with annual deliveries of 300 PJ approximately 2.5% of the level of annual heat deliveries. Two-thirds of district cooling deliveries take place in the Middle East. (Werner 2017).

Asia Context

Northern China makes extensive use of district heat, with an estimated 12.6 billion m² of building floor space covered in 2014 (BERC 2016), and over 178,000 km of heat transport and distribution pipelines. In 2016, 33% of district heat was provided by low-efficiency coal boilers, 48% was from coal-fired CHP, and most of the rest came from natural gas boilers or CHP (Benazeraf 2017).

Figure 72: Central Heating Fuel Mix in China, 2016, By Floor Area



Source: BERC via Benazeraf (2017)

This mix represents a noticeable shift from just 6 years earlier, when coal boilers held a 54% share and overall coal fuelled 97% of district heat (Xiong, et al. 2015). This shift to natural gas and higher efficiency coal CHP is ongoing and has been driven in part by China's efforts to improve air quality.

In Korea, district heating covers approximately 15% of households (Euroheat 2017a). Korea District Heating Corporation, a publicly listed state-owned entity, is the primary supplier, with a market share of 55%, covering 1.4 million households and 2,200 commercial buildings (Kang and Fanous 2017). The company also provides district cooling services to a limited number of consumers. At present, 5% of total electricity production is generated through CHP and 67% of district heat is generated by gas-fired CHP plants (Euroheat 2017a).

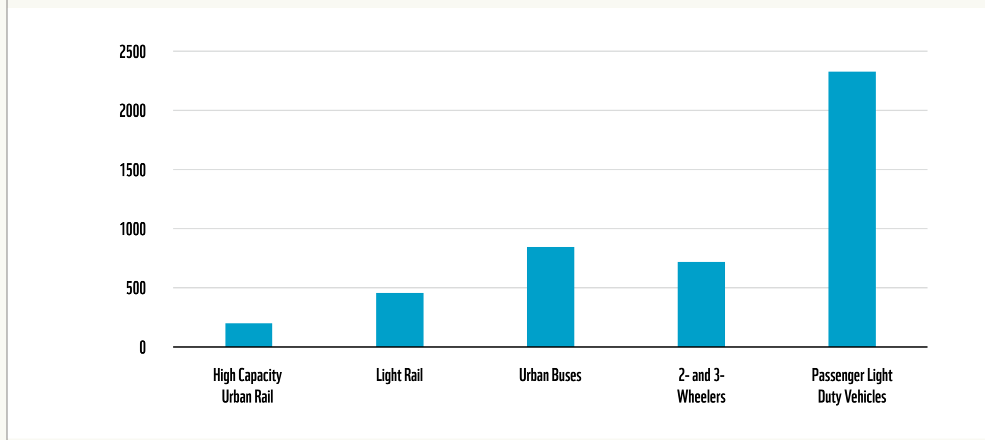
In Japan, there were 77 licensed utilities operating 139 DHC networks as of end-March 2015. These provided 12.3 PJ of cold energy, 9.0 PJ of heat energy and 0.3 PJ of hot water over the previous 12 months. Two-thirds of this was generated by natural gas, with most of the rest split between electricity and waste heat. District energy supplied in Japan has been fairly stable, fluctuating between 20-25 PJ since 2000 (Japan Heat Supply Business Association 2017). Services and other demand constitute the majority of heating sales in Japan, whereas the residential sector plays a minor role (Euroheat 2017b).

In India and the ASEAN region, the tropical climate implies that district cooling demand will be more prevalent than heating demand. Although data is limited, press reports have highlighted individual projects in India, Malaysia, the Philippines, and Singapore. Similarly, district energy is at an early stage of development in Australia and New Zealand, with relatively limited deployment.

Investment Modes

The utility-like nature of DHC means that these services have historically been provided by the public sector, particularly in developing countries. The main business models for private sector participation in DHC include: management agreements, leasing, concession agreements, privatisation, heat entrepreneurship, and energy service companies (IFC 2014). Participation options in DHC with private finance include infrastructure funds, PPP structures, and project or debt finance, potentially alongside a multilateral lender. Direct equity investment is also an option in certain markets, such as South Korea.

Figure 73: Energy Intensity by Urban Transit Mode, kJ/pkm, 2015



Source: IEA (2017c)

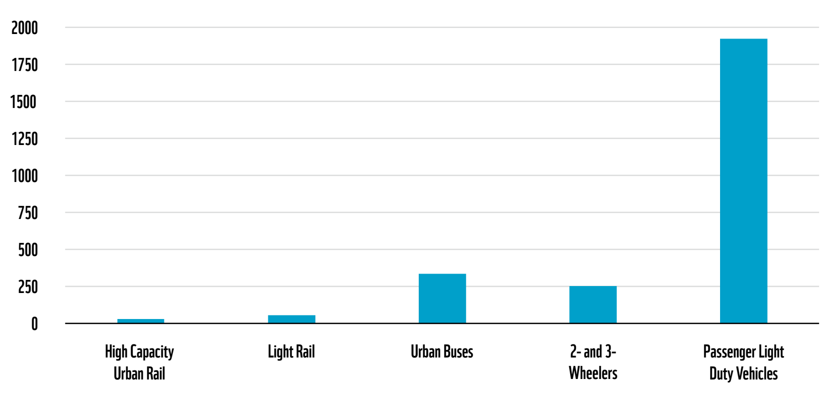
Urban Rail

Urban rail is a broad term that encompasses a wide variety of rail-based transportation types, including streetcars/trams, light rail, and high capacity urban rail. High capacity urban rail includes metros/subways and high capacity/high frequency commuter rail services, designed for large numbers of passengers and whose networks are typically completely segregated from other traffic or level crossings. Light rail and streetcars/trams operate at lower speeds and with fewer passengers per train and may share some or all of their network with other forms of traffic. Both categories of urban rail are typically powered by electricity via a third rail or overhead line, rather than by onboard fuel. (IEA 2017c)

Mitigation Potential and Other Benefits

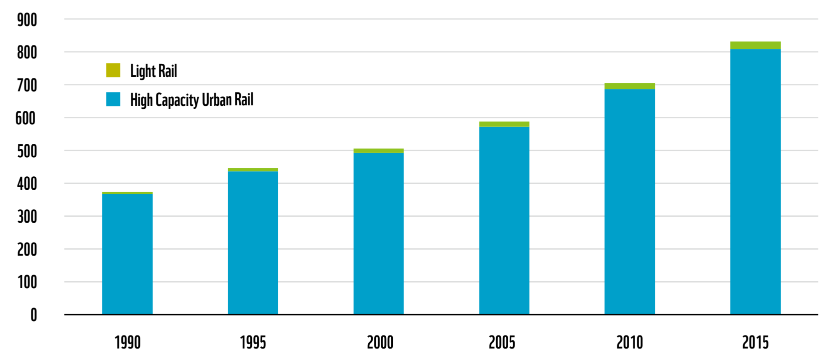
Urban rail is the least energy intensive mode of urban passenger transport, with energy requirements per passenger-kilometre (pkm) for high capacity urban rail coming in below one-tenth the level of passenger light duty vehicles (PLDVs), and light rail requirements at about one-fifth of PLDVs. (IEA 2017c)

Figure 74: CO_2 Intensity by Urban Passenger Transit Mode, gCO_2/pkm, 2015



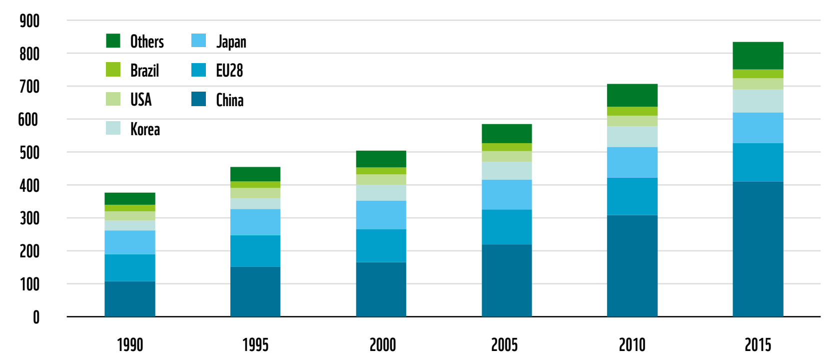
Source: IEA (2017c)

Figure 75: Urban Rail Activity by Mode, billion pkm



Source: IEA (2017c)

Figure 76: Urban Rail Activity by Geography, billion pkm



Source: IEA (2017c)

The low energy intensity of urban rail, combined with their grid-sourced power, translates directly into low CO_2 emissions intensities, which are likely to improve as the electricity system decarbonises.

In addition to the direct emissions benefits of passengers switching from higher-emissions modes, urban rail networks can generate additional benefits within their geographical footprints. These can include higher property prices and more economic activity in the vicinity of stations, reduced or slower growth in vehicle congestion, reduced fuel consumption, and higher/broader access to jobs and/or public services.

Global Context

Globally, high capacity urban rail comprises the vast majority of urban rail activity in passenger-kilometre terms, comprising approximately 400x the activity level of light rail. This is in part due to category definitions – light rail is designed for lower speeds and train capacities – but also because the majority of light rail systems are located in Europe, which has lower population densities than are served by high capacity urban rail. (IEA 2017c)

Despite growing 40% in the 10 years to 2015, urban rail activity holds the smallest share among all forms of urban passenger transport, at about 3% in pkm terms. This compares with an approximately 75% share for PLDVs and 2- and 3-wheelers, and 22% for urban buses. (IEA 2017c)

Asia Context

China has been the primary driver behind the increase in urban rail activity, accounting for almost half of global urban rail pkm in 2015, up from one-third in 1995. Japan and Korea are the two next most active single countries in terms of pkm share, although both are behind the EU28 as a whole.

Beyond China, Japan, and Korea, most large cities in Asia-Pacific have some form of urban rail passenger transit. Notable exceptions include Hanoi, Ho Chi Minh City, and Jakarta, all of which have metro or light rail lines under construction.

Elsewhere in Southeast Asia existing systems are undergoing expansion, with lines being developed or extended in Bangkok, Hong Kong, Kuala Lumpur, Manila, and Singapore, while in Australia, the country's first metro line is under construction in Sydney.

Investment Modes

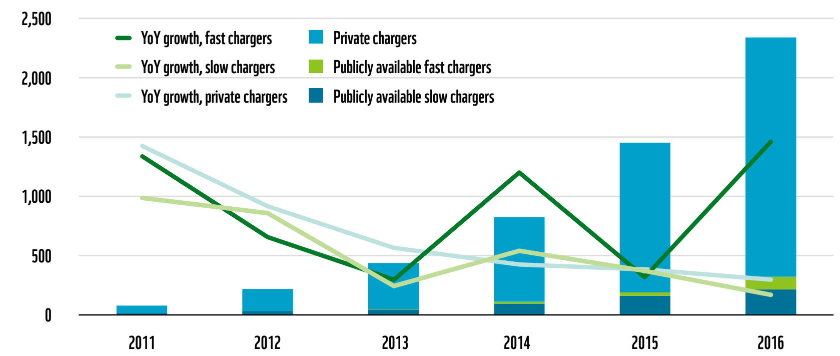
As with other major infrastructure investments, because of the high up-front capex and long-term financial commitment required, investments in urban rail projects have typically been driven by the public sector, although private finance is certainly present in the industry. Whereas in Indonesia and Vietnam, multilateral lenders and official development assistance are financing much of the investment, in Bangkok the BTS Skytrain was developed by a publicly listed company, and following its partial privatisation, Hong Kong's MTR Corporation is also publicly listed. Exposure to the sector for private finance may thus include direct equity and debt, in addition to options such as infrastructure funds, PPP structures, and project finance.

Electrical Charging

While the growth and dynamism of the electric vehicle (EV) sector is well understood, electrical charging networks are a critical enabling technology for them. Despite recent findings that the energy requirements of 87% of vehicle days in the United States could be met by existing EVs (Trancik, et al. 2016), the remaining gap presents a significant barrier to EV adoption for some consumers. By alleviating range anxiety, publicly available charging stations help overcome this barrier and allow for increased market penetration of EVs.

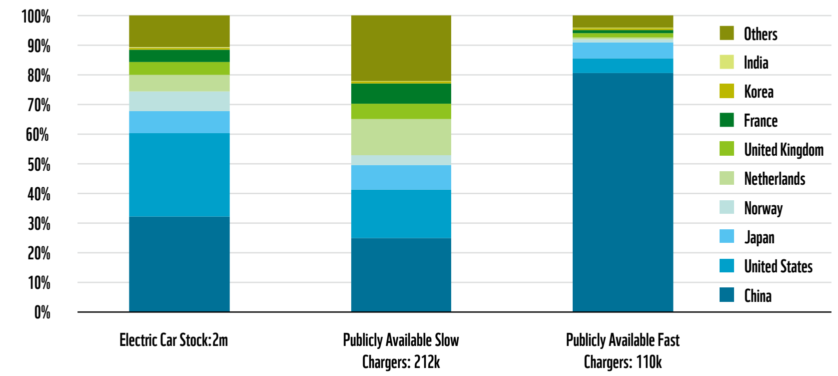
Chargers are characterised by a combination of power level, connector type and communications protocol used between the EV and the charger.

Figure 77: Global EV Charging Outlets and YoY Growth, 2011-2016 (thousands, percent)



Note: Private charger figures assume each EV is coupled with a private charger.
Source: IEA (2017d)

Figure 78: Electric Car Stock and Publicly Available Charging Outlets, by Country and Type of Charger, 2016



Note: Private charger figures assume each EV is coupled with a private charger.
Source: IEA (2017d)

Chargers are classified as Level 1, 2, or 3, which are differentiated ultimately by time of charge. Level 1 generally represents home chargers (6-8 hours), Level 2s are slow chargers (1-4 hours) and Level 3s are fast chargers (10-30 min). At present, there are competing, mutually incompatible standards for chargers of all levels differing by geography and in some cases by company (i.e., Tesla). As it is well recognised that this presents a potential barrier to EV adoption, policymakers and standards bodies are working to minimise cross-border differences (IEA 2017d).

Mitigation Potential and Other Benefits

Charging stations contribute to GHG emissions mitigation by facilitating the growth of the EV market. Within the energy sector, transport is the second-largest subsector in terms of GHG emissions after electricity/heat generation, at 15% of global total emissions. All-electric battery electric vehicles (BEVs) produce no direct emissions, while plug-in hybrid electric vehicles (PHEVs) typically have lower direct emissions than comparable conventional vehicles. EVs have lower GHG emissions than conventional vehicles in lifecycle terms as well, as most emissions for electricity generation are lower than those for burning gasoline or diesel. As the share of electricity generated from zero-emission renewable energy such as solar and wind increases, EV lifecycle emissions are expected to decrease.

Global Context

In 2016, the total number of charging points globally exceeded 2.3 million, up 61% year-on-year. The vast majority of these (86%) are private chargers, estimated by the International Energy Agency at one charging point per EV[4]. The remainder are public charging points, split roughly 2-to-1 in favour of slow chargers.

2016's growth in publicly available charging points was driven mainly by growth in fast charging outlets, which nearly quadrupled thanks to the addition of over 76,000 outlets in China, bringing its total to almost 90,000 outlets.

[4] This estimate assumes that all EV owners with dedicated parking install a home charger, and that those owners without dedicated charging have access to workplace chargers, which are not included in the tally of publicly accessible chargers in Figure 77.

Asia Context

China is the primary driver of the global growth in charging outlets, in line with its position as the country with the most EVs in service. By 2020, China targets the deployment of 4.3m private charging outlets, 500k public chargers for cars and 850 intercity quick-charge stations, among other targets for buses and taxis (IEA 2017d). While most of this investment is expected to be publicly funded, private sector and state-owned companies have also announced plans to develop charging networks.

In Japan, as was widely reported in early 2015, a Nissan survey indicated that the country had more charging outlets than gas stations. This somewhat overstates the situation, as the survey included private outlets. Even so, the 23k publicly available charging outlets as of 2016 was approximately two-thirds the number of gas stations. Of these, 6k were fast chargers. Charging infrastructure rollout funding comes from both public and private sources.

Korea is accelerating its rollout of both slow and fast charging stations. It is targeting 6,000 fast charging outlets by 2020, up from 750 in 2016, and has relaxed regulations that limited public slow charging outlets to locations with more than 100 parking spaces. Although the government has not articulated a slow charging outlet target, now any building with the space for parking, chargers and maintenance personnel may establish an outlet (Yonhap 2017). Kepco, the publicly listed state-owned electricity utility, is charged with building at least half of the targeted outlets (Korea Herald 2017).

India's EV market is still at a very early stage of development, with less than 5,000 vehicles and 500 public charging outlets (fast and slow) as of 2016 (IEA 2017d). This may change rapidly, as the government has proposed a target of full electrification of the domestic vehicle fleet by 2030 (IPIB 2017). In support of this goal, the Ministry of Heavy Industries recently adopted recommendations for the implementation of national standards for publicly available charging stations (IDHI 2017).

Australia's EV market is similar to India's in size, with just over 5,000 vehicles sold from 2011-2016 and just under 500 public charging outlets, 40 of which are fast chargers. While there is no policy support at the national level, just over half of states and territories provide or are considering the provision of financial support for charging infrastructure (ClimateWorks Australia 2017).

Investment Modes

The public sector can and has been playing a role in developing electric charging infrastructure, particularly with respect to policy mandates and standard-setting. However, in most regions where EVs are approaching wider adoption, the ubiquity of the electricity grid means that the incremental infrastructure requirements for a charging station are not capital-intensive, particularly relative to other energy sector investments. As such, in addition to the public sector, electricity utilities and vehicle manufacturers, other private sector players are developing regional, national and international business models for EV charging networks. This implies a wide variety of exposure options for private finance, from early-stage venture capital in the case of a hypothetical start-up charging service business model, to public/private equity or debt investments in a utility/spin-off pursuing something similar.

Electric car charging station in Changwon, South Korea. Charging stations contribute to GHG emissions mitigation by facilitating the growth of the EV market.

The overlap between adaptation and development assistance implies that pure-play exposure to adaptation investments via listed equities is uncommon.

Extreme weather and rising sea levels are a threat to coastal cities. Infrastructure such as this tetrapod wall in Tokyo Bay is built to reduce the impact of wave energy on coastal landscapes.

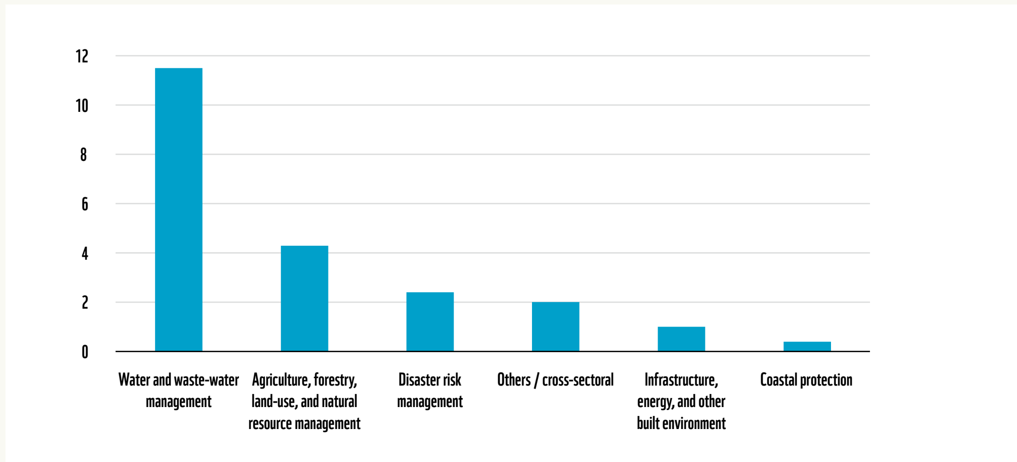
ADAPTATION

In the context of climate change, adaptation is defined as action taken or investments made to anticipate and prevent or reduce the negative effects of climate change on human and natural systems. These effects generally fall under the category of physical risk discussed in the Science chapter and affect areas such as agriculture, forestry and fisheries, water supply, human health, coastal zones, and infrastructure.

This spectrum of affected sectors overlaps significantly with development assistance. As a result, much of the investment into adaptation is driven by the public sector, including governments, official development assistance, and multilateral institutions. This implies that most potential adaptation investments will have some form of public finance linkage, whether in the form of a public-private partnership or via instruments such as green bonds or project bonds. It also implies that pure-play exposure to adaptation investments via listed equities is uncommon; rather, such exposure is embedded in the companies that may be involved.

In recent years, public investment in adaptation has focused on water and waste-water management, with over half of adaptation funds invested in that area. Agriculture, forestry, land use, and natural resource management was the next largest area of adaptation investment, with another fifth of adaptation funds invested (CPI 2017). Figure 79 below shows the average annual public investment in adaptation over 2015-16 for the primary sectors involved.

Figure 79: Average Annual Public Investment in Adaptation, 2015-16, Most Notable Sectors (USD bn)



Source: CPI (2017)

In Asia, the ADB has assessed numerous technologies for their potential suitability to meet the needs of adaptation in developing Asia (ADB 2014). While most of these are funded through public finance channels, those that include established private sector/finance involvement are presented in Table 15 below.

Table 15: Adaptation Technologies Relevant to Developing Asia With Private Sector Involvement

Technology	Description	Adaptation Need Met
Agriculture		
Crop breeding	Selective breeding for tolerance to temperature extremes, pests and diseases	Increase crop resiliency
Laser land levelling	Improve the precision of pre-planting field levelling to reduce runoff	Reduce crop water demand and agricultural water waste
Pressurised irrigation technologies	Precision irrigation to deliver water more efficiently and reduce evaporative loss	Reduce crop water demand and agricultural water waste
Coastal Resources		
Structural barriers	Levees, dikes, sea walls, tide gates, storm surge barriers	Coastal protection
Beach nourishment and dune construction	Artificial addition of sediment to a beach area with a sediment deficit; shaping sediment into dunes	Coastal protection
Human Health		
Long-lasting insecticidal bed nets	Bed nets treated with pyrethroid insecticides at the time of manufacture	Lessen the impact of changes in vector-borne diseases
Disease surveillance systems	IT devices and applications that can assist health professionals in collecting, processing, interpreting, and disseminating data more efficiently to support infectious disease monitoring and response	Incorporate advanced IT into the health sector
Water Resources		
Surface water storage	Reservoirs, cisterns, tanks and ponds to collect and store water for future use	Water quantity
Desalination	Make saltwater or brackish water suitable for human consumption, irrigation, or other uses	Water quantity
Structural barriers to flooding	Dams, dikes, locks, and levees	Inland flooding
Disaster Risk Management		
Artificial lowering of glacial lakes	Reduce likelihood of glacial lake outburst floods	Reduce disaster-related risk and lower residual risk
Early warning systems	Forecast and warn of near-term weather-related extreme events such as heat waves, flooding, coastal storms, fires, and mudslides	Reduce disaster-related risk and lower residual risk

Source: ADB (2014)

Investments in adaptation are also sometimes referred to as investments in resilience or climate resilience. It is under this label that listed equity investors may be able to generate exposure to the adaptation space, however indirectly. Resilience could be a feature of a risk management strategy, where investment funds are directed toward assets with lower long-term physical climate risk, or to companies that are systematic about disaster management planning for their operations. Alternatively, resilience could be treated as a business opportunity, with funds allocated to companies involved in providing climate resilience services, such as climate data and analytics services, catastrophe modelling, and insurance (Koh, Mazzacurati and Trabacchi 2017).

