Chapter 1

Growth and Climate Change: THE STRATEGIC CONTEXT

Main points

- Rapid technological progress, a large rise in trade, and major structural changes have transformed the global economy in the last 25 years. Developing countries now account for more than two-fifths of world GDP. Poverty dropped at the fastest rate ever in the last decade. However, since the Great Recession of 2008–09, countries at all income levels have struggled to achieve fast, equitable growth in output, jobs and opportunities. Vigorous and deliberate reforms are needed to sustain broad-based long-term prosperity.
- The next 15 years are also critical for tackling climate risk. Global carbon dioxide (CO_2) emissions from energy use increased by about 3% per year in the 2000s, around twice the pace of the years 1981–2000. The choices made in the next 15 years will either lock in a future with growing pollution and worsening climate change, or help move the world onto a more sustainable, low-carbon development path.
- Many of the policy and institutional reforms needed to revitalise growth and improve well-being over the next 15 years can also reduce climate risk. Potential "win-win" reforms in urban, land use and energy system would involve correcting market and government failures that now make economies less efficient than they could be. These are not "easy wins", however; they will require real effort.
- Many actions to reduce greenhouse gas (GHG) emissions can yield multiple benefits, such as improved air quality. Health damage from air pollution averaged over 4% of GDP in the 15 largest CO_2 emitters in 2010. Measures that reduce GHGs and air pollution together in these countries would yield health benefits of US$73 per tonne of CO_2 abated.
- The climate benefits from economic measures considered in this report could be substantial: enough to achieve at least 50% and potentially up to 90% of the emission reductions needed to get onto a 2°C pathway. All these measures are compatible with goals of boosting national development, equitable growth and broadly shared improvements in living standards, and make economic sense even before considering future avoided climate damage.
- Countries at different stages of development will necessarily prioritise different actions. For low-income countries, key challenges include strengthening institutional capacity, improving agricultural productivity, and expanding modern energy access. Middle-income countries have greater institutional capacity and resources but face complex problems of structural change and urban development. The challenge facing developed countries is to accelerate innovation, renew infrastructure and modernize public finance in ways that strengthen growth and promote decarbonisation.
- Greenhouse gases already in the atmosphere will make 2016–2035 about 0.9–1.3°C warmer than 1850–1900, on average, even if drastic action to reduce emissions is taken immediately. Thus, adaptation is essential. Financial flows from developed to vulnerable low-income countries need to increase sharply to meet adaptation needs. Many institutional reforms to facilitate adaptation will also increase the development and carbon abatement options available to countries.

1. Introduction

The world economy has been transformed over the last 25 years. Computing, communications, biotechnology, materials science and other fields are in the midst of technological revolutions, greatly expanding humanity's productive capacity. World output has more than doubled since 1990,[1] accompanied by rising international flows of knowledge, trade and capital, as well as by enormous structural changes. Developing economies have grown in importance, their share of global GDP rising from just over a quarter to more than two-fifths over this period.[2] The number of people living in urban areas surged by two-thirds, to more than half the world's population.[3]

Developing countries – the poorest and most populous region of the world – have been at the heart of many of these changes. Middle-income countries' output has more than tripled since 1990, and low-income countries' has more than doubled.[4] Growth accelerated not only in large emerging economies such as China and India, but also in many smaller and poorer countries in Asia, Africa and Latin America. In developing countries, the number of poor fell by nearly 500 million just in the last decade – the fastest pace of poverty reduction for which we have data.[5] But 2.4 billion still live on less than US$2 a day.

There is now an opportunity to build on this experience to make further major gains in human well-being in the next 10–20 years and beyond. But progress cannot be taken for granted. There are major risks that overshadow this otherwise bright prospect.