IMPLICATIONS FOR INVESTORS

Across the landscape of mitigation and adaptation investment, it seems clear that the mitigation space offers a wider range of investment opportunities and vehicles that are compatible with the current investment processes of asset owners and managers. This is especially the case for those investors whose mandates focus on secondary market instruments such as listed equities.

Asset owners and managers who are able to provide direct investment or debt finance in particular are less limited in their investment options, as across both the mitigation and adaptation spaces, market rate debt via project or corporate finance is the primary form of project funding. This averaged USD219bn per year for 2015-16 and comprised 54% of trackable climate finance flows of USD410bn/year. Of that amount, private sector primary finance flows averaged USD270bn/year over the period, with institutional investors, private equity, venture capital and infrastructure funds providing an average of just USD3bn/year, according to the Climate Policy Initiative's (CPI) Global Landscape of Climate Finance (CPI 2017).

This likely understates the activity level of these investors, as CPI does not yet track follow-on activities such as refinancing, project disposals or acquisitions, or investments into project developers. However, it is clear that there is plenty of room for these investors to increase their exposure to climate-related projects if the right vehicle can be designed.

To that end, work is ongoing at a variety of initiatives, such as the Global Innovation Lab for Climate Finance, to configure climate investment opportunities in ways that make institutional investor participation more feasible. In addition, public finance from multilateral or governmental sources such as development banks or climate funds can and has been playing a key role in attracting this kind of adjusting the risk profile of projects with risk mitigation instruments like long-term loans, concessional rates, and grants. These are discussed further in the next chapter.

"AS COMPARED TO ADAPTATION, THE MITIGATION SPACE OFFERS A WIDER RANGE OF INVESTMENT OPPORTUNITIES AND VEHICLES THAT ARE COMPATIBLE WITH THE CURRENT PROCESS OF ASSET OWNERS AND MANAGERS, PARTICULARLY FOR THOSE WHOSE MANDATES FOCUS ON SECONDARY MARKET INSTRUMENTS SUCH AS LISTED EQUITIES."

FINANCE

A 2017 survey found that 68% of global investors plan to increase their investment into climate-related or low carbon themes.

Central, Hong Kong

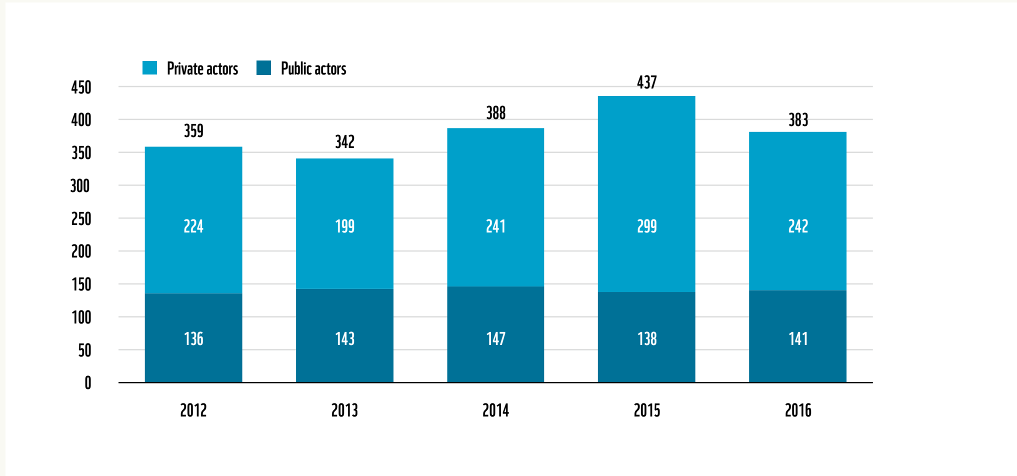
In 2015-16, climate finance flows from all public and private actors averaged USD410bn per year, 12% more the annual average of the previous two years.

Young adult female Bornean orangutan (*Pongo pygmaeus*) called Walima, hanging from a tree in Borneo. Native to only two islands, Sumatra and Borneo, orangutans are threatened by deforestation, fire and climate change. In Borneo, their numbers have fallen by 60 percent since the 1950s and are projected to decline even further over the next decade to a mere 50,000.

Climate finance flows originate ultimately from public or private sources. On the public side are governments and various public financial intermediaries, while the private side includes corporates, households, project developers, and private financial intermediaries.

In 2015-16, climate finance flows from all these parties averaged USD410bn per year, 12% more the annual average of the previous two years. This increase was driven by a large increase in private sector investment in 2015, particularly in renewable energy in China and rooftop solar PV in the US and Japan (see Figure 80 below). The decrease in finance in 2016 vs. 2015 was due to a combination of lower technology costs and reduced activity levels in some countries, particularly China. (CPI 2017)

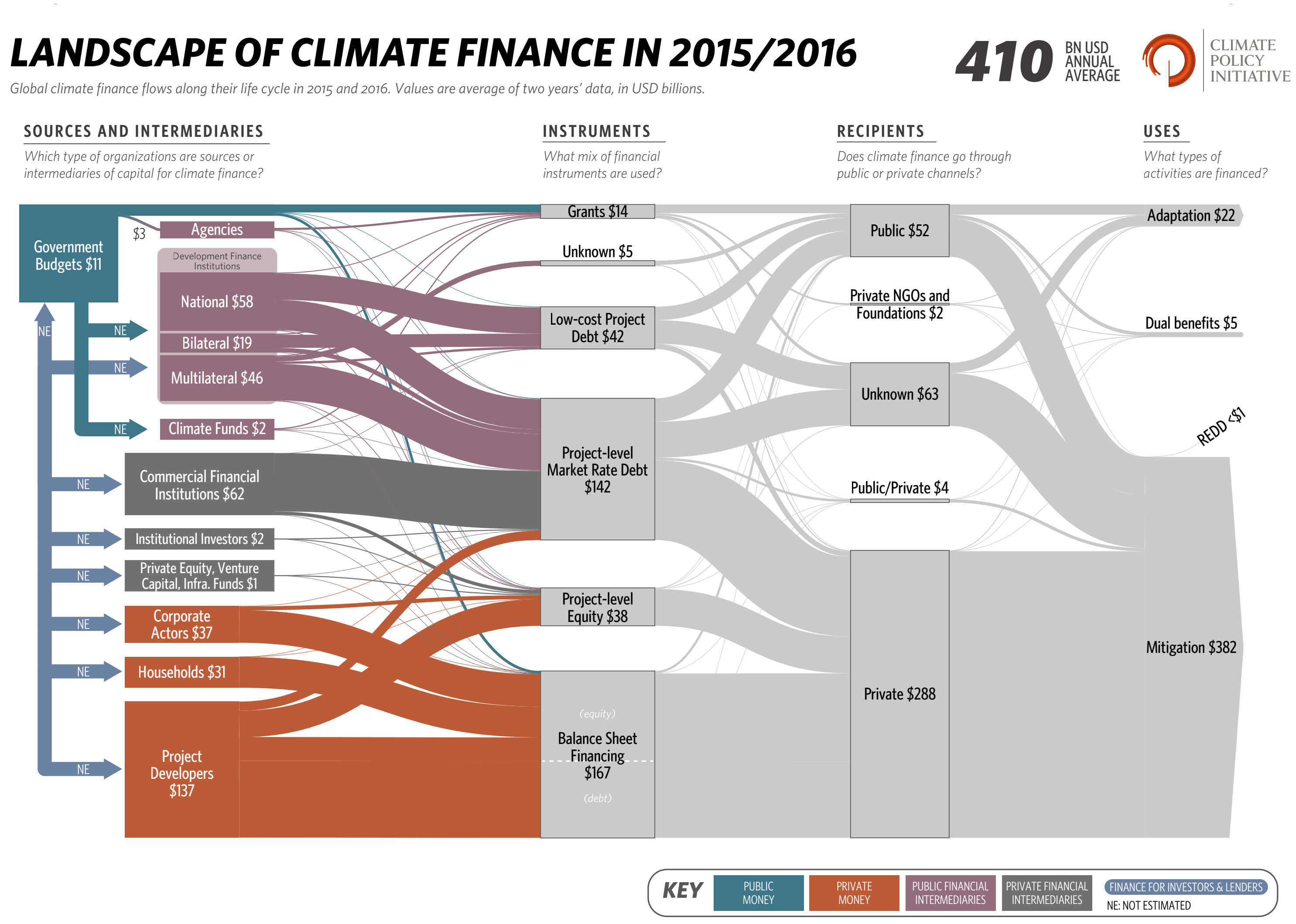
Figure 80: Breakdown of Global Climate Finance by Public and Private Actors, 2012-16 (USD bn)



Source: CPI (2017)

The CPI's annual Global Landscape of Climate Finance report provides a valuable overview of climate finance flows across the life cycle of activities, from sources and intermediaries to instruments, recipients, and uses. It shows that mitigation receives the vast majority of investment dollars: an annual average over 2015-16 of USD382bn out of USD410bn. Private sector project developers were the largest single source of finance, providing over one-third of the total, while average annual market rate debt of USD219bn per year was the most important instrument used to channel climate finance flows. It should be noted, however, that the CPI report excludes several significant funding sources and investment sectors from its landscape due to data limitations (see note, Figure 81), with the result that the landscape likely understates the level of climate finance flows from both the public and private sectors.

Figure 81: Landscape of Climate Finance (Primary Financing) in 2015/16



Note: Due to data limitations, excludes all public domestic finance from governments, and private investments in energy efficiency, transport, land use, and adaptation.
Source: CPI (2017)

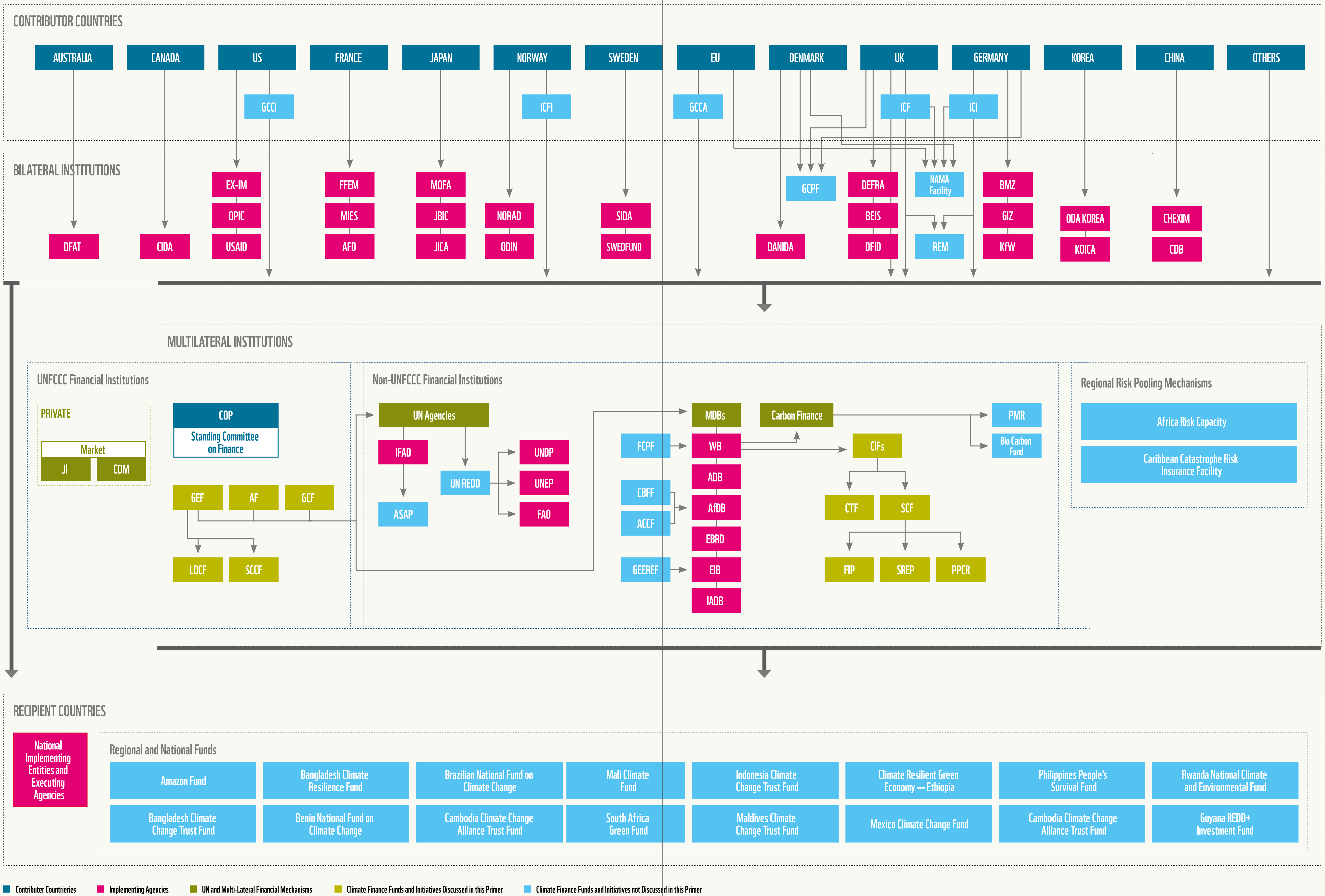
PUBLIC FINANCE

Public finance is a crucial player in addressing climate change, in particular by getting the private sector to focus a portion of its far-larger resource base on the problem (or on particular sub-elements). In combination with the appropriate policies and regulatory environment, public finance can help stimulate and direct flows of private capital by demonstrating feasibility, creating markets, fostering innovation, and reducing risk. In addition, public finance also provides critical support for delivering those public goods – such as many adaptation projects – that the private sector is unwilling or unable to provide. (Amerasinghe, et al. 2017)

Public climate finance players include multilateral development banks, official development assistance agencies, other official sources of funding, and a variety of multilateral and bilateral climate investment funds. All of these players are involved in some combination of mitigation, adaptation, or the building of capacity at the national or subnational level to improve a given country's ability to develop and implement climate projects (see Figure 82).

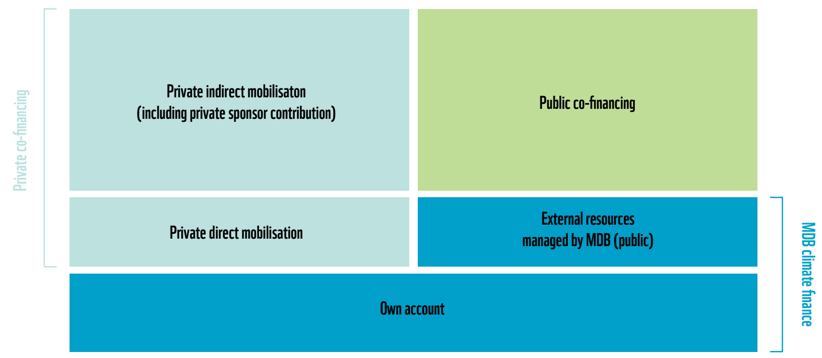
Shinjuku, Tokyo, Japan

Figure 82: Global Architecture of Public Climate Finance



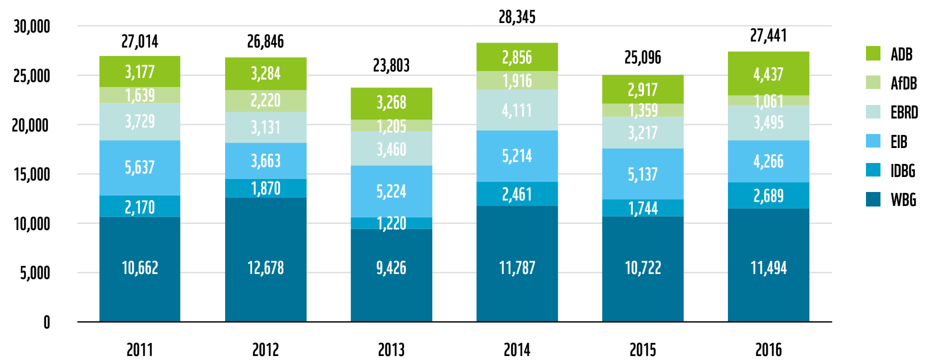
Note: This schematic is indicative and does not capture all countries, climate funds and initiatives. Further details on the bilateral institutions are available in Table 19.
Source: Amerasinghe, et al. (2017)

Figure 83: Total MDB Activity Financing, by Type of Finance



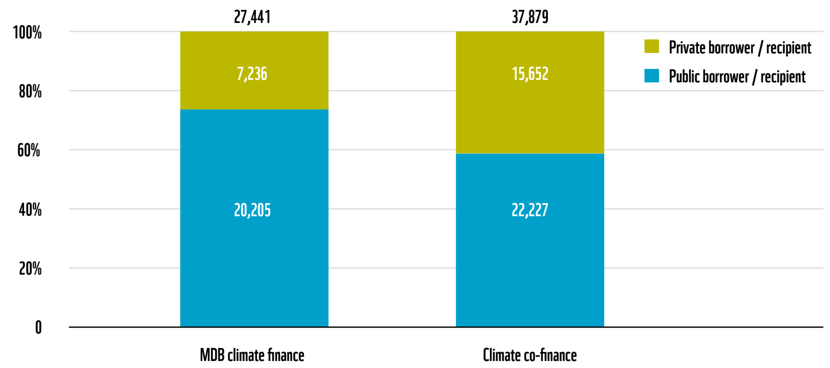
Source: EBRD, et al. (2017)

Figure 84: Reported MDB Climate Finance Commitments, 2011-16 (USD mn)



Notes: 1. In the years 2011-14 the numbers for WBG only included IFC and WB, and IFC included short-term finance (such as trade finance). In 2015 and 2016, IFC short-term finance has not been included. MIGA (Multilateral Investment Guarantee Agency) finance has been included since 2015.
2. EIB climate finance figures are restricted to developing and emerging economies in transition. In the years 2011-15 this excluded the EU-15. For 2016 the data is for the "EU-12", thereby excluding a number of EU Member States (including the Czech Republic and Malta), where the EIB is also active. In 2016, the numbers for the EBRD and EIB also include Greece.
3. IDBG numbers in the MDB joint reports include activity of the IIC only since 2015. IDBG corporate reports provide information for the corresponding year of approval by the respective Board of Executive Directors.
4. Numbers may not add up to the totals shown, due to rounding.
Source: EBRD, et al. (2017)

Figure 85: Total MDB Climate Finance and Net Climate Co-finance, 2016 (USD mn)



Source: EBRD, et al. (2017)

PUBLIC FINANCE PLAYERS

Multilateral Development Banks (MDBs)

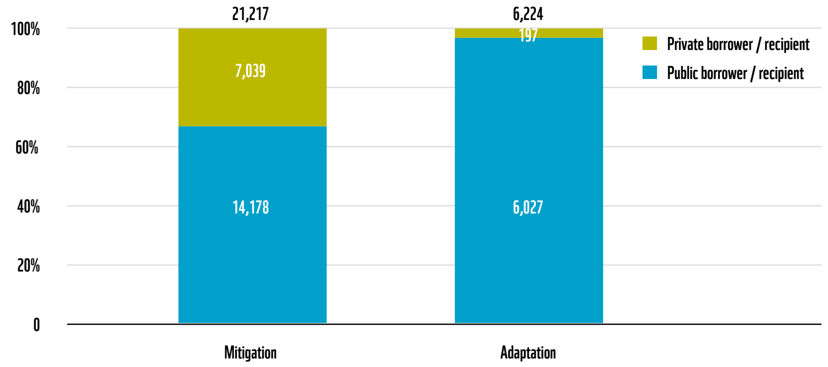
Multilateral development banks are financial institutions established by a group of countries to provide financing and advisory services for the purpose of development. Members of the banks include both developing-country borrowing nations and developed-country donor nations.

The majority of financing provided by MDBs is in the form of loans, either at market or below-market ("concessional") rates for specific projects. Project support may also come in the form of: equity; grants; other risk-sharing instruments such as guarantees; technical assistance; and other advisory activities. A key element of the value proposition of MDB involvement in a project is its ability to lower the project's financial risk profile and thus attract ("mobilise") additional external sources of funding.

Funding for the banks' financing operations generally comes from members' capital subscriptions, donor nations, and market rate bond issuance. Many of the banks also act as channels for multilateral investment funds such as the Green Climate Fund.

All of the MDBs are heavily involved in financing climate mitigation and adaptation projects, having committed over USD158bn in such projects from 2011-16. In 2016, climate finance of USD27bn comprised 20% of financing operations at the 6 primary MDBs. After including mobilised co-financing, total climate financing at these MDBs was USD65.3bn (EBRD, et al. 2017). About two-thirds of this aggregate total was allocated to public entities, with the remainder going to private enterprises. Ahead of the Paris Conference, the primary MDBs pledged to increase the share of climate finance to 20-40% of financing per year by 2020.

Figure 86: MDB Climate Finance by Project and Borrower Type, 2016 (USD mn)



Source: EBRD, et al. (2017)

Mitigation projects are the primary recipients of MDB climate finance, garnering 77% of flows in 2016 (EBRD, et al. 2017). Mitigation is also where the vast majority of MDB-involved private sector is taking place, with 97% of private sector recipients focusing on this area.

African Development Bank (AfDB)

The African Development Bank aims to reduce poverty by fostering sustainable economic development and social progress in its regional member countries. To do this, it mobilises and allocates resources for investment in its member countries and provides policy advice and technical assistance to support development efforts. These investment resources come to the AAA-rated bank primarily from international capital markets; the bank's 2018 borrowing plan targets USD8bn to be raised. Green bonds comprise a portion of the bank's resource base, with 6 green bonds in USD, AUD and SEK issued since 2013, with a face value of USD1.3-1.5bn in aggregate.

Although the AfDB does not provide financing outside of Africa, a number of the bank's non-regional member countries are Asian, including China, India, Japan, and South Korea.

Climate Activities

Following the development in 2009 of the bank's Strategy of Climate Risk Management and Adaptation, all investments financed by the bank are "climate-proof," in that they are designed to minimise the adverse effects of climate change as cost-effectively as possible.

The bank has financed the development of geothermal energy in Kenya, wind farms in South Africa and Kenya, solar thermal power in Morocco, renewable energy development in Mali, and adaptation projects in Burundi and West Africa.

Asian Development Bank (ADB)

The ADB's overarching goal is the reduction of poverty. As such, it works with member governments, independent specialists, and other financial institutions to deliver projects that create economic and development impact. The bank provides loans, technical assistance, and grants to its clients, who are the bank's member governments as well as its shareholders. The bank also assists private sector enterprises in developing member countries via equity investments and loans. The bank has 67 members, of which 48 are from within Asia.

The bank focuses its efforts on a limited range of areas, including:

- Infrastructure (energy, information and communications technology, transport, urban development, water)
- Environment
- Regional cooperation and integration
- Finance sector development
- Education

To a limited extent, the bank also operates in the areas of health, agriculture and natural resources, and public-sector management.

The bank's loan funding comes from a combination of capital market bond issues, member contributions, retained earnings from lending operations, and the repayment of loans. In 2017, total ADB lending assistance including co-financing reached USD28.9bn, of which USD19.1bn came from the ADB's own resources. Private sector lending reached USD3.2bn, and climate finance grew to a record USD4.5bn.

Climate Activities

The ADB approved almost USD20bn in climate financing from 2011-2016, of which USD17bn came from the ADB's own resources. The bank has pledged to reach USD6bn in annual climate financing from its own resources by 2020, with two-thirds aimed at mitigation and the rest at adaptation.

In addition to reporting its overall climate investment and greenhouse gas footprint, the bank has started to disclose information on each of its projects that involves climate mitigation or adaptation finance, starting with its activities in 2016. Information on the 149 relevant projects from that year, together with various cross-cuts of the top-line data, can be seen and downloaded via the bank's Climate Change Financing Dashboard.

Asian Infrastructure Investment Bank (AIIB)

The AIIB is a newly established multilateral development bank with a mission "to improve social and economic outcomes in Asia and beyond." The bank was proposed by the government of China and commenced operations in January 2016. China holds the largest voting power in the bank, at 26.9%, followed by India with 7.7%. The bank has 42 regional members, 23 non-regional members, and 19 prospective members (regional and non-regional). Notably absent are Japan and the USA.

AIIB offers sovereign and non-sovereign financing for sustainable projects in the areas of energy and power, transportation and telecommunications, rural infrastructure and agricultural development, water supply and sanitation, environmental protection, and urban development and logistics. These are consistent with its emerging thematic priorities of sustainable infrastructure, cross-country connectivity, and private capital mobilisation.

The bank's Articles of Agreement allow it to provide financing in a variety of ways, including making loans, investing in the equity capital of an enterprise, and guaranteeing loans for economic development. The bank may also underwrite or participate in the underwriting of securities issued by any entity for purposes consistent with the bank's mission.

As at 30 September 2017, the bank had USD18.5bn in members' equity (not including USD74.4bn in callable capital) and was carrying loan assets of just USD638mn. This is likely a reflection of the newness of the bank as well as of the timing of loan disbursements for approved projects, as loan approvals for 2016 reached USDD1.7bn for nine projects, and USD2.6bn for 15 projects in 2017.

Climate Activities

As sustainable infrastructure development is one of the bank's thematic priorities, it could be argued that the majority of the bank's loan book is green. Although bank executives have said that AIIB will not finance coal investments, natural gas pipelines and power plants are on the bank's project list. The bank's Sustainable Energy for Asia Strategy has the bank focusing on renewable energy, energy efficiency, rehabilitation and upgrading of existing plants, and transmission and distribution networks. 2017 project approvals are detailed in the table below.

Table 16: AIIB Loans Approved, 2017

Project Name	Sector	Country	AIIB Amount (USD mn)	Project Amount (USD mn)	MDB Co-Finance (USD mn)
Natural Gas Infrastructure and Efficiency Improvement Project	Energy	Bangladesh	60	453	ADB - 167
Dam Operational Improvement and Safety Project Phase II	Multi	Indonesia	125	300	WB - 125
Regional Infrastructure Development Fund	Urban	Indonesia	100	406	WB - 103
Andhra Pradesh 24x7 – Power For All	Energy	India	160	571	WB - 240
Nurek Hydropower Rehabilitation Project	Energy	Tajikistan	60	350	WB - 226, EADB - 40
India Infrastructure Fund	Multi	India	150	750	None
Batumi Bypass Road Project	Transport	Georgia	114	315	ADB - 114
Gujarat Rural Roads (MMGSY) Project	Transport	India	329	658	None
Round II Solar PV Feed-in Tariffs Program	Energy	Egypt	209	825	IFC et al. - 451
Metro Manila Flood Management Project	Water	Philippines	208	500	WB - 208
IFC Emerging Asia Fund	Multi	Asia	150	640	IFC - 150
Transmission System Strengthening Project	Energy	India	100	303	ADB - 50
Beijing Air Quality Improvement and Coal Replacement Project	Energy	China	250	761	None
Broadband Infrastructure Project	Telecoms	Oman	239	467	None
Bangalore Metro Rail Project – Line R6	Transport	India	335	1,785	EIB - 583

Source: AIIB

European Bank For Reconstruction And Development (EBRD)

The EBRD provides project finance, primarily in the form of loans, minority equity investments, and guarantees, to new or existing enterprises in its countries of operation, which include almost 40 countries ranging from central Europe to the Middle East and central Asia. In addition, the bank provides business advisory services and loan syndications, and promotes trade finance.

In Asia-Pacific, the only country in which the EBRD operates is Mongolia. Asia-Pacific shareholders in the bank include Australia, China, Japan, New Zealand, and South Korea.

Climate Activities

From 2006-2015, green financing comprised an average of 24% of the bank's annual investments. Ahead of the Paris Conference in December 2015, the bank launched its Green Economy Transition approach, which targeted green financing of 40% of annual business investments. The bank recently announced that it had reached that target early, with green financing of EUR4.1bn comprising 43% of total financing in 2017 (EBRD 2018).

Recent investment projects include biogas CHP plants in Belarus, energy efficiency in Ukraine, PV solar in Kazakhstan, railway modernisation in Tunisia, and residential energy efficiency in Romania.

European Investment Bank (EIB)

The EIB is owned by the 28-member nations of the European Union, and serves as the EU's long-term lending institution, promoting European economic development and integration. It is the world's largest international public bank. Its activities are mainly funded by international capital market bond issuance. In 2018, the bank's funding programme is EUR60bn. The bank's products include large benchmark/reference bonds, public bonds, and private placements.

The bank operates globally, with mandates broken down by geography. The current mandate for Asia and Latin America runs from 2014-2020 and has a ceiling of EUR3.4bn, of which EUR1.1bn is allocated to Asia.

Asian countries eligible for EIB financing under the current mandate are: Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Iraq, Laos, Malaysia, Maldives, Mongolia, Myanmar/Burma, Nepal, Pakistan, the Philippines, Singapore, South Korea, Sri Lanka, Thailand, Vietnam, and Yemen

Climate Activities

The EIB was a pioneer of green bonds, issuing the world's first Climate Awareness Bond (CAB) in 2007. Since that first issue, the bank has raised EUR18bn of CAB funding, with the proceeds financing 160 renewable energy and energy efficiency projects globally. In 2017 27% of the bank's investments went to projects supporting climate change mitigation or adaptation, and the bank has committed to increasing that share to 35% by 2020.

Table 17: Selected European Investment Bank Climate-Related Activities in Asia

Country	Activity	Category	Selected Results / Details
China	Framework loan to China's Eximbank for renewable energy and energy efficiency	Mitigation, adaptation	• Framework loan to finance diverse sizes of sub-projects eligible under the EIB's Climate Action and Environment Facility • EUR300mn sovereign loan to be on-lent by Eximbank in 2017-2020 • Focus on energy, transport, water and sewerage
India	Framework loan to India Renewable Development Agency for renewable energy and energy efficiency	Mitigation	• Framework loan to fund small and medium scale capital investments in renewable energy and energy efficiency in India • EUR119.2mn allocated from CAB portfolio
India	Framework loan to India Infrastructure Finance Company for energy sustainability and climate action	Mitigation	• Framework loan to support renewable energy and energy efficiency projects that contribute to climate change mitigation • EUR85mn allocated from CAB portfolio
India	Framework loan to EXIM Bank of India	Mitigation	• Framework loan to support renewable energy and energy efficiency projects that contribute to climate change mitigation • EUR36mn allocated from CAB portfolio
India	Bangalore Metro	Mitigation	• EUR500mn loan to support the construction of a new 18 station rapid transit line, and the purchase of 96 train cars • AIIB expected to join the financing, marking the first EIB / AIIB joint financing • EIB's largest-ever investment in India

Country	Activity	Category	Selected Results / Details
India	Lucknow Metro	Mitigation	• EUR450mn loan to support the construction of the first 23km of the new metro system, and the purchase of 80 metro cars • Projected to increase public transport share of trips in Lucknow from 10% to 27% by 2030, reducing air pollution and vehicle GHG emissions
Nepal	Nepal Power System Expansion Project	Mitigation	• Renewable energy investment supporting transmission • EUR77k allocated from CAB portfolio
Vietnam	Hanoi Metro Line 3	Mitigation	• EUR73mn loan in 2010, followed by an additional EUR68mn in 2017, to support the construction of the 12.5km metro line, purchase rolling stock and equip a new depot • Projected daily ridership of 200k

Source: EIB

Inter-American Development Bank Group (IDB GROUP)

The IDB Group is comprised of the Inter-American Development Bank (IDB), the Inter-American Investment Corporation (IIC), and the Multilateral Investment Fund (MIF). IDB is the largest source of development finance for Latin America and the Caribbean. The bank provides loans, grants, and technical assistance, and conducts extensive research. Over more than 55 years of activity, the IDB has approved more than $260 billion in loans for projects in key sectors such as transportation, energy, education, health, and water and sanitation, with an emphasis on poverty reduction. The bank approved USD11.5bn in loans and credit guarantees in 2016, of which USD2.2bn was for non-sovereign guaranteed operations in the private sector.

The bank's ordinary capital is the source of the majority of its lending. As of end-2016, its callable capital stock was USD165bn, with paid-in capital of USD6bn and retained earnings of USD20.1bn. The bank also sources lending funds from the capital markets, issuing USD15.6bn in bonds in 2016.

Although the IDB does not provide financing outside of Latin America and the Caribbean, a number of the bank's non-borrowing member countries are Asian, including China, Japan, and South Korea.

Climate Activities

The IDB's active climate finance portfolio consists of 24 projects in 13 countries with IDB financing of USD1.8bn. Sectors receiving loans include general climate change financing, adaptation policy, environmental management and governance, forest resources management, integrated disaster risk management, coastal zone management, and emergency response.

World Bank Group (WBG)

The World Bank Group provides low-interest loans, zero to low-interest credits, and grants to developing countries as part of its mission to end extreme poverty and promote shared prosperity. The group consists of five organisations: the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA), which together make up the World Bank (WB); the International Finance Corporation (IFC); the Multilateral Guarantee Association (MGA); and the International Centre for Settlement of Investment Disputes.

Climate Activities

The World Bank Group's climate practice focuses on climate finance, disaster risk management, and climate-smart agriculture. Headline figures for the Group's climate finance activities include:

- World Bank Group: Over USD10bn per year in commitments to more than 1,000 climate mitigation and adaption projects since FY2011 (12 months to end-June 2011).
  - FY2016 climate financing of USD10.4bn for 177 projects.
- IFC: USD18.3bn in climate-related long-term investments from the IFC's own account since 2005, with an additional USD11bn mobilised.
  - FY2016 figures are USD2bn and USD1.3bn, respectively.
- The World Bank and IFC are among the largest global issuers of green bonds, with over USD16bn in 212 green bonds as of September 2017.
- Conditional commitment to raise climate financing to 28% of the Bank Group's portfolio by 2020, implying a potential USD29bn per year for climate projects by then. (World Bank 2018)

Table 18: Selected World Bank Group Climate-Related Activities in Asia

Country	Activity	Category	Selected Results / Details
Bangladesh	WB-financed electrification project to promote off-grid electricity in rural communities	Mitigation / development	• Over 3.5mn solar home systems installed in rural Bangladesh • 70,000 direct jobs created
Bangladesh	IDA USD324mn emergency recovery loan (2008-2018): Emergency Cyclone Recovery and Restoration Project	Adaptation / emergency recovery	• 300 new cyclone shelters built, 459 repaired • 498 km of coastal embankment rehabilitated • Long-term disaster management program implemented
Bangladesh	USD2bn WBG funding pledge over 2017-2020 to help Bangladesh reduce vulnerability to climate change	Adaptation	• n/a
China	IFC committed USD200mn in 2017 to Kingenta, China's largest specialty fertilizer manufacturer, to help transform it into an integrated agribusiness solutions provider	Mitigation / development	• USD70mn in equity, USD75mn IFC senior loan, USD135mn from other sources • Will establish crop protection service centres to promote precision agriculture and address declining soil quality • Expected avoidance of 377 ktCO$_2$e per year
Nepal	WB-facilitated USD59mn financing of micro-hydro plants across Nepal since 2007	Mitigation / development	•13.4 MW of generating capacity constructed across 426 locations • At least 100k tonnes of CO_2 emissions avoided annually
Philippines	IFC Sustainable Energy Finance Program (SEF) provided advisory services and initial concessionary financing to attract local banks to lend to sustainable energy projects (renewable energy and energy efficiency)	Mitigation	• Initial USD10mn developed into a full investment platform funded by the Global Environment Facility and the Clean Technology Fund (CTF). • Over 300 projects, 87 of which were financed by local banks • 1m tonnes per year of carbon emissions avoided
Thailand	IFC replica of Philippines SEF provided USD12mn in blended finance with CTF to Thailand's Solar Power Company Group (SPCG) to jump-start Thailand's solar power market in 2010	Mitigation	• SPCG installed capacity grew from under 10MW to over 250MW between 2010-2014 • Over 200k tonnes per year of carbon emissions avoided • Thailand solar PV generating capacity increased from 30MW in 2006 to 2,149 MW in 2016, with a target of 3,000 MW by 2021
Vietnam	World Bank non-lending technical assistance to Vietnam's national utility to promote the deployment of renewable energy via the installation of five solar measurement stations nationwide	Mitigation	• Solar measurement stations came online in September 2017, and will collect two years of data to validate and enhance the World Bank's previous solar resource maps for Vietnam • The data will be published and made available freely online, to be a resource for solar developers in Vietnam

Source: World Bank, IFC

Official Development Assistance (ODA)

Most developed countries, and some richer developing countries, provide some form of development assistance to less-developed nations. In the jargon of aid, this is termed official development assistance (ODA) or official aid (OA). The aid provided may be provided directly, channelled through the provider's development agency or relevant government department (typically, the Ministry of Foreign Affairs or equivalent), or contributed to one or more multilateral institutions such as MDBs or funds.

As defined by the IMF, ODA financing must: a) come from official sources (governments or their agencies); b) have as its main objective the promotion of the economic development and welfare of developing countries; and, c) be concessional in nature, with a grant element of at least 25% (using a fixed 10% rate of discount). Lending by export credit agencies that is purely for export promotion is excluded. (IMF 2003)

Countries and territories with GNI per capita below USD12,745 in 2013, as published by the World Bank, are eligible to receive ODA, with the exception of G8 members, EU members, and countries with a firm date for entry into the EU (OECD 2017a). Countries above that threshold may receive OA but not ODA.

The eligible countries and territories are categorised by income level (least developed, other low income, lower-middle income, upper-middle income), which may be used to differentiate the concessional terms of the aid given. For example, at the Japan International Cooperation Agency (JICA), ODA loans to low-income least developed countries are offered with a 40-year repayment period, an interest rate of 0.01%, and a 10-year grace period. In contrast, ODA loans from JICA to borrowers from upper middle-income countries may be fixed or floating rate, and have varying repayment periods (15-40 years) and grace periods (5-12 years), with the level of interest rate charged dependent on whether or not the purpose of the loan is a high priority for JICA. "Quality" infrastructure projects are in the highest priority category, with projects addressing environmental and climate change issues, health/medical care and services, disaster prevention and reduction, and human resource development in the next-highest category. All other projects receive the agency's general terms.

The OECD's Development Assistance Committee (DAC) is the forum for OECD members with development activities to discuss aid and development issues. It has 30 members, who collectively provided USD145.5bn in ODA in 2015. Of this total, 24% was channelled via various multilateral institutions. Of the remaining US110.6bn that was provided bilaterally,

USD45.1bn (31% of bilateral aid) supported environmental issues, of which USD34.7bn (23.9% of bilateral aid) focused on climate change specifically (OECD 2017b).

The largest providers of ODA in dollar terms are the USA, the UK, Germany, the EU, and Japan, who collectively provided 62% of the total ODA contributed by DAC members, although as a group, the Scandinavian countries (Denmark, Norway, and Sweden) provided more aid (USD14bn) than the EU (excluding member state ODA) or Japan. Each of these countries has one or more entities through which they provide assistance.

Table 19: OECD Development Assistance Committee Selected ODA Details by Member

Country	Agencies	2015 ODA (USD bn)	Multilateral Institution Share of ODA	Environment Share of Bilateral ODA	Climate Change Share of Bilateral ODA
Australia	Department of Foreign Affairs and Trade	3.2	21.2%	14.7%	13.0%
Austria	Austrian Development Agency	1.2	40.7%	33.0%	22.9%
Belgium	Enabel	1.9	40.1%	56.2%	32.1%
Canada	Global Affairs Canada (previously CIDA)	4.3	30.2%	28.5%	10.6%
Czech Republic	Czech Development Agency	0.2	64.8%	17.2%	11.5%
Denmark	DANIDA	2.6	25.7%	22.7%	16.3%
European Union	EuropeAid, ECHO, EEAS	13.8	0.9%	20.8%	17.5%
Finland	Ministry of Foreign Affairs	1.3	45.1%	20.9%	15.2%
France	FFEM, MIES, AFD	9.2	37.9%	60.5%	48.3%
Germany	BMZ, GIZ, KfW	17.8	19.4%	48.9%	39.9%
Greece	Ministry of Foreign Affairs	0.3	69.9%	4.3%	4.3%
Hungary	Ministry of Foreign Affairs and Trade	0.2	69.6%	n/a	n/a
Iceland	ICEIDA	0.04	22.1%	73.4%	37.1%
Ireland	Irish Aid	0.7	40.5%	20.7%	17.3%
Italy	ESTERI	3.8	53.6%	43.8%	27.9%
Japan	MOFA, JICA, JBIC	9.3	20.3%	52.7%	48.8%
Korea	ODA Korea, KOICA, MOFA	1.9	19.3%	17.1%	13.2%
Luxembourg	Ministry of Foreign Affairs	0.4	27.6%	25.7%	12.9%
The Netherlands	Ministry of Foreign Affairs	5.8	26.9%	35.3%	29.9%
New Zealand	New Zealand Aid Programme	0.4	18.9%	46.0%	15.0%
Norway	NORAD	4.3	22.6%	27.0%	24.3%
Poland	Polish Aid	0.4	73.2%	6.1%	3.3%
Portugal	Instituto Camões	0.3	45.8%	14.1%	13.1%
Slovak Republic	SlovakAid	0.1	79.7%	14.5%	2.0%
Slovenia	Ministry of Foreign Affairs	0.1	60.3%	24.6%	17.7%
Spain	AECID	1.6	57.9%	21.5%	13.8%
Sweden	SIDA	7.1	31.6%	39.6%	27.7%
Switzerland	SDC	3.5	22.3%	17.2%	11.9%
United Kingdom	DEFRA, BEIS, DFID	18.7	36.6%	33.1%	30.6%
United States	USAID, MCC	31.1	13.7%	10.4%	3.5%

Source: OECD (2017)

A critically endangered wild female Amur leopard (*Panthera pardus orientalis*) on rocky hillside, Kedrovaya Pad reserve, Primorsky Krai, Far East Russia in January 2009. Climate Change is causing the suitable habitat for Amur leopards to shrink, due to a change in their forest habitat and a decrease in prey.

China's International Development Finance Activities

China does not participate in the DAC as a donor country, and there is limited official information available about its international development finance activities, as this kind of information is considered to be a state secret.

AidData, a research lab at The College of William & Mary has put together a dataset that tracks the known universe of overseas Chinese official finance between 2000-2014. The data includes both Chinese aid and non-concessional official financing and represents projects with USD354bn in financing over the period, not far behind the USD395bn in official finance provide by the US over the same period (AidData 2017).

The data show that in 2014, China's "ODA-like" financing was USD6.9bn, while non-ODA official financing totalled USD30.4bn. The vast majority of the ODA financing, at least USD6.1bn, was provided by the policy lender Export-Import Bank of China (Chexim), as it is the only bank designated by the Chinese government to provide government concessional loans and preferential export buyers' credit.

Chexim's primary mandate is to facilitate national development strategies. As of end-2016, the bank had total assets of CNY3.3tr and loans of CNY2.4tr. As a policy lender, in addition to the bank's position as the sole provider of concessional finance, Chexim is a major supporter of China's Belt and Road Initiative, having agreed to support over 1,200 BRI projects worth over CNY700bn, or almost one-third of its 2016 loan book (Chexim 2017).

Chexim also provided two-thirds (USD20.9bn) of the non-ODA financing in 2014. China Development Bank (CDB), another policy lender, provided no ODA financing and USD5.2bn of non-ODA financing. China's remaining policy lender, Agricultural Development Bank of China (ADBC), was not represented in the data. Although there is limited information about the terms of the finance in these official flows, it appears to be a mixture of grants, technical assistance, concessional and non-concessional loans and export credits, and debt rescheduling. (AidData 2017)

CDB's financing activities in the 2014 data were consistent with its expertise in infrastructure and basic industry, with 80% of its USD5.2bn in official flows in 2014 going to two projects in Angola (oil & gas) and Argentina (rail), and much of the rest to similar sectors (AidData 2017). The bank is the world's largest development bank, with assets of CNY14.3tr at the end of 2016, CNY10.3tr of which is the loan book. The majority of its development activity is focused domestically, but the bank is also charged with supporting China's "Going Out" policy, the capstone of which is the Belt and Road Initiative. Supporting infrastructure investment is a major part of the bank's activities in this regard.

Belt And Road Initiative (BRI)

Originally called the One Belt, One Road initiative, China's Belt and Road Initiative, announced in 2013, seeks to build infrastructure ties between China and Central and Southeast Asia, the Middle East, Africa, and Europe. The "belt" is essentially the old Silk Road from China to Europe via Eurasia, while the "road" traces the maritime version of the Silk Road from China through Southeast Asia and the Indian Ocean, to Africa and the Arabian Peninsula, and on to the Mediterranean.

The BRI currently encompasses 72 countries and is the largest ever infrastructure programme. Current annual investment is around USD150bn, and total investment through 2049 is projected to reach USD8tr (WWF 2018). As of September 2017, the policy banks have directed CNY1.4tr to BRI projects (SCMP 2017).

Silk Road Fund

The Silk Road Fund is a USD40bn fund established in 2014 by China to fund the BRI's projects in resources and energy development and infrastructure. Initial funding of USD10bn was provided by the State Administration of Foreign Exchange, China Investment Corporation, CDB, and Chexim. The fund's primary form of investment is equity, although it can invest in debt and other funds. It may also work alongside other entities such as international development organisations and domestic or foreign financial institutions to jointly set up funds (Silk Road Fund 2015).

Climate Activities

Chexim was one of the first domestic banks to introduce a green credit strategy, in 2007. Since then the bank has increased its emphasis in this area, setting a strategic target in 2012 of becoming a pioneer in practicing green finance in its 12th Five-Year Development Plan, and shoring up its capabilities via exchanges with the World Bank and IFC. The bank's inaugural green bond in December 2016 (CNY1bn) was the first green bond issued by a Chinese policy bank. In 2015, the bank's lending of CNY100.5bn to green sectors and projects comprised 4.7% of its loan book, and reduced CO_2 emissions by 14mn tonnes (Chexim 2016).