First, in the wake of the Great Recession of 2008–09, countries at all income levels are struggling to restore or achieve fast, equitable growth in output, jobs and opportunities. Despite the rapid growth before the crisis, the world is not on track to eradicate extreme poverty by 2030, as envisaged in the Sustainable Development Goals that are now being drafted.[6] Improvement in broader measures of human development has also slowed since the crisis.[7]

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Climate risk, meanwhile, is an increasing concern. The strong growth performance before the financial crisis was accompanied by a surge in energy consumption and greenhouse gas (GHG) emissions.[8] This development model, if carried forward, would generate spiralling emissions and, ultimately, severe climate damage that would undo the very gains in well-being that we seek.[9]

Major recent natural disasters have inflicted significant economic and human costs, including Typhoon Haiyan in the Philippines, Hurricane Sandy in the United States, major droughts in China, Brazil and the Horn of Africa, and floods in Europe. Such extreme events are likely to increase in both frequency and magnitude with unchecked climate change. Nor are extreme events the only concern. Existing climate variability is already a major source of poverty and insecurity among the rural poor. For them even small increments to risk in the form of delayed rain, higher temperatures, slightly more intense or protracted drought can mean disaster.

Tackling the challenge of strong, equitable and sustainable growth will require huge new investments and shifts in resource use. Actions today and in the next 15 years will be critical to stabilising and then reducing emissions to try to meet the international target of keeping the average global temperature increase below 2°C.[10] They will either lock in a future with inefficient infrastructure and systems, growing pollution and worsening climate change, or help move the world onto a more sustainable, low-carbon development path that strengthens resilience and begins to slow and reverse the accumulation of climate risk.

A critical insight of this report is that many of the policy and institutional reforms needed to revitalise growth and improve well-being over the next 15 years can also be critical to tackling climate risk. There are many potential "win-win" reforms that can simultaneously energise development and grapple with climate risk, but they may not be "easy wins". Real-world economies are rife with market and government failures. Correcting these can generate multiple benefits that transform the cost-benefit calculus of reforms. For example, we illustrate the very large co-benefits that can arise from policies to cut GHGs and local air pollution.

The report highlights three fundamental drivers of change that these reforms will draw upon: more efficient resource use, infrastructure investment, and innovation. And it focuses on three socio-economic systems that hold the key to yield multiple economic, social and environmental benefits: cities, land use, and energy systems. These systems are crucial for change in the next 10–20 years, because they are so important for the global economy and emissions, are already undergoing rapid change, and usually possess some institutions and policy frameworks that render them capable of reform and contributing to improved outcomes.

The Commission estimates that at least 50% and – with broad and ambitious implementation –potentially up to 90% of the actions needed to get onto a 2°C pathway could be compatible with goals of boosting national development, equitable growth and broadly shared improvements in living standards.

Reforms will entail costs and trade-offs, and will often require governments to deal with difficult problems of political economy, distribution and governance. But an argument that tackling climate risk is simply too costly, whether in terms of growth, competitiveness, jobs or impact on the poor, can be overstated, especially when the multiple benefits of climate action are fully taken into account. Complementary social protection and adjustment policies can help vulnerable groups and sectors make what is often a difficult transition.

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There is no simple reform formula or agenda that will work for all countries. Each will deal with development and climate challenges differently, based on levels of economic, human and institutional development, social and political structures, history, geography and natural endowments. Countries will need creative experiments, to "learn by doing" and thus to find the right path for their own circumstances.

This introduction lays the foundation for the rest of the report. It begins by examining the growth and climate risks that could overshadow the global economy in coming years. It then looks at ways for countries to advance both economic and climate goals together, including "no-regrets" reforms, critical sectors and drivers of change, and the potential economic and GHG impact of reforms and actions discussed in the report. The differing challenges in low-, middle- and high-income countries are then examined. The chapter ends by showing why actions in the next 15 years are particularly critical.

2. Growth risks and climate risks

The world has made tremendous gains in human well-being over recent decades. Yet there are signs that countries could downshift to a weaker growth and poverty reduction trajectory in the aftermath of the Great Recession of 2008–09. Understandably, policy-makers are now focused on how to craft reforms to spark renewed growth and development – but they are also aware of growing climate risks.

The current model of development carries with it a growing risk of locking in a high pollution path. Current economic and poverty reduction gains may then prove unsustainable in the long run, as rapidly rising GHG emissions result in serious climate damage. Continued, rapid economic progress cannot be taken for granted. There is thus an urgent need for sustained policy and institutional reforms to revitalise growth and poverty reduction, strengthen resilience, avert lock-in and begin to slow and ultimately reverse the accumulation of climate risk.

2.1 Growth risks

The world economy may struggle to resume its strong performance before the Great Recession. Global annual growth averaged about 4% in the 2000s, before the crisis.[11] A more volatile and uncertain landscape has emerged in the years since, however. World growth did rebound to 5% in 2010 but has steadily decelerated since, falling to only 2.8% in 2013.[12] Forecasters expect a slight pickup in 2014, but there is high uncertainty around these projections.

Growth risks in developed countries

Developed countries were at the epicentre of the financial crisis and have also underperformed in the years since. After a modest rebound in 2010, growth in countries in the Organisation for Economic Co-operation and Development (OECD) has decelerated, falling to 1.3% in 2013.[13] The large gap between actual and potential output that opened up during the crisis has fallen much more slowly than in previous recessions. Output gaps in 2013 remained as high as 3.5% of potential output in the United States and the Euro area, according to OECD estimates. Potential output itself has deteriorated relative to pre-recession trends.

Unemployment in the OECD was 7.9% in 2013, only slightly below a peak of 8.3% in 2010.[14] Stagnating median incomes, high youth unemployment and rising inequality are a source of disquiet in many developed countries. In the longer run, there are concerns about the fiscal impacts of ageing populations, exacerbated by the steep increase in public sector debt as a consequence of the crisis.

The causes of the crisis and its weak aftermath are intensively debated. Theories include shocks to aggregate demand; overly tight fiscal and monetary policies; financial sector risk-taking coupled with weak regulation; too much private debt and protracted deleveraging; and excessive government intervention and uncertainty caused by unpredictable policies.

This report does not attempt to resolve these debates. However, extended cyclical downturns can cause adverse structural changes that reduce the economy's long-term potential output. Prominent analysts are concerned that developed countries may fall into an extended period of "secular stagnation".[15] Broad programmes of policy and institutional reforms are needed to modernise and buttress public finance, enhance innovation, and boost growth and employment opportunities in the developed world today.

Figure 1

Countries at different stages of development

LOW-INCOME COUNTRIES

US$1,035 or less GNI / capita
36 countries
~ 0.9 billion people

MIDDLE-INCOME COUNTRIES

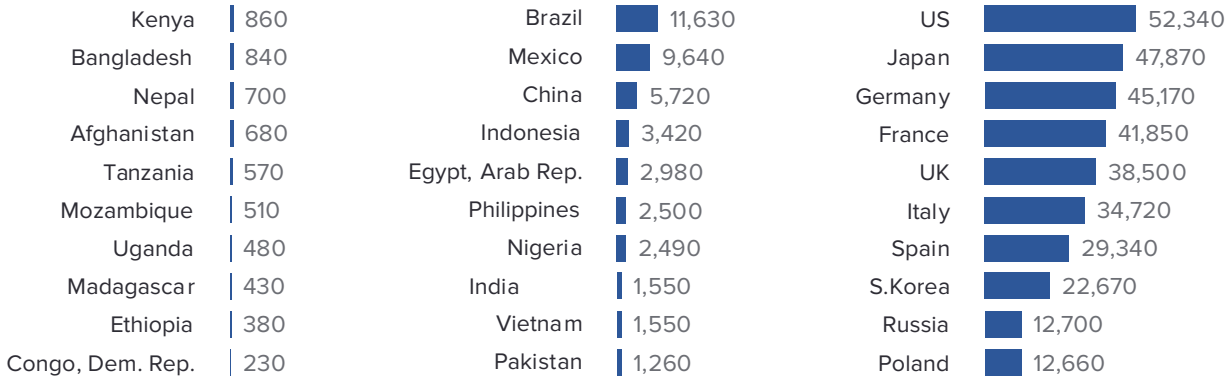
US$1,035-12,616 GNI / capita
103 countries
~ 4.9 billion people