CDB launched its first ever international climate bond in November 2017, raising USD1.6bn (USD500mn and EUR1bn). The bonds were verified by Ernst & Young and certified by the Climate Bonds Initiative. The proceeds are targeted at low carbon transport, wind, and water projects in support of the BRI, at locations including China, Kazakhstan, Pakistan, and Sri Lanka (CDB 2017a). The bank published its green bond framework in the same month to facilitate further international issues. As of end-2016, CDB's portfolio of green loans reached CNY1.6tr, and comprised 15.2% of its loan book, significantly higher than the sector average of 8.8% (CDB 2017b).

Climate-Focused Multilateral Funds – UNFCCC-related and Climate Investment Funds

The UNFCCC has had a financial component since it was established, and over the years it has established a number of additional investment funds to invest in climate change mitigation and adaptation. These include the Global Environment Facility and its related funds, and the Green Climate Fund.

The secretariat of the UNFCCC has estimated that the additional investment and financial flows required in 2030 to address climate change amounts to 0.3-0.7% of global GDP and 1.1-1.7% of global investment. Other studies from the OECD and NCE estimate a USD7tr annual investment requirement between 2016-30 to achieve the 2 Degree Scenario, while the IEA has tabulated USD53tr in cumulative investments required between 2016-35 to make the transition to a low-carbon energy system (GCF 2016). To that end, the UNFCCC parties at the Paris Conference set a goal of mobilising USD100bn annually by 2020 in pursuit of the 2DS goal.

GLOBAL ENVIRONMENT FACILITY (GEF)

The Global Environment Facility was established just ahead of the 1992 Earth Summit in Rio to address the world's most pressing environmental problems. It was originally a USD1bn pilot program in the World Bank to promote environmental sustainable development and to assist the protection of the global environment. It has since provided over USD18bn in grants and mobilised a further USD88bn in financing for over 4,000 projects in 170 countries.

The GEF, via its trust fund, provides grants to projects across a wide variety of environmental issues, including climate change, biodiversity, international waters, land degradation, and sustainable forest management. It also serves as the financial mechanism for 5 major international conventions: the UNFCCC, the UN Framework on Biological Diversity, the Stockholm Convention on Persistent Organic Pollutants, the UN Convention to Combat Desertification, and the Minamata Convention on Mercury.

All GEF-funded projects are created and managed by the 18 institutions who act as GEF Agencies. These institutions include multilateral institutions such as UNDP and UNEP, MDBs including the World Bank and the ADB, regional development banks and funds, and NGOs such as Conservation International and the WWF.

Although GEF funding mainly supports government projects and programs, this does not preclude private sector involvement, and the GEF is actively working via its Agencies to expand its private sector engagement. Its blended finance approach, which provides instruments to reduce project risk, includes guarantees, subordinated or concessional debt, and junior equity, can enhance the commercial attractiveness of projects to catalyse external (private sector) investment. In 2013-14, its USD175mn of blended finance projects mobilised USD1.1bn in private sector investment, while the USD1.4bn it provided via normal channels mobilised just USD800mn.

The GEF trust fund is funded by contributions from donor members (including both developed and developing countries) on a quadrennial funding cycle. For the 2014-2018 cycle, donors pledged USD4.4bn. The GEF also administers several other trust funds in addition to its own, and acts as the interim secretariat for the Adaptation Fund; summary details are provided below:

Least Developed Countries Fund (LDCF)

The LDCF was established in 2001 under the UNFCCC to provide assistance to those least developed countries who are particularly vulnerable to climate change. The fund helps countries generate and implement national adaptation programs that identify their most pressing adaptation needs. Target sectors include water; agriculture and food security; health; disaster risk management and prevention; infrastructure; and fragile ecosystems.

The LDCF is funded by voluntary funds from donor countries. Its USD1.2bn portfolio of adaptation projects in over 50 countries is the largest such portfolio in the least developed countries and mobilised an additional USD4.8bn from partners. As of end-2017, the fund had USD97mn available to support future projects (World Bank 2017b)

In Asia-Pacific, countries categorised as least developed are: Afghanistan, Bangladesh, Bhutan, Cambodia, Kiribati, Laos, Myanmar, Nepal, Solomon Islands, Timor-Leste, Tuvalu, and Vanuatu.

Special Climate Change Fund (SCCF)

The SCCF was established in 2001 under the UNFCCC to finance projects relating to: adaptation; technology transfer and capacity building; energy, transport, industry, agriculture, forestry and waste management; and economic diversification. Of these, adaptation is the top priority.

This fund is intended to complement the LDCF, as unlike the LDCF, all vulnerable developing countries that are party to the UNFCCC are eligible to apply to the SCCF for project funding. The SCCF's funds come primarily from voluntary contributions from donor countries. As of 2017, the SCCF has a portfolio of nearly USD350mn supporting 77 projects in 79 countries. The fund has USD9.6mn available to support future projects (World Bank 2017c).

Adaptation Fund (AF)

The Adaptation Fund is a multilateral fund established in 2001 under the Kyoto Protocol of the UNFCCC. It is funded in part by a 2% share of the proceeds from the sale of Certified Emissions Reductions issued under the Protocol's Clean Development Mechanism, as well as by voluntary contributions from donor countries. Via grants, the AF finances concrete adaptation projects and programmes in developing countries that are vulnerable to the negative effects of climate change and are Parties to the Kyoto Protocol, with a limit of USD10mn per country.

The AF has invested in a wide range of sectors related to adaptation: food security; water management; agriculture; rural development; disaster risk reduction; coastal zone management; urban development; and forests. As of end-2017, the fund's cumulative resource base since inception was USD724mn, with USD217mn available to support future projects (World Bank 2017d).

Since inception, the Fund has approved USD460mn to over 70 adaptation initiatives around the world. In Asia Pacific, the fund has been active in Cambodia, Cook Islands, Fiji, India, Indonesia, Micronesia, Mongolia, Nepal, Pakistan, Papua New Guinea, Samoa, Solomon Islands, and Sri Lanka.

GREEN CLIMATE FUND (GCF)

The GCF is the largest of the UNFCCC-related climate funds and is the chosen vehicle for a significant share of the USD100bn per year that advanced economies have formally agreed to jointly mobilise by 2020. At present, the GCF has USD10.3bn in funds pledged, USD2.6bn in approved investments in over 60 countries, and has leveraged USD9.2bn in total financing.

The fund was established in 2011 with the intention to support developing countries in their climate change mitigation and adaptation efforts, aiming to split its financing equally between the two categories. The fund is open to all developing country parties to the Convention, and unlike the AF, there is no limitation on the amount of funds a single country can access. Fundraising began in 2014, and the first full year of operations was 2016.

The fund invests through accredited international agencies such as MDBs and UN agencies, and may also give countries direct access via national and sub-national implementing bodies such as government agencies, national development banks, and NGOs, although these need to be accredited as well. A unique feature of the GCF is that private sector entities can be accredited as implementing bodies or intermediaries; a number of international investment and commercial banks, including Credit Agricole, Deutsche Bank, and HSBC, have been accredited by the GCF.

The GCF focuses its investments on eight "strategic result areas": energy generation and access; transport; buildings, cities, industries and appliances; forests and land use; health, food and water security; livelihoods of people and communities; ecosystems and ecosystem services; and, infrastructure and the built environment.

The GCF actively works to engage with the private sector and has established a Private Sector Facility to that end. The fund uses flexible financial instruments, including debt, equity, and guarantees, and can combine them with concessional funding to promote private sector involvement in multiple ways. These include de-risking investments, bundling small projects into portfolios of a scale that is attractive to institutional investors, and developing public-private partnerships for infrastructure resilience projects.

Further to its efforts to involve the private sector, the fund recently closed an RFP for its new "Mobilising funds at Scale" initiative, offering USD500mn to unlock private sector finance in developing countries via low-emission, climate-resilient projects that crowd in capital. The GCF shortlisted 30 of the 350 proposals received, in areas ranging from risk mitigation for solar PV to a green sukuk programme.

In Asia, the GCF has funded adaptation and mitigation projects in Bangladesh, India, Mongolia, various Pacific Islands, Pakistan, Papua New Guinea, Sri Lanka, and Vietnam.

CLIMATE INVESTMENT FUNDS (CIFs):

The CIFs are a USD8.3bn group of four investment funds established in 2008, focused on providing mitigation and adaptation finance to developing and middle-income countries. The funds were developed by industrialised and developing countries as an interim measure pending the effectiveness of a UNFCCC-agreed structure for climate finance (ICF 2014). They are intended to complement existing bilateral and multilateral financing mechanisms, and to foster a programmatic, rather than project-based, approach to climate finance.

The CIFs are independent of the UNFCCC, and operate via five MDBs – AfDB, ADB, EBRD, IADB, and WBG, with the latter also acting as trustee. The CIFs expect their pledges of USD8.3bn to attract an additional USD58bn of co-financing for their portfolio of over 300 projects.

One unique element regarding the CIFs is the "sunset clause" they contain, which requires each fund "to conclude its operations once a new financial architecture is effective," with the caveat that the funds may continue operations if UNFCCC agrees. This has introduced uncertainty into their operations, as the CIFs have not clarified whether, how and when the clause may be exercised (ICF 2014). With the advent of the GCF – essentially, the new UNFCCC financial architecture – and its increasing operational momentum, this issue continues to linger. In particular, although each of the funds in the CIFs are either fully invested or close to it, new contributions to the funds have dried up. This is presumably due to the fact that the donor base of the CIFs and the GCF overlap significantly, and they are likely to have concerns about duplication of efforts.

Clean Technology Fund (CTF)

The USD5.5bn CTF aims to provide scaled-up non-grant financing middle income countries to contribute to the demonstration, deployment and transfer of low-carbon technologies with a significant potential for long-term GHG emissions savings. The fund invests in clean technologies including renewable energy, energy efficiency, and clean transport. Almost USD5bn in investments is approved and under implementation, with which the CTF expects to mobilise another USD48bn in co-financing. In particular, the fund has allocated over USD950mn to concentrated solar power as part of its efforts to catalyse further investment in the technology to bring CSP costs down. (CIF 2017a)

The fund includes a USD491mn dedicated private sector program, which has allocated funds to six thematic areas: geothermal power, mini-grids, mezzanine finance, energy efficiency, solar PV, and early stage renewable energy. As its initial funding is almost depleted, the CTF is working on strategies to raise funds in the capital markets to fund its next generation of investments. The fund is considering new areas such as energy storage and distributed generation, as well as potentially opening the fund to allow investors to take part in its portfolio. (CIF 2017a)

The fund has a portfolio of 109 approved and pipeline projects, and says its programmatic approach allows for greater coordination, cooperation and financial flows. These flows may be undertaken in a variety of ways, including concessionary and non-concessionary long-term loans, equity, guarantees, subordinated debt, local currency swaps and guarantees, and contingent recovery loans. In Asia-Pacific, the fund has active projects in India, Indonesia, the Philippines, Thailand, and Vietnam. (CIF 2017a)

Strategic Climate Fund (SCF)

The SCF aims to provide financing to pilot new development approaches or to scale-up activities aimed at a specific climate change challenge or sectoral response. The SCF currently finances three such programs: the Forest Investment Program, Pilot Program for Climate Resilience, and Scaling Up Renewable Energy in Low-Income Countries Program.

Forest Investment Program (FIP)

FIP is a USD750mn funding window under the SCF that provides grants and low-interest loans to provide direct investment to address the drivers of deforestation and forest degradation both inside and outside of the forest sector. Globally, FIP-endorsed investments are expected to lead to 28mn hectares of forest landscape under improved management.

In 2012, FIP set aside USD50mn in concessional funds to contribute to the financing of FIP-relevant projects that engage the private sector. The fund selected five projects for financing and a further three for revision and potential financing. These projects included the commercial reforesting of modified lands in a region of Brazil, climate change mitigation and poverty reduction in Burkina Faso via the development of the cashew sector, and a guaranteed fund in Mexico for financing low-carbon forestry investments. FIP may consider a second round for this kind of private sector engagement if more FIP resources become available.

FIP is essentially fully invested in 51 projects as of September 2017 (World Bank 2017e), with a small negative balance after accounting for anticipated project commitments through FY2021. It is unclear whether the FIP's funding will be replenished.

The program supports many facets of REDD+ (the UN's program for reducing emissions from deforestation and forest degradation), including capacity building, landscape approaches, indigenous peoples, forest monitoring, and sustainable forest management. In Asia-Pacific, FIP is active in Bangladesh, Indonesia, Laos, and Nepal. (CIF 2017b)

Pilot Program for Climate Resilience (PPCR)

PPCR is a USD1.2bn fund that focuses on climate change adaptation and resilience building. The fund includes USD137mn of private sector funding. PPCR takes a programmatic approach to assist national governments in integrating climate resilience into development planning across sectors and stakeholder groups. This approach involves a long-term strategic arrangement of linked investment projects and activities to achieve large-scale systematic impacts and take advantage of synergies and co-financing opportunities. The program also provides funding to put these plans into action.

The PPCR is essentially fully invested in approximately 60 projects as of September 2017 (World Bank 2017e), with approximately USD30mn remaining for further project investment. It is unclear whether the program's funding will be replenished.

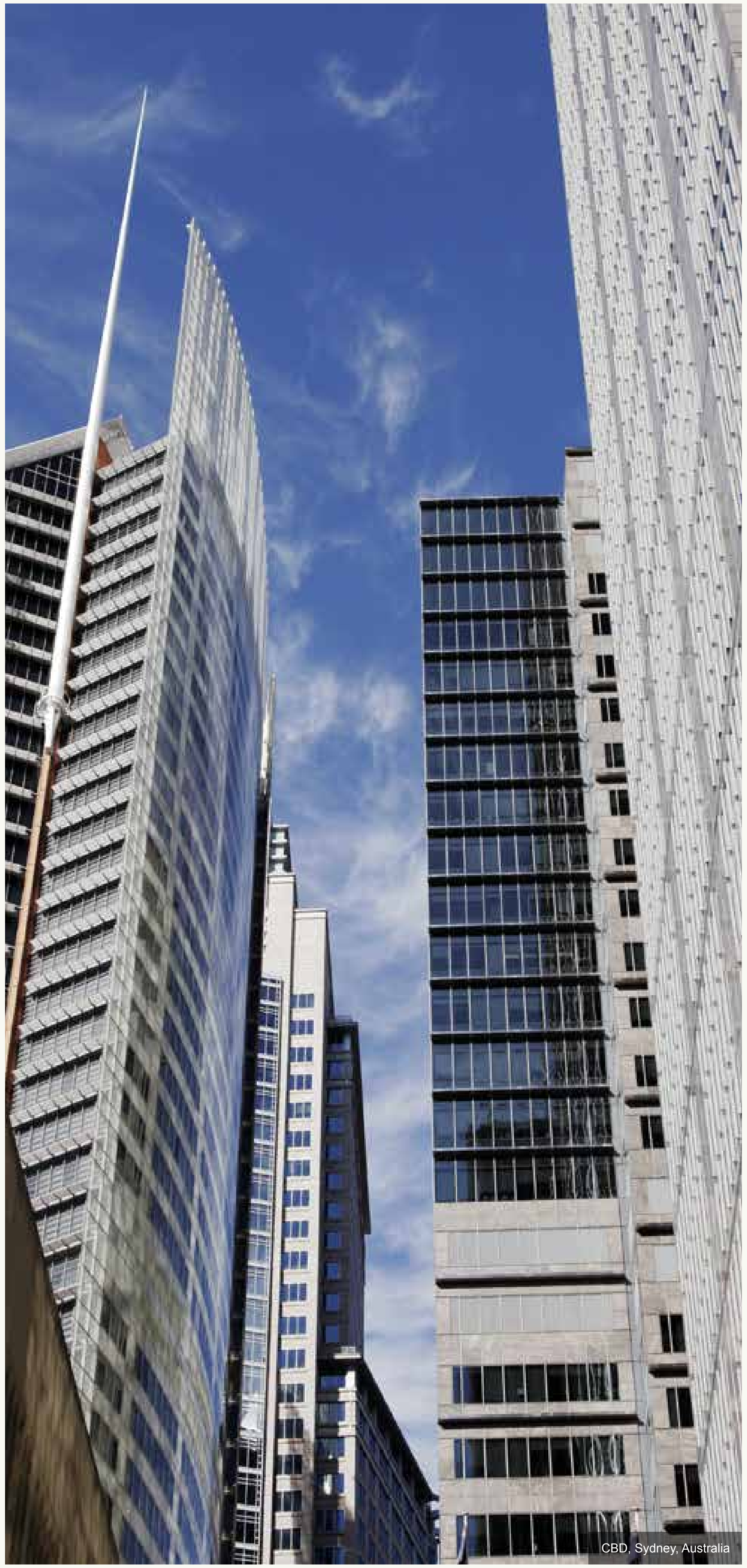
The program invested in sectors including agriculture and landscape management, water resources management, climate information systems and disaster risk management, infrastructure, and capacity development and regulatory work. In Asia-Pacific, the program is active in Bhutan, Bangladesh, Cambodia, Nepal, Papua New Guinea, the Philippines, Samoa, and Tonga. (CIF 2017c)

Scaling-Up Renewable Energy Program (SREP) in Low Income Countries

SREP is a USD750mn funding window under the SCF that aims to demonstrate the economic, social, and environmental viability of renewable energy in developing countries. The fund includes USD86mn in dedicated private sector financing and expects to mobilise USD5bn in co-financing across its 66 approved and pipeline projects. The program offers concessional loans, grants, equity investment, and risk reduction instruments such as guarantees.

SREP is essentially fully invested in 66 approved and pipeline projects as of December 2017 accounting for USD811mn in allocations (CIF 2017d). It is unclear whether SREP's funding will be replenished.

SREP takes a programmatic approach, with its MDB implementation agencies working with countries to develop investment plans for renewable energy. The fund has 27 pilot countries with 19 investment plans endorsed to date (CIF 2017d). In Asia-Pacific, the pilot countries are Bangladesh, Cambodia, Kiribati, Mongolia, Nepal, Solomon Islands, and Vanuatu.



CBD, Sydney, Australia

Table 20: Summary of Selected Multilateral and Bilateral Climate Funds with Activities in Asia

Fund Name	Fund Focus	Fund Type	Funds Pledged	Eligible Countries	Type of Support Provided
Global Environment Facility (GEF)	Mitigation, Capacity building	Multilateral	Most recent round: USD4.4bn	Developing country parties to the conventions the GEF serves, or who are eligible to receive WB financing or UNDP technical assistance	Grants; Non-grant program provides: Co-financing, Concessional loans, Risk mitigation, Equity
The Adaptation Fund (AF)	Adaptation	Multilateral	USD724mn	All developing countries that are Parties to the Kyoto Protocol	Grants
The Least Developed Countries Fund (LDCF)	Adaptation	Multilateral	USD1.3bn	All Least Developed Countries	Grants
The Special Climate Change Fund (SCCF)	Adaptation, Mitigation	Multilateral	USD352mn	All developing countries that are Parties to the UNFCCC. Priority is given to vulnerable countries in Africa, Asia, and Small Island Developing States	Grants
Clean Technology Fund (CTF)	Mitigation	Multilateral	USD5.5bn	ODA-eligible developing countries with active MDB in-country programs	Co-financing, Concessional loans, Risk mitigation, Equity
Forest Investment Program (FIP)	Adaptation, Mitigation, REDD+	Multilateral	USD750mn	ODA-eligible developing countries with active MDB in-country programs. Priority is given to vulnerable Least Developed Countries, including Small Island Developing States	Co-financing, Concessional loans, Grants
Pilot Program for Climate Resilience (PPCR)	Adaptation	Multilateral	USD1.2bn	Same as above	Co-financing, Concessional loans, Grants
Scaling-Up Renewable Energy Program in Low-Income Countries (SREP)	Mitigation	Multilateral	USD750mn	Same as above	Co-financing, Concessional loans, Grants, Risk mitigation, Equity
Global Climate Change Alliance (GCCA)	Adaptation, Mitigation, REDD+	Multilateral	USD326mn	Least Developed Countries and Small Island Developing States that are recipients of official development assistance	Grants
Nordic Development Fund (NDF)	Adaptation, Mitigation	Multilateral	EUR1.0bn	27 low-income and lower middle-income countries in Africa, Asia and Latin America. Eligible countries in Asia include Bangladesh, Cambodia, Kyrgyz Republic, Lao PDR, Maldives, Mongolia, Nepal, Pakistan, Sri Lanka, and Vietnam	Grants
Nordic Climate Facility (NCF)	Adaptation, Mitigation	Multilateral	EUR27mn	21 low-income countries in Africa, Asia and Latin America. Eligible countries in Asia include Bangladesh, Cambodia, Lao PDR, Nepal, Sri Lanka, and Vietnam	Grants
International Climate Initiative (ICI)	Adaptation, Biodiversity, Mitigation, REDD+	Bilateral	EUR1.7bn	Broad eligibility, including developing, newly industrializing, and transition countries in Africa, South and Southeast Asia, Small Island States in the Pacific and the Caribbean, and others	Concessional loans, Grants
International Climate Fund (ICF)	Adaptation, Mitigation, REDD+	Bilateral	USD6.0bn	Broad eligibility: funding for adaptation is for poor and vulnerable countries, including least developed countries, small island states and Africa; funding for mitigation may include some middle-income countries	Grants
Green Climate Fund (GCF)	Adaptation, Mitigation	Multilateral	USD10.3bn	All developing countries that are Parties to the UNFCCC	Co-financing, Concessional loans, Grants, Risk mitigation, Equity

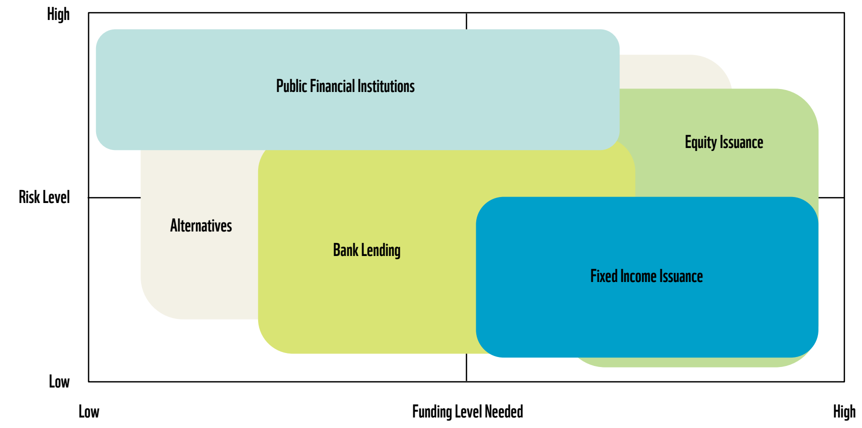
Source: Adapted from USAID (2017)

PRIVATE FINANCE

The private finance ecosystem can play both direct and indirect roles with respect to addressing climate change. As seen in CPI's climate finance landscape (Figure 81, above), the private sector is the predominant source of direct investment in mitigation, led by project developers, with non-bank private financial intermediaries currently playing a smaller role.

This smaller direct role is a function of the structure of the financial system, which tends to focus on more mature sectors with relatively high minimum funding needs. This does not match up well with the comparative newness of the various technologies and business models involved in delivering climate investment, nor with the limited scale of many projects. This mismatch is precisely why public financial institutions are involved: to accelerate the development of the climate mitigation and adaptation investment space such that perceived risk of these projects is lowered to the point that those institutional investors – asset owners as well as asset managers – capable of providing direct finance are able to get involved.

Figure 87: Indicative Positioning of Funding Sources for Direct Financing of Climate Investments



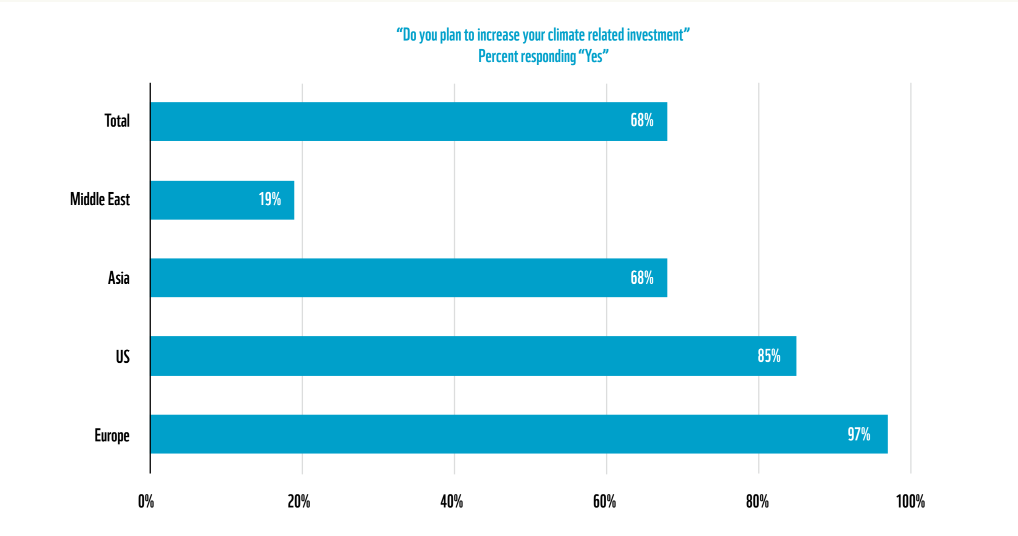
Note: Excludes infrastructure and other public goods from consideration. "Alternatives" includes private equity, venture capital, real estate, fund of funds, infrastructure, commodities, real assets, illiquid credit and insurance-linked investments.
Source: WWF

Until that happens, in most cases, indirect investment via equity or debt securities is the primary channel through which most institutional investors will be able to apply their capital to address climate change. These instruments have a varying degree of direct impact on the real economy:

- **Fixed income:** investment in the primary bond market translates almost directly to investment in the real economy; in the secondary bond markets, the impact in the real economy is indirect;
- **Equity:** investment in equity – unless in special purpose vehicles dedicated to projects – has an indirect impact on investment in the real economy, both in primary and secondary markets. However, equity investors can also influence investees' capital through voting power. This applies mostly to listed equities portfolios, for which shareholders have their say on the corporate strategy including the allocation of retained earnings. (FtF 2015)

Climate issues have become more mainstream in the world of private finance, and generally fall into the ESG category (environmental, social, and governance) in industry parlance. A 2017 survey by HSBC found that 68% of global investors plan to increase their investment into climate-related or low carbon themes (Knight 2017). European and US investors were the leaders in this regard, with investors in Asia, and especially the Middle East, lagging:

Figure 88: Institutional Investor Survey on Climate Investment, July 2017



Note: HSBC-commissioned survey of CIOs, Heads of Portfolio, and Heads of Investment Strategy at 497 investment houses.
Source: Knight (2017)

The leopard lacewing butterfly (*Cethosia cyane*), ranges from India, throughout Southeast Asia, into the islands of Malaysia and Indonesia, and east to Papua New Guinea.
Collection pressures, destruction of tropical rainforests, climatic change, and rampant use of pesticides have caused problems for leopard lacewings.

This intention is consistent with the trend seen in the broader ESG and sustainable investment space, with such assets increasing by 25% from 2014 to 2016, to USD23tr, representing 26% of total managed assets (GSIA 2017). However, there are a number of barriers to green investor flows, mostly related to standards and information availability. These are summarised in the table below.

Table 21: Green Investor Experience by Asset Class

Asset class	Demand barriers to green investment flows	Supply barriers to green investment flows	Challenges in green investor practices	Primary gap identified
Listed Equities	Technology and policy risk associated with certain sectors and areas e.g. renewables.	Portfolios heavily invested in certain domestic economies may have limited opportunities. (Global portfolios offer more opportunities.)	Incorporation of green issues and active ownership underway, but challenges with usefulness of company data.	Data Policy framework
Fixed income	Greenwashing linked to lack of standards for green bonds and clarity on use of proceeds.	Oversubscription of green bonds, although overall issuance is low.	Green bonds standards under development. Investor incorporation of green issues underway for corporate and sovereign bonds, but challenges with credit rating agencies' consideration of green issues and private debt.	Standards Policy framework
Private equity	Technology and policy risk associated with certain areas. Limited demand for thematic private equity with mixed performance records.	Early stage and high-risk investments are unsuitable for many mainstream investors.	Limited Partners asking General Partners to integrate green issues, with due diligence tools underway. Challenges in quantifying and monitoring implementation.	Supply Policy framework
Infrastructure	Considered a specialist asset class outside regular asset allocation by some asset owners.	Deals are considered unsuitable by asset owners lacking specialist knowledge, or may fall outside regular asset allocation.	Industry capacity-building underway through GRESB on green issues.	Demand and Supply
Real estate and property	-	-	Green practices underway including certification and for energy efficiency, but challenges in quality and consistency of reporting by companies.	Data
Real assets e.g. farmland, timberland	-	-	Responsible investment practices underway covering green issues.	-

Source: PRI (2016b)

TCFD: Policy and Voluntary Action Driving Climate Integration

For asset owners and asset managers, the quality and availability of relevant information is one of the key barriers to incorporating climate issues in their investment processes. In part to address this deficiency, on June 29, 2017, the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) issued its final report, providing recommendations on climate-related financial disclosures that are applicable to organisations across sectors and jurisdictions. If adopted widely, the recommendations will normalise and improve the standards of corporate climate risk disclosures, allowing investors to better assess their own climate-related portfolio risk and provide this information to their clients and beneficiaries.

The report knits existing frameworks into a single framework for disclosure on the assessment and management of climate-related risks and opportunities and encourages board-level engagement with the issue. It strongly recommends using scenario analysis techniques as part of the process. The framework contains the following key elements (FSB TCFD 2017a):

- Adoptable by all organisations
- Included in financial filings
- Designed to solicit decision-useful, forward-looking information on financial impacts
- Strong focus on risks and opportunities related to the transition to a lower-carbon economy

The recommendations focus on four key themes aligned with how organisations operate: governance, strategy, risk management, and metrics and targets. The themes are fleshed out with recommended disclosures organisations should include in their financial filings in each of the four areas, in order to provide investors and other stakeholders with the information that will help them understand the reporting organisation's assessment of its climate-related risks and opportunities. The disclosing organisations themselves will also benefit from the process, gaining a better understanding of the real financial implications of climate-related risks and their potential impacts on business models, strategy and cash flows.

Figure 89: TCFD Recommendations and Supporting Recommended Disclosures

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures			
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
-	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Source: FSB TCFD (2017a)

The TCFD highlights scenario analysis as its preferred tool for producing forward-looking information with respect to assessing climate risks and opportunities in a way that enhances the robustness and flexibility of strategic plans. It also believes such information is important for investors and other stakeholders in understanding how vulnerable individual organisations are to climate-related risks, and how such vulnerabilities might be addressed (see Table 22). The TCFD highlights the importance of climate scenario analysis by publishing a full Technical Supplement on the use of scenario analysis (FSB TCFD 2017c).

The PRI, a leading global proponent of responsible investment, has positioned climate change as the highest-priority environmental, social and governance (ESG) issue facing investors. In response to the TCFD final report the PRI climate risk indicators were introduced in 2018, and saw responses from 480 PRI member investors representing USD42tr in AUM.

Table 22: Reasons to Consider Using Scenario Analysis for Climate Change

1	Scenario analysis can help organizations consider issues, like climate change, that have the following characteristics: • Possible outcomes that are highly uncertain (e.g. the physical response of the climate and ecosystems to higher levels of GHG emissions in the atmosphere) • Outcomes that will play out over the medium to longer term (e.g. timing, distribution, and mechanisms of the transition to a lower-carbon economy) • Potential disruptive effects that, due to uncertainty and complexity, are substantial
2	Scenario analysis can enhance organizations' strategic conversations about the future by considering, in a more structured manner, what may unfold that is different from business-as-usual. Importantly, it broadens decision makers' thinking across a range of plausible scenarios, including scenarios where climate-related impacts can be significant.
3	Scenario analysis can help organizations frame and assess the potential range of plausible business, strategic, and financial impacts from climate change and the associated management actions that may need to be considered in strategic and financial plans. This may lead to more robust strategies under a wider range of uncertain future conditions.
4	Scenario analysis can help organizations frame and assess the potential range of plausible business, strategic, and financial impacts from climate change and the associated management actions that may need to be considered in strategic and financial plans. This may lead to more robust strategies under a wider range of uncertain future conditions.
5	Scenario analysis can assist investors in understanding the robustness of organizations' strategies and financial plans and in comparing risks and opportunities across organizations.

Source: FSB TCFD (2017a)

CBD, Singapore

The recommendations and recommended disclosures are supported by further guidance for all sectors. For the financial sector and certain high-emissions industries, the TCFD provided supplemental guidance to highlight important sector-specific considerations. The financial sector was organized into four major categories, based mainly on activities performed (FSB TCFD 2017b):

- Banks (lending)
- Insurance companies (underwriting)
- Asset owners (investing)
- Asset managers (asset management)

For reference, an integrated table of recommendations, including the TCFD's all-sector guidance and financial sector supplemental guidance, is presented below in Table 23.

Table 23: TCFD Recommendations, Recommended Disclosures, and Guidance for All Sectors, Integrated with Supplemental Guidance for the Financial Sector

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	Recommended Disclosures	Recommended Disclosures	Recommended Disclosures
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
Guidance for all sectors: In describing the board's oversight of climate-related issues, organizations should consider including a discussion of the following: • processes and frequency by which the board and/or board committees (e.g., audit, risk, or other committees) are informed about climate-related issues, • whether the board and/or board committees consider climate-related issues when reviewing and guiding strategy, major plans of action, risk management policies, annual budgets, and business plans as well as setting the organization's performance objectives, monitoring implementation and performance, and overseeing major capital expenditures, acquisitions, and divestitures, and • how the board monitors and oversees progress against goals and targets for addressing climate-related issues.	**Guidance for all sectors:** Organizations should provide the following information: • a description of what they consider to be the relevant short-, medium-, and long-term time horizons, taking into consideration the useful life of the organization's assets or infrastructure and the fact that climate-related issues often manifest themselves over the medium and longer terms, • a description of the specific climate-related issues potentially arising in each time horizon (short, medium, and long term) that could have a material financial impact on the organization and distinguish whether the climate-related risks are transition or physical risks, and • a description of the process(es) used to determine which risks and opportunities could have a material financial impact on the organization. Organizations should consider providing a description of their risks and opportunities by sector and/or geography, as appropriate.	**Guidance for all sectors:** Organizations should describe their risk management processes for identifying and assessing climate-related risks. An important aspect of this description is how organizations determine the relative significance of climate-related risks in relation to other risks. Organizations should describe whether they consider existing and emerging regulatory requirements related to climate change (e.g., limits on emissions) as well as other relevant factors considered. Organizations should also consider disclosing the following: • processes for assessing the potential size and scope of identified climate-related risks and • definitions of risk terminology used or references to existing risk classification frameworks used.	**Guidance for all sectors:** Organizations should provide the key metrics used to measure and manage climate-related risks and opportunities. Organizations should consider including metrics on climate-related risks associated with water, energy, land use, and waste management where relevant and applicable. Where climate-related issues are material, organizations should consider describing whether and how related performance metrics are incorporated into remuneration policies. Where relevant, organizations should provide their internal carbon prices as well as climate-related opportunity metrics such as revenue from products and services designed for a lower-carbon economy. Metrics should be provided for historical periods to allow for trend analysis. In addition, where not apparent, organizations should provide a description of the methodologies used to calculate or estimate climate-related metrics.
	Banks should describe significant concentrations of credit exposure to carbon-related assets. Additionally, banks should consider disclosing their climate-related risks (transition and physical) in their lending and other financial intermediary business activities.	**Banks** should consider characterizing their climate-related risks in the context of traditional banking industry risk categories such as credit risk, market risk, liquidity risk, and operational risk. **Banks** should also consider describing any risk classification frameworks used (e.g., the Enhanced Disclosure Task Force's framework for defining "Top and Emerging Risks").	**Banks** should provide the metrics used to assess the impact of (transition and physical) climate-related risks on their lending and other financial intermediary business activities in the short, medium, and long term. Metrics provided may relate to credit exposure, equity and debt holdings, or trading positions, broken down by: Industry; Geography; Credit quality (e.g., investment grade or non-investment grade, internal rating system); Average tenor **Banks** should also provide the amount and percentage of carbon-related assets relative to total assets as well as the amount of lending and other financing connected with climate-related opportunities.

		Insurance companies should describe the processes for identifying and assessing climate-related risks on re-/insurance portfolios by geography, business division, or product segments, including the following risks: • physical risks from changing frequencies and intensities of weather-related perils, • transition risks resulting from a reduction in insurable interest due to a decline in value, changing energy costs, or implementation of carbon regulation, and • liability risks that could intensify due to a possible increase in litigation.	**Insurance companies** should provide aggregated risk exposure to weather-related catastrophes of their property business (i.e., annual aggregated expected losses from weather-related catastrophes) by relevant jurisdiction.
		Asset owners should describe, where appropriate, engagement activity with investee companies to encourage better disclosure and practices related to climate-related risks to improve data availability and asset owners' ability to assess climate-related risks.	**Asset owners** should describe metrics used to assess climate-related risks and opportunities in each fund or investment strategy. Where relevant, asset owners should also describe how these metrics have changed over time. Where appropriate, **asset owners** should provide metrics considered in investment decisions and monitoring.
		Asset managers should describe, where appropriate, engagement activity with investee companies to encourage better disclosure and practices related to climate-related risks in order to improve data availability and asset managers' ability to assess climate-related risks. **Asset managers** should also describe how they identify and assess material climate-related risks for each product or investment strategy. This might include a description of the resources and tools used in the process.	**Asset managers** should describe metrics used to assess climate-related risks and opportunities in each product or investment strategy. Where relevant, asset managers should also describe how these metrics have changed over time. Where appropriate, **asset managers** should provide metrics considered in investment decisions and monitoring.

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	Recommended Disclosures	Recommended Disclosures	Recommended Disclosures
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
Guidance for all sectors: In describing management's role related to the assessment and management of climate-related issues, organizations should consider including the following information: • whether the organization has assigned climate-related responsibilities to management-level positions or committees; and, if so, whether such management positions or committees report to the board or a committee of the board and whether those responsibilities include assessing and/or managing climate-related issues, • a description of the associated organizational structure(s), • processes by which management is informed about climate-related issues, and	**Guidance for all sectors:** Building on recommended disclosure (a), organizations should discuss how identified climate-related issues have affected their businesses, strategy, and financial planning. Organizations should consider including the impact on their businesses and strategy in the following areas: • Products and services • Supply chain and/or value chain • Adaptation and mitigation activities • Investment in research and development	**Guidance for all sectors:** Organizations should describe their processes for managing climate-related risks, including how they make decisions to mitigate, transfer, accept, or control those risks. In addition, organizations should describe their processes for prioritizing climate-related risks, including how materiality determinations are made within their organizations.	**Guidance for all sectors:** Organizations should provide their Scope 1 and Scope 2 GHG emissions and, if appropriate, Scope 3 GHG emissions and the related risks. GHG emissions should be calculated in line with the GHG Protocol methodology to allow for aggregation and comparability across organizations and jurisdictions. As appropriate, organizations should consider providing related, generally accepted, industry-specific GHG efficiency ratios. GHG emissions and associated metrics should be provided for historical periods to allow for trend analysis. In addition, where not apparent, organizations should provide a description of the methodologies used to calculate or estimate the metrics.

• how management (through specific positions and/or management committees) monitors climate-related issues.	• Operations (including types of operations and location of facilities) Organizations should describe how climate-related issues serve as an input to their financial planning process, the time period(s) used, and how these risks and opportunities are prioritized. Organizations' disclosures should reflect a holistic picture of the interdependencies among the factors that affect their ability to create value over time. Organizations should also consider including in their disclosures the impact on financial planning in the following areas: • Operating costs and revenues • Capital expenditures and capital allocation • Acquisitions or divestments • Access to capital If climate-related scenarios were used to inform the organization's strategy and financial planning, such scenarios should be described.		
	Insurance companies should describe the potential impacts of climate-related risks and opportunities, as well as provide supporting quantitative information where available, on their core businesses, products, and services, including: • information at the business division, sector, or geography levels; • how the potential impacts influence client, cedent, or broker selection; and • whether specific climate-related products or competencies are under development, such as insurance of green infrastructure, specialty climate-related risk advisory services, and climate-related client engagement.	**Insurance companies** should describe key tools or instruments, such as risk models, used to manage climate-related risks in relation to product development and pricing. **Insurance companies** should also describe the range of climate-related events considered and how the risks generated by the rising propensity and severity of such events are managed.	
	Asset owners should describe how climate-related risks and opportunities are factored into relevant investment strategies. This could be described from the perspective of the total fund or investment strategy or individual investment strategies for various asset classes.	**Asset owners** should describe how they consider the positioning of their total portfolio with respect to the transition to a lower-carbon energy supply, production, and use. This could include explaining how asset owners actively manage their portfolios' positioning in relation to this transition.	**Asset owners** should provide the weighted average carbon intensity, where data are available or can be reasonably estimated, for each fund or investment strategy. In addition, **asset owners** should provide other metrics they believe are useful for decision making along with a description of the methodology used.
	Asset managers should describe how climate-related risks and opportunities are factored into relevant products or investment strategies. **Asset managers** should also describe how each product or investment strategy might be affected by the transition to a lower-carbon economy.	**Asset managers** should describe how they manage material climate-related risks for each product or investment strategy.	**Asset managers** should provide the weighted average carbon intensity, where data are available or can be reasonably estimated, for each product or investment strategy. In addition, **asset managers** should provide other metrics they believe are useful for decision making along with a description of the methodology used.

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.
	Guidance for all sectors: Organizations should describe how resilient their strategies are to climate-related risks and opportunities, taking into consideration a transition to a lower-carbon economy consistent with a 2°C or lower scenario and, where relevant to the organization, scenarios consistent with increased physical climate-related risks. Organizations should consider discussing: • where they believe their strategies may be affected by climate-related risks and opportunities; • how their strategies might change to address such potential risks and opportunities; and • the climate-related scenarios and associated time horizon(s) considered.	**Guidance for all sectors:** Organizations should describe how their processes for identifying, assessing, and managing climate-related risks are integrated into their overall risk management.	**Guidance for all sectors:** Organizations should describe their key climate-related targets such as those related to GHG emissions, water usage, energy usage, etc., in line with anticipated regulatory requirements or market constraints or other goals. Other goals may include efficiency or financial goals, financial loss tolerances, avoided GHG emissions through the entire product life cycle, or net revenue goals for products and services designed for a lower-carbon economy. In describing their targets, organizations should consider including the following: • whether the target is absolute or intensity based, • time frames over which the target applies, • base year from which progress is measured, and • key performance indicators used to assess progress against targets
	Insurance companies that perform climate-related scenario analysis on their underwriting activities should provide the following information: • description of the climate-related scenarios used, including the critical input parameters, assumptions and considerations, and analytical choices. In addition to a 2°C scenario, insurance companies with substantial exposure to weather-related perils should consider using a greater than 2°C scenario to account for physical effects of climate change and • time frames used for the climate-related scenarios, including short-, medium-, and long-term milestones.		
	Asset owners that perform scenario analysis should consider providing a discussion of how climate-related scenarios are used, such as to inform investments in specific assets.		

Note: The Task Force acknowledges the challenges and limitations of current carbon footprinting metrics, including that such metrics should not necessarily be interpreted as risk metrics. The Task Force views the reporting of weighted average carbon intensity as a first step and expects disclosure of this information to prompt important advancements in the development of decision-useful, climate-related risk metrics. The Task Force recognizes that some asset owners and asset managers may be able to report weighted average carbon intensity for only a portion of their investments given data availability and methodological issues.
Source: TCFD (2017a, 2017b)

TCFD and Regulatory Actions on Climate and ESG in Asia

The TCFD's recommendations were received positively by a wide range of stakeholders, including governments, regulators, institutional investors, and corporate issuers. Although they are voluntary, it seems likely that they will be the model framework for regulators when it comes to climate disclosures.

In Asia, all major (and minor) equity markets encourage or require some form of corporate ESG disclosure, on a mandatory, voluntary, and/or comply-or-explain basis (see Table 24 below), driven by legislation or via the regulator or local stock exchange. However, only two markets in the region require such disclosure from pension funds, and less than half have a requirement for investment managers (PRI 2016a).

Over the near term, the TCFD's recommendations may therefore be more likely to be implemented at the corporate level than at the asset owner or asset manager level. However, given the prominence of the TCFD and the already widespread exposure to ESG issues in these markets, pension fund rules and stewardship codes in the region may also incorporate the TCFD recommendations over the medium term.

For those markets where limited guidance is provided on the extent and scope of ESG/climate disclosure (i.e., most of them), TCFD implementation at the corporate level should have the effect of providing a relatively consistent level of climate risk disclosure across the region. This will have benefits within markets and across markets, as investors and policymakers alike will be able to develop a better understanding of climate risks in and across the relevant markets.

Table 24: Asia-Pacific ESG Disclosure Regulation Status

Country	Pension Fund Regulation	Stewardship Code	Government Imposed Corporate ESG Disclosure	Non-Government Imposed Corporate ESG Disclosure
Australia	MESG	VESG	MESG, M*S, ME	VESG, MG
Bangladesh	N	N	MG	VESG
China	N	N	VE, VESG, MG	VESG
Hong Kong	N	VESG	N	C/EE, VS, C/EG
India	N	N	M*ESG, VESG	N
Indonesia	N	N	MESG	VESG
Japan	N	VESG	M*E, VE	C/EESG
Malaysia	N	VESG	C/EESG, MESG, VESG, MG	N
Philippines	N	N	M*ESG	VESG
Pakistan	N	N	MESG	MESG
Singapore	N	VESG	VESG	VESG, C/EESG
South Korea	M*ESG	VESG	M*E	N
Thailand	N	N	MESG, VESG	VESG
Vietnam	N	N	MESG	VESG in progress

Source: PRI (2016a)

N = No regulation of this kind in place
V = Voluntary
M = Mandatory
C/E = Comply-or-explain
ESG = Regulation that addresses ESG issues comprehensively
E = Environmental regulation
S = Social regulation
G = Governance regulation
*Only applies to certain institutions, sectors or regions

The blue webbed flying frog (*Rhacophorus reinwardtii*) is typically found in Indonesia and Malaysia. Amphibians are among the groups most sensitive to any change, whether it is caused by habitat loss, invasive species, disease, trade or climate change. Nearly 33% of the amphibian species of the world are categorized as threatened. Amphibians are often recognized as indicators of ecosystem health.

With respect to climate issues, there has been a wide range of regulatory responses across Asia-Pacific. China's efforts have been the most substantial, with the ongoing implementation of the PBOC's 2015 Establishing China's Green Financial System plan (PBOC 2015). The plan, developed together with UNEP Inquiry, made 14 recommendations to create a comprehensive green financial ecosystem, including banking, bonds, funds, ratings, stock indices, carbon trading, lender liability, and disclosure.

As of late 2017, China has made significant progress in implementing these recommendations, most importantly by establishing the strategic framework and policy guidelines for the green financial system in 2016 (IIGF 2017). This has contributed to the rapid development of China's green bond market, which raised USD37.1bn in 2017, second only to the USD42.4bn raised in the US, and up from zero in 2014. Of that amount, USD22.9bn was aligned with international green definitions, and accounted for 15% of the global green bond market. This was still enough for second in the country league tables, ahead of France's USD22.0bn (CBI 2018b).

The green bond market in the rest of Asia-Pacific is still at a relatively early stage of development, with many governments and regulators only recently issuing relevant guidelines and standards for certification and issuance. The top 5 regional issuers of green bonds in the region by cumulative issuance as of 2017 are China (USD47.7bn), India (USD6.6bn), Japan (USD6.1bn), Australia (USD4.6bn), and South Korea (USD2.05bn) (CBI 2018c). Elsewhere in the region, in early 2018 Hong Kong announced a HKD100bn green bond issuance programme for public works as well as a grant scheme to promote private issuance of green bonds. Singapore has a similar grant scheme, while Indonesia and Malaysia have issued framework regulation for green sukuks, complementing the ASEAN green bond standards issued in late 2017.

Table 25: Asia-Pacific Financial System Regulatory Responses to Climate Change

Australia

- Firms expected to integrate climate risk into internal risk management processes, including modelling potential impacts under different scenarios and time horizons.
- APRA formed an internal Climate Change Financial Risk Working Group.
- Regulated entities to be surveyed on their climate risk practices.
- Climate change risk may be incorporated into system-wide stress testing.
- Inter-agency initiative on whether companies are taking steps to protect themselves and their customers from risks caused by climate change.

China

- PBOC one of eight central banks to commit to establishing the Network of Central Banks and Supervisors for Greening the Financial System.
- Guidelines to incentivise green products.
- Green bond guidelines released by PBOC, CSRC.
- Green bond verifier guidelines jointly released by CSRC and PBOC.
- Mandatory environmental disclosures.
- Environmental stress testing.
- Pilot green finance zones.

Hong Kong

- Pilot green bond grant scheme and issuance programme announced.
- HKQAA an approved verifier under the Climate Bonds Standard and Certification Scheme.

India

- Renewable energy sector designated as a priority sector for bank lending.
- Final green bond guidelines released by SEBI.

Indonesia

- Roadmap for sustainable finance.
- Regulation for green bond issuance.
- Rules on sustainable finance for financial services companies, issuers, and public companies.

Japan

- Green bond guidelines released by Ministry of Environment.

Malaysia

- SRI sukuk framework and green sukuk incentives established.

Singapore

- MAS one of eight central banks to commit to establishing the Network of Central Banks and Supervisors for Greening the Financial System.
- Green bond grant scheme.
- MAS to help expand the range of ESG-related products and broaden green and sustainable finance talent pool.
- MAS to include climate-related scenarios in future stress testing exercises.
- MAS to encourage industry adoption of TCFD recommendations.

Taiwan

- Green bond listing requirements issued.

ASEAN

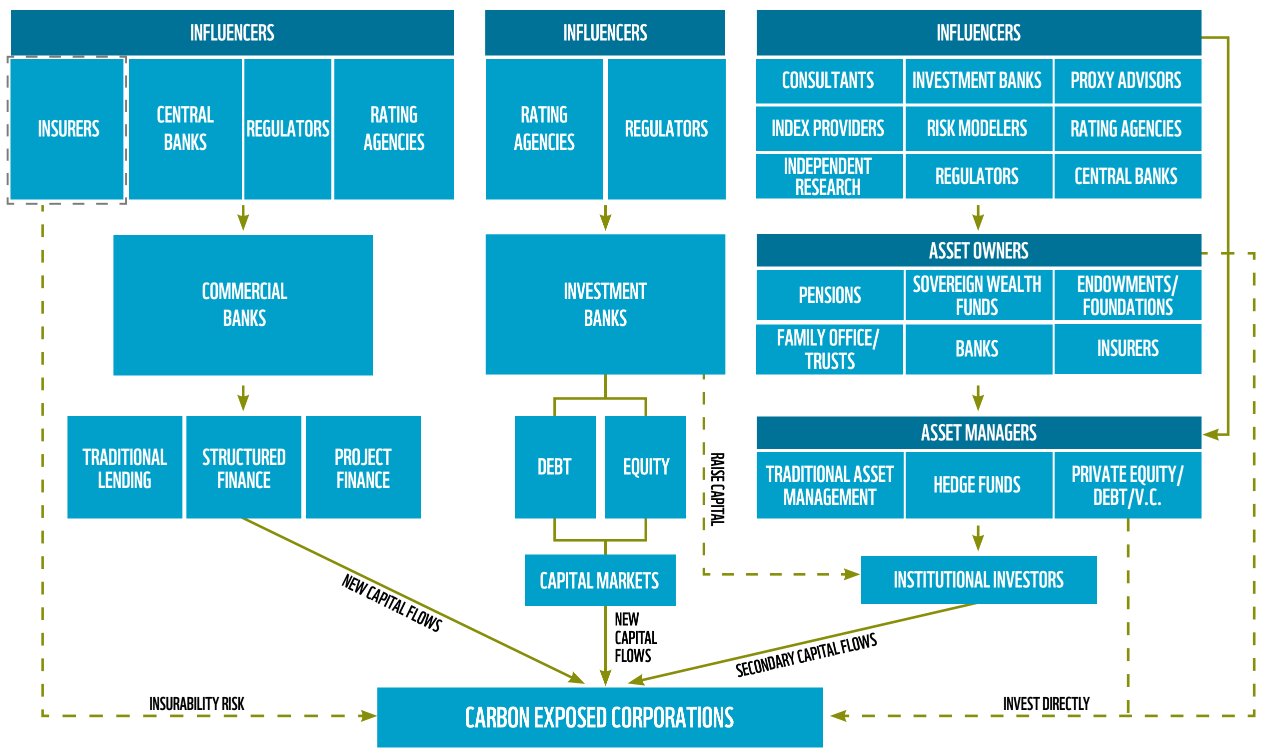
- Green bond standards for ASEAN developed and issued by the ASEAN Capital Markets Forum, based on the International Capital Market Association's Green Bond Principles. Excludes fossil fuel.

Source: Deloitte (2018), ACMF (2017), BNM (2017), CBI (2018a)

Private Finance Players – Potential Climate Integration Actions

The private finance architecture offers multiple points where climate risk can be identified, quantified, and/or managed. On the investment side, the primary locus for this is between asset owners and their portfolio companies (directly or via asset managers), but the investment environment also includes entities with significant influence over these actors, including investment consultants, risk modelers, proxy advisers, rating agencies, and policymakers.

Figure 90: Climate Risk Intervention Points Within the Private Finance Architecture



Source: WWF

"THE ABILITY TO MEASURE CLIMATE/CARBON EXPOSURE IS A CRUCIAL ELEMENT WHEN IT COMES TO CLIMATE CHANGE INTEGRATION."

Asset Owners, Asset Managers, and Climate Change Integration

Asset owners as well as asset managers need to integrate the assessment of climate change issues into their operations and investment processes. Ideally, this would be driven from the top – with the board level establishing the asset owner's climate-related beliefs, policies and targets, and communicating them down the organisation. For asset managers, the need for such integration is partially about client service – asset owners with climate processes will likely have a preference for engaging asset managers with complementary capabilities.

There are a number of discrete and overlapping methods for asset owners and asset managers to employ with respect to addressing climate change. As Table 26 suggests, these can be integrated at various levels, from an operating principle, to an engagement strategy or stock selection screen (Harnett 2017).

Table 26: Methods for Integrating Climate Change Issues

Climate Change Integration Methods
Active Investment in Green Bonds/Clean Tech/Renewables/etc.
Capital Investment Appraisal
Climate Change Integrated into Fundamental Analysis Reports
Climate Exposure Metrics and Target Setting
Direct Engagement with Corporations
Decarbonisation/Divestment
Education of Managers and/or Members
ESG as Central Operating Principle
ESG-tilted Management Incentive Structures
Negative and Positive Screening
Responsible Investment (RI) (investment policy; risk management policy; ESG-focused hiring policy)
Shareholder Voting
Strategic Asset Allocation

Source: Harnett (2017)

Climate Exposure Metrics

The ability to measure climate/carbon exposure is a crucial element when it comes to climate change integration. There is an increasing variety of tools and metrics available to institutional investors to assess their climate exposure. These have typically been backward-looking, and include carbon footprinting, carbon intensity, green/brown exposure metrics, and portfolio emissions. This limitation, combined with the TCFD's articulation of the benefits of forward-looking disclosure and scenario analysis, has generated a consensus on the need for climate assessment tools and metrics that align with this focus. This has led to the development of two additional and complementary sets of methodologies (WWF 2017):

- **Climate risk exposure:** this is an investment approach focusing on risks and opportunities. Assessing the climate-related value at risk in the investment portfolio is increasingly important for asset owners given its order of magnitude.
- **Climate alignment:** this approach assesses how investment portfolios are consistent with and contribute to the public policy objective of climate mitigation in the Paris Agreement – that is to ensure that global warming stays well below 2°C, aiming for 1.5°C.

Each methodology has different strengths and weaknesses, with respect to asset class coverage as well as approach (e.g. top-down portfolio analysis versus bottom-up security/sector analysis). There is currently no single methodology that is able to capture all relevant issues for asset owners, but the market is evolving rapidly (WWF 2017). Table 27 below provides an overview of the various climate assessment metrics methodologies.

Table 27: Overview of Climate Assessment Methodologies

	NAME OR TYPE	DESCRIPTION	STRENGTHS	WEAKNESSES
CLIMATE RISK	**Climate TRIP**	This tool was developed by Mercer. It is commercially available and enables assessment of climate-related risks across asset classes at the portfolio level	Forward-looking nature, integrates a comprehensive set of risk factors (both physical and transition risks)	Sector-specific exposure is only estimated for public equity, with limited granularity
CLIMATE RISK	**Cicero**	This tool categorises climate risks for investors; the tool for assessing physical climate risk (ClimINVEST) is not yet available	Builds on climate scenario analysis, forward-looking nature	Limited granularity of climate risk categories for investors
CLIMATE RISK	**Carbon delta**	This tool calculates the climate Value at Risk of companies and has been commercially available since end 2016	Forward-looking nature, across all sectors	Limited granularity
CLIMATE RISK	**Energy transition risk**	This tool is being developed by 2° Investing Initiative, as part of a research consortium with seven organisations (several deliverables are not yet available), and focuses on the energy transition risk of seven sectors	Forward-looking nature, sophisticated and granular metrics	Limited to equities and bonds
CLIMATE ALIGMENT	**Sustainable Energy Investment Metrics (SEIM)**	This tool was developed by 2° Investing Initiative, as part of a research consortium with seven organisations. It is commercially available and free. The tool currently covers four sectors (power, oil & gas, coal mining, automotive) in public equity portfolios, and further coverage (aviation, shipping, cement, steel) and asset class (corporate bonds) is under development	Forward-looking nature, free, bottom-up asset-level data approach and flexibility that allows the use of different emission reduction scenarios	Only available for a limited number of sectors and for the public equity asset class
CLIMATE ALIGMENT	**Exane**	This tool has been developed by BNP Paribas. Analysis is bespoke, and covers five public equity sectors (utilities, automotive, materials, retail, real estate)	Forward-looking nature	Relies on past trends or declared company targets instead of asset-level data
OTHER	**Carbon footprint**	This tool has been developed and fine-tuned by multiple organisations, and is currently commercially available through many channels (e.g. CDP, Ecofys, MSCI, South Pole Group, Trucost, etc.)	Road-tested and widely available, can be used for all sectors and several asset classes	Backward-looking, and thus does not provide very relevant information to asset owners on how they can adapt their portfolios to climate-related financial risks; cannot be used for measuring green exposure; coverage of several asset classes remains bespoke
OTHER	**Green/brown exposure**	This covers a group of tools that assess technology exposure by sector on the basis of metrics like company revenue, R&D, capital expenditure plans. It is currently offered by multiple organisations (e.g. MSCI, Carbone 4, Bloomberg, Trucost, Oekom, Inrate, South Pole Group, FUSE LCE, Profundo, etc.)	Easy to implement, can be applied across asset classes. Can be used to track current (e.g. revenues) or forward-looking (e.g. R&D, capital expenditure plans), and data are generally of high quality as it stems from company reporting	Binary distinction masks the actual impact or relative 'greenness' of different activities. Technology exposure does not necessarily correlate to carbon risk exposure, nor identify opportunities
OTHER	**Climate scores**	This covers a group of tools that provides qualitative scores to companies on climate issues — often combining above-mentioned carbon footprinting, green/brown exposure with other ESG analysis. Different tools are currently on the market (e.g. MSCI, Oekom, Solaron, Trucost, South Pole Group, Inrate, Carbone 4, Vegeo, Eiris, FTSE, Sustainalytics, etc.)	Combine different approaches into one	Backward-looking, poor correlation to climate-related risks and opportunities
OTHER	**Portfolio avoided emissions**	These tools aim to respond to inability of carbon footprinting to track green investments, by tracking greenhouse gas emission reductions from an assumed baseline	Ability to measure green investments	No standard method to identify baseline or common understanding of definition for avoided emissions. Analysis is therefore bespoke and generally not comparable

Source: 2° Investing Initiative via WWF (2017)

Engagement

A key component of climate change integration for asset owners and managers is engagement with portfolio companies and policy makers. At the portfolio company level there are multiple avenues for such engagement, ranging from voting on or even sponsoring shareholder resolutions to direct contact with company management that articulates investor concerns and objectives. This can be done as part of an internal process, or in alignment with one or more investor coalitions focused on the issue (see below). Engagement with policy makers is more likely to be effective as part of a coalition for all but the largest asset owners and managers.

Portfolio Decarbonisation

The Portfolio Decarbonization Coalition (PDC) is an investor coalition in which members commit to reduce the carbon footprint of their portfolios in one of two ways: via reallocation or corporate engagement. Members also agree to publicly disclose an overview and key features of the employed techniques and methods. PDC has 32 signatories with over USD3tr in assets under management, and USD800bn in decarbonisation commitments to date.

The signatories have adopted a range of decarbonisation strategies, including engagement, negative and/or positive screening, and voting. Investors are employing more holistic analyses and are increasingly extending their decarbonisation focus beyond listed equity and property, and into corporate fixed income, while also increasing green exposures (PDC 2017).

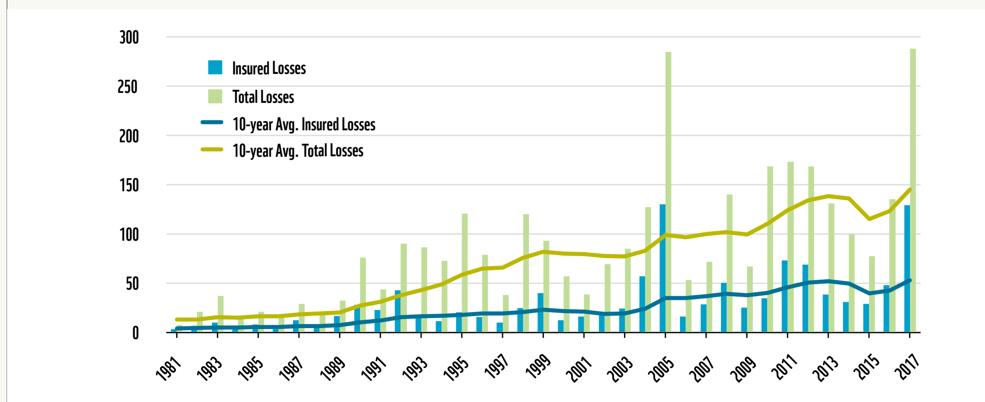
Another approach involves index replication and decarbonisation, which may be suitable for long-term passive investors seeking to reduce carbon exposure. Andersson et al. as well as Russell Investments have demonstrated that it is possible to construct a decarbonised version of a mainstream index such as the MSCI AC World, with relatively low tracking error (30-70 basis points, depending on the approach used) and a 50%+ reduction in carbon footprint (Andersson, Bolton and Samama 2016); (Russell 2016). These approaches typically require carbon footprint data, which tends to be more available for larger-cap stocks, and involve the elimination of high-carbon index members and subsequent sector rebalancing. The resulting decarbonised index should be re-evaluated to ensure climate alignment with the 2°C goal.

The back-tested approaches generated excess returns vs. the index on the order of 40-100 basis points (annualised), possibly due to the market's devaluation of the coal sector over the course of the measurement period (Russell 2016). This suggests that these approaches can provide a hedge against the timing of the repricing of high-carbon assets, which for the most part do not appear to incorporate any meaningful level of CO_2 pricing.

Insurers

As asset owners, insurers need to earn a high enough return on premiums paid to be able to settle future claims from written policies. In the case of climate change, the physical risks the sector is exposed to appear to be increasing, as weather-related events increase in frequency and damage. While some of these insured losses can be mitigated via reinsurance, should temperature trends continue, at some point premiums will surpass the ability of clients to pay for them.

Figure 91: Global Weather-Related Losses, 1981-2017, USD bn (2017 dollars)



Source: Swiss Re (2018)

In terms of climate change perceptions, the Geneva Association, a leading international insurance industry think tank, surveyed over 60 C-level insurance executives from 21 companies and found that 38% of the companies viewed climate change as a core business issue, 29% as a sustainability issue that is transitioning to core business, while the remainder see it as a CSR/sustainability issue (Geneva Association 2018).

In their investments, insurers are increasingly using ESG criteria in their investment processes. This ranges from simple negative ESG screens – the most widely used method – to full ESG integration, actively and systematically including ESG risk and opportunities into their investment analyses. Most insurers also require their external asset managers to have integrated ESG factors into their investment processes (Geneva Association 2018).

The primary investment-side challenges articulated in the survey were similar to those seen in Table 21 above (Geneva Association 2018):

- Lack of generally accepted standards for "green" across various asset classes.
- Lack of standardisation of projects and contracts increases the due diligence burden.
- Supply of green instruments is insufficient to accommodate large-scale portfolio allocations to green issues, particularly green bonds.
- Insurers also expressed demand for new green instruments such as loans and securitisations.
- Green/resilient infrastructure is particularly appealing as an investment for life insurers, given their need for long-duration asset-liability matching. However, capital charges under insurance and financial regulations pose constraints to their activity in this space.
- Other than some renewable energy, green/clean technology opportunities do not meet insurers' risk-adjusted return requirements.

INFLUENCERS

The various influencers in the financial ecosystem play important supporting roles with respect to the investment processes of asset owners and managers. This support ultimately boils down to the provision of information and recommendations with respect to specific issues institutional investors face or decisions they need to make. Because of this influence, it is critical that asset owners/managers engage with these parties on climate change issues.

Credit Rating Agencies

The large credit rating agencies (CRAs) are arguably ahead of the curve when it comes to incorporating climate risks into their products. While both CRAs and investors agree that the "G" in ESG is the most important factor in their credit analyses, environmental and climate issues have been gaining traction (PRI 2017a).

In late 2017, S&P Global Ratings published a lookback analysis which identified over 700 cases from July 2015 to August 2017 where environmental and climate concerns affected corporate ratings, almost 10% of corporate rating assessments over the period. Over 100 of these cases resulted in a rating impact. This was double the level of cases and ratings impacts found by a similar exercise published in 2015 (S&P 2017).

While the leading CRAs may be incorporating ESG factors into their assessments, visibility into this process is limited, aside from governance. Transparency on how the other two factors ("E" and "S") are assessed has room for improvement.

In China, domestic CRAs are focused on expanding their green bond capabilities, in light of a green bond market that went from zero to over USD30bn in issues in less than 3 years. As such, most ESG attention is on the environmental component.

Table 28: Credit Rating Agency Progress on ESG

CRA Type	Progress on ESG	Key Findings
Global CRAs This group contains the two largest and most established CRAs: Moody's Investors Service and S&P Global Ratings.	**Leading the pack – strong efforts** Visible progress in complementing rating analysis with additional research publications on ESG considerations to refine and improve methodologies and transparency.	**Motivation**: See signing PRI statement as a reaffirmation of what they were already doing in terms of ESG integration and transparency. Client demand is increasing but still localised. **Focus**: Publication of papers on how they integrate ESG into their criteria; exploring creation of additional ESG scores; recent research focus is evident primarily on climate change and "green" evaluation. **Internal capacity**: Expanding. Hiring staff with ESG backgrounds as well as equipping existing credit analysts and rating committees with ESG expertise; providing new ESG evaluation tools; expanding analytics and sourcing expertise from third-party providers (e.g. S&P Dow Jones Indices' acquisition of Trucost plc). **Transparency**: Both CRAs acknowledge there is scope for improvement. **Challenges**: Investor willingness to pay for non-rating ESG-orientated products and services; meeting growing demand for more extensive commentary on ESG issues for issuers beyond current credit ratings.
Smaller/regional CRAs – Specialists This group contains smaller and more specialised agencies: Liberum Ratings, RAM Ratings and Scope Ratings AG.	**Catching up – good efforts** Younger; less developed in the publication of working frameworks than the global agencies but demonstrating strong commitment to incorporating ESG factors as they grow.	**Motivation**: Belief in the value of ESG and an interest in satisfying increasing investor demands in this area. **Focus**: Most still at the development stage of formal measures and using them consistently in all ratings. **Internal capacity**: Nascent. As an example, a CRA has charged some of its most senior staff to establish a taskforce that will develop the necessary framework, processes, internal capacity and manage their commitments under the statement. **Transparency**: Internal methodologies are generally still being developed and transparency, besides high-level methodology papers, is limited. **Challenges**: As the smaller and regional CRAs are still relying mostly on issuers' fees, they face more commercial pressure, potentially compromising ESG integration.
Regional CRAs – Chinese This group represents a sub-set of the regional ones and includes Dagong Global Credit Ratings, China Chengxin and Golden Credit Ratings.	**Early days – focusing on green** Generally consider ESG from a green bond perspective.	**Motivation**: Government policy in China has generated significant interest in green bonds and CRAs have responded by developing green bond rating processes. **Focus**: Almost exclusively on the environmental impact of the projects rated. **Internal capacity**: Expanding to meet increasing demand for green bond assessment processes. **Transparency**: Remains an issue due to language barriers and significant discrepancies between ratings assigned by local agencies and global agencies for the same issuer. **Challenges**: One CRA notes that the biggest challenge to its rating process is how to internalise environmental costs.

Source: PRI (2017a)

Index Providers

The market capitalisation-weighted indices of companies such MSCI, FTSE, and S&P provide an easily comprehensible indicator of market performance. These indices are replicated by passive investors and are used as allocation guidelines for sector diversification and relative risk assessment by the majority of investors.

Much active and essentially all passive investment is benchmarked against mainstream indices tracking global, regional, country, or sector performance. However, index providers also offer a wide range of specialised indices, including ones focused on sustainability, ESG ratings, climate change, and low-carbon products. These would need to be assessed both for compatibility with investment mandate, as well as for climate alignment.

Investment Consultants

Investment consultants are an important part of the investment processes of many asset owners, providing advice on the deployment of trillions of dollars. Investment consultants help asset owners in many ways, including the selection and appointment of asset managers, providing access to technical expertise and research, and in understanding and interpreting information provided by asset managers (PRI 2017b).

However, according to a 2017 review by PRI, investment consultants generally provide limited advice on ESG issues, despite growing evidence of the materiality of these issues to portfolio value. On both the supply and demand sides of the equation, ESG issues are not normally raised, and addressing these issues frequently involves extra cost to the asset owner (PRI 2017b).

As the TCFD's recommendations are implemented and the materiality of climate issues becomes more apparent, asset owners may become more proactive about seeking advice on climate/ESG issues from their service providers.

Table 29: Global Distribution of Investment Consultants

	Staff location	Number of consultants
1	USA	6,380
2	UK	3,559
3	Australia	535
4	Canada	452
5	Germany	315
6	Switzerland	313
7	Netherlands	298
8	South Africa	262
9	France	209
10	Ireland	147
11	Singapore	111
12	Hong Kong	108

Source: IC Research Institute via PRI (2017b)

Investor Coalitions

Asset owners, managers and influencers can participate in a variety of investor coalitions to share best practices, signal their commitment, and amplify their engagement with portfolio companies and policy makers.

Table 30: Investor Coalitions

Name	Description	Population	AUM	Website
Principles for Responsible Investment (PRI)	UN-affiliated leading global proponent of responsible investment. Established six principles for investors about ESG integration into investment practices and investee companies. Promotes ESG in the investment industry, coordination between signatories, and reporting on progress toward implementing the principles.	354 asset owners, 1216 investment managers, 222 service providers	USD70tr	https://www.unpri.org
Montreal Carbon Pledge	Investors commit to measure and publicly disclose the carbon footprint of their investment portfolios on an annual basis. Overseen by PRI.	150 commitments	USD10tr	http://montrealpledge.org
Portfolio Decarbonization Coalition (PDC)	Members commit to reduce the carbon footprint of their portfolios via reallocation or corporate engagement. USD800bn in decarbonisation commitments to date.	32 members	USD3tr+	http://unepfi.org/pdc/
Asia Investor Group on Climate Change (AIGCC)	Asia-based. Aims to create awareness among Asia's asset owners and financial institutions about the risks and opportunities associated with climate change and low carbon investing.	19 members	n/a	http://aigcc.net
Investor Group on Climate Change (IGCC)	ANZ-based. Aims to encourage government policies and investment practices that address the risks and opportunities of climate change.	65 members	AUD2tr	https://igcc.org.au
Institutional Investor Group on Climate Change (IIGCC)	Europe-based. Aims to mobilise capital for the low carbon future by amplifying the investor voice and collaborating with business, policymakers and investors.	150 members	EUR21tr	http://www.iigcc.org
Ceres Investor Network on Climate Risk and Sustainability	US-based. Sustainability non-profit whose investor network members engage and collaborate on ESG issues to advance leading investment practices, corporate engagement strategies and policy solutions.	146-member investor network	USD23tr	https://www.ceres.org/networks/ceres-investor-network
Global Investor Coalition on Climate Change (GIC)	Coalition of AIGCC, IGCC, IIGCC, and Ceres. Advances global investor collaboration to improve investor practices, corporate actions and international policy responses to climate change.	n/a	n/a	http://globalinvestorcoalition.org
Climate Action 100+	Five-year initiative launched in December 2017. Investors commit to engage with the world's largest corporate GHG emitters to improve governance on climate change, curb emissions and strengthen climate-related financial disclosures. Coordinated by PRI and GIC component groups.	256 global investors	USD28tr	http://www.climateaction100.org
CDP (formerly Carbon Disclosure Project)	Requests standardized climate change, water and forest reporting from some of the world's largest listed companies (including 1300 high-carbon companies) through annual questionnaires sent on behalf of institutional investors that endorse them as 'CDP signatories'.	Backed by 827 investors	USD100tr	https://www.cdp.net/en
ClimateWise	Insurance industry association focused on the risks and opportunities of climate change. Established six principles to frame member activities as they respond to climate change across their business activities. Members are required to annually disclose their individual progress against the principles. Submissions are audited, members are ranked, and aggregate progress is publicised.	29 members	n/a	https://www.cisl.cam.ac.uk/business-action/sustainable-finance/climatewise

Source: Coalition websites

Proxy Advisory Firms

Proxy advisory firms provide institutional investors with recommendations (and supporting research and data) on how to vote on management and shareholder proxy proposals. As part of their annual policy revisions, two of the primary proxy advisory firms, Institutional Shareholder Services (ISS) and Glass Lewis, both updated their proxy voting guidelines on climate change issues for 2018 in light of the TCFD's recommendations (Gibson Dunn 2017).

ISS had previously generally supported shareholder proposals seeking company disclosure on climate risks. Its updated policy also supports proposals addressing how a company identifies, measures, and manages such risks. In Asia, the update applies to Japan, China, Hong Kong, and Singapore (Gibson Dunn 2017).

Glass Lewis has codified its policy on climate change-related shareholder proposals and will generally support proposals seeking disclosure on climate risks, scenario analyses, and other considerations, for companies that have elevated exposure to climate risks. For other companies, Glass Lewis will review TCFD-related proposals for disclosure on a case-by-case basis. This policy applies to the US and Canada (Gibson Dunn 2017).

Asian elephant (*Elephas maximus*) and calf at the Minneriya National Park in Sri Lanka. Asian elephants are very vulnerable to changing climate conditions. These elephants are more exposed to a wide temperature variability in the face of climate change, ranging from freezing to 40 degrees. Hence, they are at a higher risk of experiencing heat stress.

CONCLUSION
Implications for Investors

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Teaoraereke Village, Tarawa.Two children from what might be the last generation of Kiribati.

As the vast majority of institutional funds is mandated toward secondary market issues, many institutional investors have limited ability to invest directly in climate change mitigation or adaptation opportunities. However, this does not mean they are helpless in the face of the problem.

Investors should make use of existing and emerging tools to assess the climate risk their portfolios contain, a task that may become easier as the TCFD's recommendations are implemented. From there, they can determine to what extent this risk can be mitigated, whether it be through portfolio decarbonization, corporate engagement, intra-sector substitution, or some other relevant method.

Although the policy and regulatory environment with respect to climate change is constantly shifting, the direction of travel seems clear. As such, a climate risk assessment will likely need to be repeated on a regular basis, particularly once the TCFD's supplemental recommendations for the financial sector are adopted. This would essentially have the effect of integrating the environmental component of the ESG approach into investors' investment processes.

As the TCFD stated in its report, "climate-related risk is a non-diversifiable risk that affects nearly all industries" (FSB TCFD 2017a). Institutional investors are in the process of coming to grips with the risks involved.

Annex A: Observed and Projected Impact of Climate Change in Asia-Pacific

Country/ Region	Observed/ Projected	Temperature (mean annual change)	Precipitation	Sea Level Rise / Ocean Situation	Extreme Events	Other
East Asia						
Japan	Observed	• +1°C over past century • Increased number of hot days (over 35°C). • Hokkaido winter temperatures +1.3°C over past century. • Decrease in frost frequency and in the number of days with cold temperatures.	• Higher number of days with heavy precipitation. • Higher number of days with no precipitation. • Significant reductions in the amount of snowfall.	• Accelerating rate of sea level rise of 5 mm per year since 1993.	• Increase in the frequency and intensity of extreme weather events, such as heavy rain, landslides, floods and extreme heat.	
	Projected	• +2 to 3°C over the next 100 years for all of Japan. • +4°C around the Sea of Okhotsk over the next 100 years. • Higher number of extreme hot days (over 35°C). • Number of frost days lowered by 20, to 45 days per year.	• +10% mean precipitation over the 21st century. • Summer precipitation +17-19%.	• Projected sea level rise of 5 mm per year throughout 21st century.	• Increase in heavy precipitation events in Hokkaido. • Higher frequency and intensity of extreme weather events, such as tropical cyclones, heatwaves, and heavy rainfall.	• Significant shift in the geographic distribution and range of marine and terrestrial species. • Earlier flowering and later senescence of some plant species, including iconic cherry trees, with potential for ecosystem mismatches (plants, birds and insects being at greatest risk). • Negative impacts to fruit crops and an increase in abnormal fruits. • Potential temporary increased yield in grain harvests in Hokkaido. • 40% decrease in rice yields in central and southern Japan.
South Korea	Observed	• +1.5°C over past century • +0.4-0.8°C excluding urbanisation effect. • Between 1960 and 2003, warm days and nights have become more frequent while cool days and nights have become less frequent. • Warm summer temperatures occur more frequently; cold summer temperatures occur less frequently.	• Since 1990, increase of annual rainfall by 7% and days with heavy rainfall by 23%. • Decrease of annual number of rainy days by 14%.	• +0.1m sea level rise since the 1970s.	• Increase in the frequency and intensity of extreme weather events, such as snowfall, drought, and heavy rain events.	
	Projected	• It is estimated that the average temperature will rise 1.2° by the 2020's, 2.4°C by the 2050's, and 4.0°C by the 2080's.	• ROK lies at the south of the widespread region across Eastern Asia where projected precipitation shows increases of 10-20%.			• + Rice yield to 2050, potential decline thereafter.
China	Observed	• +0.8°C since 1960, avg. rate of 0.18°C per decade. Rate of increase is most rapid in DJF (0.36°C per decade). Temp. increases are particularly rapid in the northern regions in the winter. • Freq. of "hot" days and "hot" nights has increased significantly since 1960 in every season. • Avg. number of "hot" days/year +16 days (+4.5% of days) btw. 1960-2006. The rate of increase is seen most strongly in SON. • Avg. number of "hot" nights/year +31 nights (+8% of nights) btw. 1960-2006. The rate of increase is seen most strongly in JJA. • Freq. of "cold" days and "cold" nights has decreased significantly since 1960 in every season. • Avg. number of "cold" days/year -12 days btw. 1960-2006. • Avg. number of "cold" nights/year -34 btw.1960-2006.	• Rainfall over China does not appear to show any consistent increase or decrease since the 1960s. A statistically significant decreasing trend is seen in SON at the rate of 0.9 mm per month (2.2%) per decade. • Significant trends are, however, evident in particular regions: Northwest China positive trends are observed in the dry season. In southeast China, significant increasing trend of 5.6 mm per month (3.3%) per decade is observed.	• China's coastal sea level has increased at an average rate of 2.5 mm per year during the past 50 years, higher than the global average of 1–2 mm per year. • Local rates of sea-level changes vary considerably and have been much higher in coastal cities that are sinking due to the weight of construction and over-withdrawals of groundwater.	• Both the frequency of tropical cyclones affecting China and the rainfall brought by these storms have decreased over the past 50 years. • Yet their destructive force has grown, as indicated by higher maximum wind speeds and lower barometric pressure in storm centres.	
	Projected	• Mean annual temperature is projected +1.3-3.5°C by the 2060s and +1.7-5.5°C by the 2090s. The range of projections by the 2090s under any one emissions scenario is around 2°C. • Projected rate of warming is greatest in winter (DJF) with +2.0-6.4°C projected by the 2090s. • Projected increases are most rapid in northern and western regions of China, with projected increases in annual mean temperature of around 2-6°C in the northern regions and the Tibet Plateau, but more moderate increases of around 1.5-5°C in southern China. • All projections indicate higher frequency of days and nights that are considered "hot" in current climate, lower frequency of days and nights that are considered "cold". • Projections indicate that "hot" days will occur on 16-25% of days by the 2060s, and 17-34% of days by the 2090s. • Nights that are considered "hot" for the annual climate of 1970-1999 are projected to occur on 16-25% of nights by the 2060s and 17-34% of nights by the 2090s.	• NE China projected to receive more rainfall in the dry seasons, less in wet season (JJA). • NW and north-central China projected to receive increases in rainfall all year round. • Mixed rainfall projections for the Tibetan Plateau region; some large increases in wet-season rainfall over the southern areas near Nepal and Bhutan, but decreases in DJF. • Southern regions of China: more wet-season rainfall, less dry-season rainfall. • Proportion of total annual rainfall that falls in heavy events +2-10% by the 2090s in all the models. • Max 1- and 5-day rainfalls are expected to increase. Annually, 1-day maxima change by +1-17 mm, and 5-day maxima change by +2-23 mm by the 2090s.	• China's State Oceanic Administration projects that by the end of the 2030s, sea level along China's southern and eastern coasts will have risen 8–13 cm over 2010 levels.	• The IPCC's assessment is that globally, tropical cyclone wind speeds will "likely" increase, while the frequency of tropical cyclones will "likely" decrease or show no change.	

Mongolia	Observed	• Average annual temperature in Mongolia has increased by 2.14°C during 1940-2008. • The number of 'hot days' has increased between 16 and 25 days between 1961-2007, while the number of 'cold days' decreased between 13 and 14 days. • The warm season has increased in length by 8 to 13 days, while the cold season length decreased by 7 to 11 days between 1961-2007.	• Lower mean annual precipitation over most of Mongolia since the 1940s. However, Gobi Altai has experienced a statistically significant increase in precipitation since 1961. • Winter precipitation has increased, while summer rainfall decreased.	• n/a	• From 1960-2007 number of days with dust storms has increased from 18 days to 57 days. • Since the 1940s, significant increase in the freq. of extreme high temps, while extreme low temps. have decreased. • Higher avg. annual permafrost temp at depths of 10-15m over the past 10-40 years in the regions of Hovsgol, Hangai, and Hentei Mountain, with greater warming in the latter 15-20 years.	
	Projected	• Temperature is projected to increase between 2.1-3°C by mid-21st century and between 3.1-5°C by end-21st century. Summer projected to see a higher intensity of warming in the future. • The annual number of "cold" days and nights are projected to decrease under low, medium, and high emissions scenarios throughout the mid and late 21st century. • The annual number of "hot" days and nights are projected to increase under low, medium, and high emissions scenarios throughout the mid and late 21st century.	• Mean annual precipitation is projected to increase over Mongolia for mid- and late 21st century. Precipitation expected to increase more in winter than summer. • In general, projections indicate that Mongolia will experience a milder winter with more snow and hotter and drier summers, despite the slight increase in precipitation as a result of high evaporation.	• n/a	• Permafrost is projected to melt throughout the 21st century. • The annual 'number of frost days' is projected to decrease under B1, A1B, and A2 emissions scenarios by mid- and late 21st century. Central northern Mongolia and the Altai Mountains in the western part of the country are projected to experience the largest decrease in the number of frost days under both temporal scales.	• The forest belt in northern Mongolia is projected to experience increased aridity during the 21st century. • Mongolian ecosystems are projected to shift northward in the latter half of the 21st century as a result of increasing temperatures and evapotranspiration.
South Asia						
India	Observed	• Mean annual temp +0.56°C per 100 years over 1901-2007. Warming trend has accelerated over 1971-2007 and is mainly due to warming in the winter and post-monsoon seasons. Mean winter season temp +0.70°C over the past 100 years, while the post-monsoon season increased by 0.52°C. • Mean minimum temp +0.12°C per 100 years over 1901-2007. However, within the past 35 years minimum temperature has increased significantly at a rate of 0.20°C per decade.	• Decreasing monsoon and post-monsoon season rainfall trends Assam and within the Brahmaputra and Barak river basins over 1901-2010, with the most pronounced decline over the last 30 years. • Seasonal mean rainfall in India has decreased and exhibits inter decadal variability • Mean monsoon rainfall between 1871-2009 exhibits a slight decreasing trend of 0.4mm/yr.	• In South Asia, sea levels had risen by around 0.21 m as of 2009.	• One-day extreme rainfall has increased in many areas of India between 1951 and 2007. Northern India has experienced more frequent extreme rainfall events over the 20th century. • Central India has experienced an increase in the frequency and intensity of extreme rainfall events, while moderate precipitation events have exhibited a significant decreasing trend.	• Rice: While overall rice yields have increased, rising temperatures with lower rainfall at the end of the growing season have caused a significant loss in India's rice production. Without climate change, average rice yields could have been almost 6% higher (75 million tons in absolute terms). • Wheat: Recent studies shows that wheat yields peaked in India and Bangladesh around 2001 and have not increased since despite increasing fertilizer applications. Observations show that extremely high temperatures in northern India – above 34°C – have had a substantial negative effect on wheat yields, and rising temperatures can only aggravate the situation.
	Projected	• Mean summer warming over India is projected to increase by 5°C by the end of the 21st century under the RCP8.5 emission scenario. • Warm spells are projected to increase over India by 30-45 days under RCP2.6 and 15-200 days under RCP8.5. • Models project that warm nights will increase by the end of the 21st century and occur on 40% of nights under RCP2.6 and 85% of nights under RCP8.5. • Projected temperature increases are lower in the south of India as compared to the north.	• Mean monsoon rainfall over India is projected to increase by the end of the 21st century. The models project increases between 15-40%. Models also project an increase in the inter-annual and inter-seasonal variability of monsoon rainfall. • Projections point to an increase in the frequency of years with above average monsoon rainfall and years with below average rainfall.	• Sea level is projected to rise throughout the 21st century. Projections indicate an increase of 0.6-0.8 m under the RCP2.6 emission scenario and an increase of 1.0-1.1 m under the RCP8.5 scenario by 2081-2100.	• Droughts are projected to increase in northwestern India under RCP8.5 scenario by the 2080s, while eastern India is projected to see an increase in the length of dry spells under this same scenario.	• Seasonal water scarcity, rising temperatures, and intrusion of sea water may threaten crop yields, jeopardizing the country's food security. • Under current trends, substantial yield reductions in both rice and wheat can be expected in the near and medium term. • Under 2°C warming by the 2050s, the country may need to import more than twice the amount of food-grain than would be required without climate change.
Pakistan	Observed	• During the last century, Pakistan's average annual temperature increased by 0.57°C compared to 0.75°C for South Asia. The warming is mainly due to increase in winter temperature. • During 1960-2007: • Mean temp +0.6°C to 1.0°C over the hyper-arid plains, arid coastal areas, and mountain regions of Pakistan. • Min. summer temp. over central Pakistan has shown a pronounced warming trend while in the extreme north and south have shown a slight cooling trend in some climatic zones. • No significant warming or cooling in the coastal belt.	• During the last century, average annual precipitation increased by 25%. • Rainfall declined 17%-64% during the seven strong El Niño events in the last 100 years • From 1960-2007: • Winter and summer rainfall fell 10%-15% in in the arid plains and coastal areas. • Summer rainfall rose 18%-32% over the core monsoon region of Pakistan.	• Observed sea level rise along the Karachi coast was 1.1 millimetres per year in the past century.	• Heat wave days per year increased by 31 days in the period 1980-2007. Cold waves decreased in northeastern and southern parts and increased in western and northwestern parts of the country.	From 1960-2007: • A decrease of 5% in relative humidity over Balochistan province. • An increase of 0.5%-0.7% in solar radiation over the southern half of the country. • A decrease of 3%–5% cloud cover over central parts of Pakistan, and a consequent increase of 0.9°C in temperature. • The northern parts of the country outside monsoon region have suffered from expanding aridity.

	Projected	• Pakistan's projected temperature increase is expected to be higher than the global average. • Projected temperature increase in northern parts is expected to be higher than the southern parts of the country. • The frequency of hot days and hot nights is expected to increase significantly.	• Pakistan's rainfall projections do not indicate any systematic changing trends. • An increasing trend in the rainfall over the Upper Indus Basin and decreasing trend in the Lower Indus Basin.			• Major crop yields such as of wheat and rice are expected to decrease significantly. • Water availability per capita is projected to decrease to an alarming level.
Bangladesh	Observed	• Average monsoon-season maximum and minimum temperatures show an increasing trend annually at the rate of 0.05°C and 0.03°C, respectively. • An increasing trend of about 1°C in May and 0.5°C in November during the 14-year period from 1985 to 1998 has been observed.	• The erratic nature of rainfall and temperature has increased in Bangladesh.		• Significant increasing trends in the cyclone frequency over the Bay of Bengal during November and May, which are main months for cyclone activity in the Bay of Bengal, have been observed.	
	Projected	• Mean annual temperature is projected to increase by 1.4°C by 2050 and 2.4°C by 2100.	• As yet it is difficult to project rainfall changes for the Ganges River floodplain, with some models projecting wetter and others projecting drier conditions.	• Potential rise in sea level of over 27 cm by 2050. • Sea level rise is projected for Bangladesh, with disagreement about how much. One study suggests an increase of 30-100 cm by 2100, while the IPCC Third Assessment gives a global average range with a slightly lower values of 9-88 cm.	• The frequency of tropical cyclones in the Bay of Bengal may increase and, according to the IPCC's Third Assessment Report, there is "evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%" (IPCC 2001).	
Sri Lanka	Observed	• General increasing temperature trend by 0.16°C per decade, with the highest increase of minimum temperature being about 2.0°C at Nuwara Eliya.	• Noticeable decreasing trend in rainfall pattern in most of the island excluding the northeast; mean annual precipitation decreased by 144 millimetres (7%) compared to the period 1931-1960.			
	Projected	• Mean annual temperatures are projected to increase by 1.0°C.	• The mean rainfall is projected to fall by 4%, with accompanying changes in the quantity and spatial distribution of rainfall.		• Increased climate variability and extreme events across Sri Lanka.	
Nepal	Observed	• There is some debate about whether average annual temperatures in Nepal have risen since 1960. According to Shrestha et al. (1999), Dhakal (2003), and Liuand Chen (2000), temperatures between 1977-1994 rose 0.5°C-0.6°C per decade, particularly in the northern mountains, while McSweeney et al. suggest that temperatures between 1960 and 2003 decreased slightly during the warm and dry season (March-May).	• Mean rainfall has significantly decreased on an average of 3.7mm (-3.2%) per month per decade, and this decrease is particularly significant during the monsoon period between June-September.	• n/a	• Heat wave days per year increased by 31 days in the period 1980-2007. Cold waves decreased in northeastern and southern parts and increased in western and northwestern parts of the country.	• Glacial melt – The Himalayan glaciers are an important, renewable water source, feeding all of the country's rivers. Rising temperatures in the north of the country could increase the rate of glacial melt and increase the risks from GLOFs (Glacial Lake Outburst Floods).
	Projected	• Mean annual temperature is projected to increase by 1.3-3.8°C by 2060 • Warming is expected to occur more rapidly during the dry months (December-May).	• Winters are projected to be drier and monsoon summers wetter, with some estimating a three-fold increase in monsoon rainfall. This could result in more frequent summer floods and winter droughts.	• n/a		
Southeast Asia						
Indonesia	Observed	• Mean annual temperature has increased by 0.3°C since 1990.	• Mean annual rainfall has decreased by 2-3% since 1990. • Precipitation patterns have changed; there has been a decline in annual rainfall in the southern regions of Indonesia and an increase in precipitation in the northern regions. • Recent trends can be correlated with a change in the timing of seasons. During the period of 1991-2003, in parts of Sumatra and Java, the wet season began up to 20 days later than the average compared to 1960-1990.			

	Projected	• Mean annual temperature is projected to increase by 0.2-0.3°C per decade.	• Changes in the seasonality of precipitation are projected: parts of Sumatra and Borneo may become 10 to 30% wetter by the 2080's during Dec-Feb; Jakarta is projected to become 5 to 15% drier during June-Aug. • Increasingly drier conditions over the next decades are projected, while by 2100 projections suggest increases in annual precipitation across the majority of the Indonesian islands, except in southern Indonesia where is it projected to decline by up to 15%. • A 30-day delay in the annual monsoon is projected to impact Indonesia, bringing a 10% increase in rainfall later in the crop year (April-June), and up to 75% decrease in rainfall later in the dry season (July–September).			
Philippines	Observed	• Mean temperatures across the South Pacific have increased by approximately 1°C since 1970, at an average rate of 0.3°C per decade. Temperatures appear to be increasing more rapidly in the southern reach of the archipelago. • Sea surface temperatures in the Pacific have increased between 0.6 to 1.0°C since 1910, with the most significant warming occurring after the 1970s.	• Recent evidence suggests a tendency for wetter conditions during the dry season, as the frequency of heavy storms during this period have increased. This dynamic is most notable during La Nina periods. • The number of rainy days has increased since 1990s, as has the inter-annual variability of onset of rainfall.		• There has been an increase in the frequency of cyclones entering Philippines Area of Responsibility during the period 1990 to 2003.	
	Projected	• +0.9-1.1°C by the 2020s and +1.8-2.5°C by 2050 under the SRES A2 (medium high) emissions scenario. • Under a business as usual evolution of greenhouse gases (RCP 8.5), avg. warming of approximately 4°C is simulated across all models by the end of the century, with some models indicating temperature increases above 5°C. • The best-case scenario (RCP2.6), which would require ambitious global agreements in reducing emissions shows an average warming of approximately 1°C by the end of the century. Even within this scenario, some models show temperature increases approaching 2°C.	• Reduction in rainfall in most parts of the country during the summer (Mar-May) season is expected. • Likely increase in rainfall during the southwest monsoon season in Jun-Aug. • Increases in rainfall are also likely during the northeast monsoon months of Dec-Feb. • A 60–100% increase in annual rainfall is projected for the Central Visayas and Southern Tagalog provinces, including Metro Manila. • Up to 11% reduction in annual average rainfall is projected for Mindanao by 2050.	• Sea levels are projected to rise by the end of the century (2090-2099) by 0.35 m, although the spatial manifestation of this rise will not be uniform due to circulation changes and ocean density.	• increases in both the frequency and intensity of extreme daily rainfall events.	
Malaysia	Observed	• Increase in mean surface temperature: 0.6-1.2°C, 1969-2009.	• Increased rainfall intensity -> 1-hour rainfall intensity (2000-2007) increase by 17% compared to 1970s values.	• 4.6 cm to 11.9 cm, satellite altimetry data (1993-2010).	• In 2007: Massive floods in Batu Pahat, Johor Baru, Kluang, Kota Tinggi, Mersing, Muar, and Segamat from Typhoon Utor. • Flood losses ~ RM 1.5 billion.	
	Projected	• Mean annual surface temperature is projected to increase by 1.0-1.5°C by 2050 in peninsular Malaysia, 1.3-1.7°C in Sabah, and 1.0-1.5°C in Sarawak.	• By 2050, average annual rainfall is projected to increase by 113 mm (+12%) in peninsular Malaysia, by 59 mm (+5.1%) in Sabah, and by 150 mm (+8%) in Sarawak.	• By 2100, sea level is expected to rise by 0.25-0.52m in peninsular Malaysia, and by 0.43-1.06m in Sabah and Sarawak.		
Vietnam	Observed	• Mean annual temperature has increased by 0.4°C since 1960, with the rate of increase more rapid in the dry seasons (November, December, January and February, March, April) and in the southern parts of Vietnam. • The frequency of "hot" days and nights has increased significantly since 1960 in every season, and the annual frequency of "cold" days and nights has decreased significantly.	• Mean rainfall over Vietnam does not show any increase or decrease since 1960. • The proportion of rainfall falling in heavy events has not changed significantly since 1960, nor has the maximum amount falling in 1-day or 5-day events.	• Observations show that average sea level has decreased by 0.20 cm per year (1965-2006) at Hon Dau station, by 0.260 cm per year (1978-2006) at Son Tra station, and has increased by 0.398 cm per year (1981-2006) at Vung Tau station.	• The frequency of tropical cyclones operating in the East Sea has been observed to have decreased over the past several decades, although the frequency of tropical cyclones that affect Vietnam has increased by 0.43 event per decade in the past 50 years.	

	Projected	• Mean annual temperature is projected to increase by 1°C by 2050, with similar projected rates of warming for all seasons. Some studies indicate that similar warming is likely to occur across all regions, while others suggest that the country's southern climatic zone will experience smaller warming than the northern and north-central zones. • Substantial increase is expected in the frequency of days and nights that are considered "hot" under current climate and decrease in the number of days and nights considered "cold" under current climate.	• Winter rainfall is expected to increase by 8% and summer rainfall by 1% by 2050. Autumn rainfall is projected to decline by 4% by 2050, while no change is projected for spring rainfall. • The proportion of total rainfall that falls in heavy events is projected to increase by 2-14% by the 2090s, and the probability of extreme rainfall and flooding will increase, particularly in northern regions and cities such as Hanoi, with increased risk of landslides in mountainous areas.	• Sea level is projected to rise between 28 cm (low-emission scenario) and 33 cm (high emission scenario) by 2050.	• A temperature rise of 1°C is projected to increase the number of heatwaves by 100-180%, while the number of cold surges would decrease by 20-40%.	
Singapore	Observed	• From 1972 to 2014, annual average temperature has increased from 26.6°C to 27.7°C. • From 1972, the number of warm days & nights have increased at a rate of 11.5 and 8.0 per decade, and the number of cool days & nights have decreased at a rate of -1.4 and -9.3 per decade.	• General uptrend in annual average rainfall from 2192 mm in 1980 to 2727 mm in 2014.	• Annual sea levels in the Straits of Singapore rose at the rate of 1.2–1.7 mm yr. in the period 1975-2009.	• Annual number of days with hourly rainfall totals exceeding 40 mm (heavy rain) + 2.6 days per decade from 1980-2016. • Annual number of days with hourly rainfall totals exceeding 70 mm (very heavy rain) + 0.9 days per decade from 1980-2016.	• General wind patterns influenced by northeast and southwest monsoons. • No clear trends as wind speed is environment dependent (e.g. presence of buildings and trees).
	Projected	• Changes in daily mean temperatures are projected to increase 1.4-4.6°C by end-century (2070-2099) with respect to the baseline period 1980-2009. • More warm days and warm nights for Feb to Sep throughout the 21st century.	• The contrast between the wet months (Nov to Jan) and dry months (Feb and Jun to Sep) is projected to become more pronounced.	• End-century (2070-2099) mean sea-level rise projections relative to baseline period ranges from 0.25 m to 0.76 m. • Changes in extreme sea levels for the Singapore region over the 21st Century are likely to be dominated by the regional time-mean sea level rise, with only small future changes to the storm surge and wave components.	• Increasing trends in both intensity and frequency of heavy rainfall events as the world warms.	• Singapore will continue to be influenced by the northeast and southwest monsoons. • No substantial changes in wind direction but potential increase in wind speeds during the northeast monsoon season.
Cambodia	Observed	• The rate of temperature increase is most rapid in the drier seasons (Dec-Feb and Mar-May), increasing 0.20-0.23°C per decade, and slower in the wet seasons (Jun-Aug and Sep-No), increasing 0.13-0.16°C per decade.	• Mean rainfall over Cambodia are unclear, with some areas experiencing increases and others decreases but these changes are not statistically significant.			
	Projected	• Mean annual temperatures are projected to increase across Cambodia by 0.7-2.7°C by the 2060s, and 1.4-4.3°C by the 2090s. • All projections indicate substantial increases in the frequency of days and nights that are considered "hot" in current climate, with hot days increasing by 14-49% and hot nights increasing by 24-68% by 2060. • All projections indicate decreases in the frequency of days and nights that are considered 'cold,' with these events becoming exceedingly rare.	• As yet it is not possible to get a clear picture for precipitation change, due to large model uncertainties, however increases in rainfall appear to be likely during the monsoon season for Cambodia.			
Laos	Observed	• An average increase of 0.1 to 0.3°C per decade between 1951 to 2000. • The year 1998 was the highest in temperature in the past two decades with average temperatures of 30°C.	• Decrease in total rainfall between 1961 and 1998.	• n/a	• Number of droughts and floods over the last three decades has increased.	
	Projected	• Warmer climate by the end of the century with longer dry seasons. • Hot and cool day periods might increase in length.	• Increase in rainfall across all the country, • Number of wet days might increase across the Mekong River basin by 2080.	• n/a	• Increase in intensity and in frequency of extreme events (primarily flooding) with implications on agriculture, food security, infrastructure, and lives.	

Thailand	Observed	• +0.95°C between 1955-2009, well above the avg. global increase of 0.69°C. • Annual highest, average and lowest temperatures have also been increasing by about 0.86°, 0.95° and 1.45° respectively over the past 55 years. The increase has been especially significant since 1994. • Number of warm days and nights (>35°C and >25°C) has increased between 1970-2006, with considerable regional differences: North (12 days), Northeast (20 days), Central (27 days), East (23 days) and South (35 days).	• The total amount of rainfall between 1955 and 2014 did not change significantly. • Declining rainfall trend In Central and East Thailand; increasing rainfall trend in the Northeast and Gulf region as well as the Bangkok metropolitan area. • Decadal variations in rainfall volume are linked to El Niño – Southern Oscillation (ENSO). • Significant increase of rainfall between Nov-Apr and a decrease between May-Oct. • Decreasing number of rainy days by 1 day per decade. • Number of intense rain days is increasing. • Changing rainfall patterns: Normally rain falls during the monsoon season (May-Sep), which has been partly disrupted especially between 2006 and 2010, with longer dry spells in the middle of the rainy season and more intense precipitation.	• The sea level in the gulf of Thailand has risen about 3-5 mm per year from 1993-2008, compared to a global avg. of 1.7 (±0.5) mm per year. • The effects of sea level rise overlaid with land subsidence, may mean up to 25 mm per year of net sea level rise in some areas such as the larger Bangkok metropolitan area or the river mouths in the gulf of Thailand.	• Long dry spells and flash flood events have become more frequent and intense. • Frequency and intensity of tropical storms has increased, as well as the frequency of hailstorms during change of seasons (from rainy to winter and winter to summer). • Unpredictable cold spells: Between 2000 and 2010, the Northeast monsoon (cold wind) became stronger and more variate.	
	Projected	• Major climate models indicate a temperature rise for the whole country of Thailand, particularly the central plain and lower North-eastern region. Projections for the increase of mean temperatures vary between 0.4° and 4.0°C in the next 100 years, rising from an average of 29°-33°C in the early 21st century to 33°-35°C until the year 2100. • The number of warm days (>35°C daily mean temperature) per year is expected to increase, particularly in the Chao Phraya River basin, central plain, and lower Northern regions, meaning an extension of the summer/hot period (with maximum daily temperature > 35°C) of 2-3 months on average. • The Northeastern, Central, and Southern regions are expected to have hot periods extended to 5-6 months, by the end of the century, while the Northern region is expected to extend to 3-4 months. • The duration of the cold period (with cold days, temperature < 16°C) in the North and Northeast will shorten after mid-century from currently 2-2.5 months to 1-2.5 months.	• Rainfall will have higher variability. In the beginning of the century (2010s), Thailand has encountered increasing rainfall variability and fluctuation. From the middle of the century (>2050s), the total annual precipitation is expected to increase, especially in the areas near the Mekong River as well as the Southern region. In Western Thailand, precipitation is expected to remain almost unchanged. • Average temperature and humidity are expected to rise especially in the rainy season.	• The mean sea level of the Andaman coast in Krabi province is expected to rise by about 1 cm annually over the next 25 years, with shoreline shifts between 10-35m.		• The intensity (expressed in wind speed) of the Southwest monsoon (May-October) coming from the Andaman Sea is expected to increase about 3-5 % by 2100s.
Oceania						
Australia	Observed	• Australia's climate has warmed in both mean surface air temperature and surrounding sea surface temperature by around 1°C since 1910. • Since 1960, average summer temperatures have increased by 0.6°C and winter temperatures have increased by 0.85°C. • There has been a reduction in the frequency of cool nights and cool days and an increase in the frequency of warm nights and hot days over Australia with the changes most pronounced to the East of the country.	• May–July rainfall has reduced by around 19 per cent since 1970 in the southwest of Australia. • There has been a decline of around 11 per cent since the mid-1990s in the April–October growing season rainfall in the continental southeast. • Rainfall has increased across parts of northern Australia since the 1970s.	• Sea levels have risen around Australia. The rise in mean sea level amplifies the effects of high tides and storm surges.	• The duration, frequency and intensity of extreme heat events have increased across large parts of Australia. • There has been an increase in extreme fire weather, and a longer fire season, across large parts of Australia since the 1970s.	• Oceans around Australia have warmed and ocean acidity levels have increased.
	Projected	• Australian temperatures are projected to continue increasing with more extremely hot days and fewer extremely cool days. • For the A1B emissions scenario projected temperature increases are larger over central and western regions of Australia, with changes of up to around 4°C. Along most of the coastal regions, changes of around 2.5°C are more typical.	• Winter and spring rainfall is projected to decrease across southern continental Australia, with more time spent in drought. • For precipitation changes, decreases of 20%+ are projected over some parts of the far west, but moderate decreases of ~5% are more typical over most of Western Australia, as well as eastern Queensland, Victoria, and southern South Australia. Much of the Northern Territory, Queensland, and parts of New South Wales are projected to experience increases of up to 5%, with increases of up to 10% in the far north.	• Sea-level rise and ocean acidification around Australia are projected to continue.	• The number of days with weather conducive to fire in southern and eastern Australia is projected to increase.	• Past and ongoing greenhouse gas emissions mean further warming of ocean temperatures.

New Zealand	Observed	• Increase in average atmospheric temperature of 1°C (+/-0.28°C) since 1910. • One-half fewer frosts than occurred in 1930.		• Overall sea level has been rising at a rate of about 3mm/year since the early 1990s and is now approximately 60mm higher than in 1993. • Observed sea level rise of 170 mm (+/-10mm) since 1900.	• Increase in the number of days with high intensity (>25mm) rainfall events in some western parts of South Island over the period 1930 to 2004.	• 15% decrease in ice volume over the 30 years since monitoring began.
	Projected	• The midrange of projections is an average temperature increase of 0.9°C by 2040, 2.1°C by 2090. • North Island: Halving or more of the number of frosts by 2100 in the central plateau (to <15 days per year). • North Island: 40+ extra hot days (>25°C) a year in Auckland by 2100. • South Island: Frosts expected to be rare in coastal locations by 2050.	• Little change in mean precipitation for all New Zealand, but large geog. variation. • North Island: By 2040 overall precipitation decreases in the east by up to 5% (though seasonally variable), with smaller changes in the west. • South Island: By 2040, increases in the west by 5% and decreases in the east (smaller change).		• Heavier and more frequent extreme rainfalls, but also more droughts. On average, 2 or more extra weeks of drought annually by mid-century for much of North Island and eastern South Island. • North Island: West - In summer and autumn rainfall decreases, in winter and spring rainfall increases by up to 5%. East (Gisborne/Hawkes Bay)- decrease in rainfall in winter and spring by up to 5 to 10%. • South Island: In winter and spring, more precipitation in the west and south (10% or more increase – responsible for much of the annual change), reduced precipitation in the east (north of Oamaru). Heavier and more frequent extreme rainfalls.	Ocean acidification: • pH changes are greater in cooler waters. • North Island: Upwelling areas such as the Hauraki Gulf are more vulnerable to a given change. • South Island: Impact in high latitude Southern Ocean expected first, from 2040 onwards. • Wind & circulation: • Increase in strongest winter winds by 2100. • North Island: Less westerly wind component and more easterly episodes, as tropical zones move south in summer. • South Island: More frequent and stronger westerlies during winter and spring.
Papua New Guinea	Observed	• Mean annual temperature has increased by 1°C since 1970. • For Papua New Guinea, the overall observed near surface temperature trend (0.50ºC) resembles both the global and tropical Asian trend, with an overall error of +/- 0 .15ºC. • Mean sea surface temperatures has increased by 0.6-1.0°C since 1910. • Annual number of hot days and hot nights has increased.	• Areas with a pronounced wet and dry season that receive less than 2000mm rainfall include: Markham Valley, Bulolo Valley, Maprik - Angoram area, Eastern highlands, and coastal areas near Cape Vogel, Port Moresby and Daru.		• The numbers of category 4 and 5 storms in the Pacific region have more than doubled when comparing their frequency and occurrence between 1975-1989 and 1990-2004.	
	Projected	• Mean annual temperatures are projected to increase by 1.4-3.1°C by 2100.	• Rainfall projections are inconsistent, indicating +/-25% changes.	• Sea level expected to rise 0.19-0.58m by 2100.	• More frequent El Nino events could also increase the intensity of tropical cyclones along the pacific, with important implications for disaster management and response in the Papua New Guinea. • Sea-level rise will lead to accelerated coastal erosion and saline intrusion into freshwater sources.	• Acidification of the ocean through increased absorption of CO_2, causing pH to fall by an approximately 0.3-0.4 units by 2100; coral reefs growth rates will consequently suffer.
Timor-Leste	Observed	• An analysis of global data by the IPCC shows that in the Timor-Leste region, temperature from 1901 -2005 has increased 0.5-0.8°C over the century, while data for 1979-2005 suggests a lower decadal increase of 0.1-0 .3°C with a mild acceleration over the later decades.				
	Projected	• Mean annual temperature is projected to increase by 1.5°C by 2050, and the rate of warming is projected to increase with more frequent heat waves and more frost days.	• Rainfall is also expected to increase, in relation to the 1961-1990 reference period by 2%, 4% and 6% by 2020, 2050 and 2080 respectively. • The AK-2010 analysis indicates seasonal differences with mild drying effect for Timor-Leste over the Jun-Aug period by 2080.			

Source: World Bank Climate Change Knowledge Portal; McSweeney, C., New, M. & Lizcano, G. 2010. UNDP Climate Change Country Profiles; UK Met Office Hadley Centre; Chaudry, Q. 2017. Climate Change Profile of Pakistan. Asian Development Bank.; Case, M. & Tidwell, A. Nippon Changes. WWF; Case, M., Ardiansyah, F. & Spector, E. Climate Change in Indonesia. WWF; Singapore National Climate Change Secretariat; Meteorological Service Singapore; National Hydraulic Research Institute of Malaysia; TransRe Fact Sheet: Climate Change in Thailand; Australia Bureau of Meteorology State of the Climate Report 2016; Office of the Prime Minister's Science Advisory Committee, 2013. New Zealand's Changing Climate and Oceans.

Annex B: Resource List

This Annex presents a list of resources that may be of use to readers interested in delving more deeply into the various aspects of climate change. WWF is not affiliated with any of these resources and makes no guarantee regarding their continued availability or utility.

Resource	Description	Website
AidData	Source for independently gathered data on China's official finance, covering 2000-2014.	https://www.aiddata.org
CAIT Climate Data Explorer	Extensive repository of climate-related data, including historical GHG emissions by country and sector.	http://cait.wri.org
Carbon Tracker Initiative	Extensive reports, analyses, and infographics on the impact of the energy transition on capital markets and the potential investment in high-cost, carbon-intensive fossil fuels.	https://www.carbontracker.org
CDP (previously Carbon Disclosure Project)	Runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts. Offers a wide variety of research reports based on their data.	https://www.cdp.net/en
Climate Action Tracker	Provides regularly updated, detailed assessments of emissions reduction policies and commitments on a country basis, covering ~80% of global emissions.	https://climateactiontracker.org
Climate Bonds Initiative	Established one of the leading international certification standards for green bonds. Source of green and climate bond market information.	https://www.climatebonds.net
FAOSTAT Emissions Database	The statistics database of the Food & Agriculture Organization. Source of a variety of global, regional, and national GHG emissions data; particularly useful for LUCF emissions.	http://www.fao.org/faostat/en/
FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance	Many reports related to climate finance, particularly the annual Global Trends in Renewable Energy Investment Report	http://fs-unep-centre.org
Grantham Research Institute on Climate Change and the Environment	In addition to publishing research on other topics, maintains the Climate Change Laws of the World and Climate Change Litigation of the World databases.	http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/
International Energy Agency	Extensive amounts of (free and paid) data and publications on energy-related topics, including GHG emissions.	http://www.iea.org
International Renewable Energy Agency	Source of extensive studies and data on renewable energy, including capacity, cost and employment.	http://irena.org
National Aeronautics and Space Administration	Source of a wide variety of informational resources and climate data, including atmospheric CO2, sea and land temperatures, and sea level.	https://climate.nasa.gov/
National Oceanic & Atmospheric Administration	Source of a wide variety of climate data, including atmospheric CO_2 and historical temperature records.	http://www.noaa.gov
Principles for Responsible Investment	Wide variety of resources regarding ESG issues, including increasing emphasis on climate risks and opportunities.	https://www.unpri.org
REN21	Wide variety of resources regarding renewable energy.	http://www.ren21.net
UNEP Finance Initiative	Resources relating to the intersection of finance and the environment.	http://www.unepfi.org
UNFCCC Secretariat	Central node for UNFCCC-related data & information; maintains the registry for NDCs.	https://unfccc.int
World Resources Institute	Sustainability-oriented research organisation focusing on climate, energy, food, forests, water, and sustainable cities. Many useful publications and data sets.	http://www.wri.org

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Polar bear (*Ursus maritimus*) swimming in the water in front of an iceberg, Beaufort Sea, Arctic Ocean, Alaska. Science has established that there is a strong correlation between melting sea ice and the reduction in the polar bear population.

Climate Change in a Nutshell

SCIENCE

Atmospheric CO_2 concentration recently surpassed 410ppm, after ranging between 200-250ppm for 800,000 years.

POLICY

Over 90% of countries ratified the legally binding Paris Agreement to address climate change.

Tarawa, the capital island of Kiribati with the house of parliament in the foreground.
© Raimon Kataotao

FINANCE

USD825bn in recent fossil fuel investments versus USD383bn in climate-related investments.

TECHNOLOGY

The rapid expansion of renewables within the global power supply is one of the primary vectors for reducing emissions.

WWF

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