HIGH-INCOME COUNTRIES

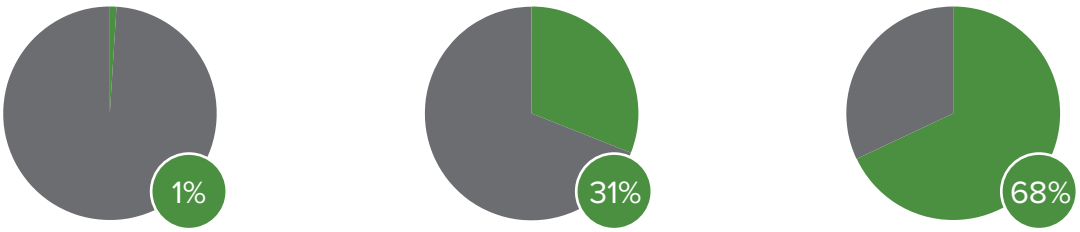
US$12,616 or more GNI / capita
74 countries
~ 1.3 billion people

TOP 10 MOST POPULOUS, ORDERED BY GNI PER CAPITA IN 2012

CURRENT US$

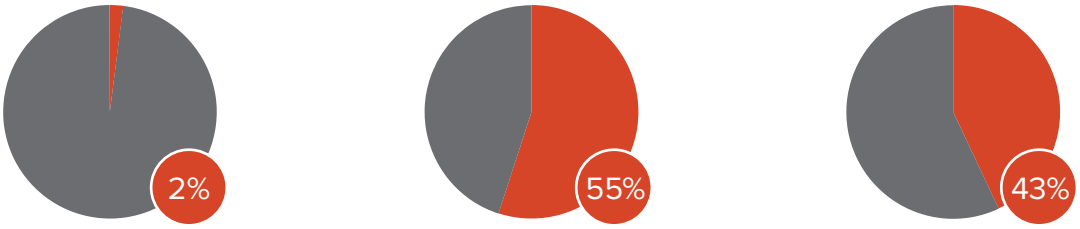


SHARE OF WORLD GDP IN 2012



SHARE OF WORLD GHG EMISSIONS IN 2010

EXCLUDING LUCF



Note: GNI per capita is using the World Bank Atlas Method, in current US$. GHG emissions exclude land use, land use change and forestry (LULUCF). Source: The World Bank, 2014.[16]

Growth risks in developing countries

Developing economies are also finding it difficult to regain their growth momentum in the wake of the crisis. Developing country growth averaged close to 7% annually in 2001–07, but slipped below 5% in 2013–14.[17]

The causes of the slowdown in developing countries are diverse. They include more difficult global conditions, including slow post-crisis growth in developed world imports, volatile foreign capital flows and lower prices for many primary commodities, as well as the need to curb overly expansive macroeconomic policies, and deeper structural and institutional impediments to growth.

There are also some general reasons why the growth boom in developing countries in the 2000s could turn out to have been a temporary episode. Empirically, high growth that is sustained over several decades is extremely rare. China and Korea are two outstanding examples in this select group. It is much more common for developing countries to experience "spells" of both high and low growth lasting 10–15 years, sometimes characterised as "growth miracles" and "growth failures".[18]

Developing economies are also finding it difficult to regain their growth momentum in the wake of the crisis.

There are good theoretical reasons why high-growth spells in developing countries might not be sustained. "Catch-up" growth is a basic mechanism of economic development, in which poor countries grow by importing advanced ideas and technologies, but it does not occur automatically. Achieving sustained growth requires developing countries both to strengthen fundamentals such as human capital and institutions, and to foster structural change, which sees labour, capital and entrepreneurs move from traditional to new, higher-productivity sectors. Achieving structural change is fraught with both government and market failures. Examples of the former might include a lack of key public infrastructure, and of the latter knowledge failures that lead to inadequate investment in importing foreign technologies. Overcoming such failures requires a constant, high-level engagement by government to experiment with reforms, learn from mistakes, and implement what seems to work at a given time. Such reform capacity may not exist, or be present only fitfully, according to changing political conditions.[19]

We thus have good reasons to think that if developing countries are to regain and sustain the fast growth of the 2000s into the next decades, they will need to undertake intense and sustained reform over the long term. These reforms will both build up fundamental capabilities and promote structural change.

It is important to remember the particular development challenges faced by middle- and low-income countries, as well as by countries with abundant natural resources – a group that cuts across income lines.

Low-income countries are marked by high poverty. Three-quarters of their population live on less than US$2 a day.[20] In sub-Saharan Africa extreme poverty is not only widespread but deep: large numbers live well below the absolute poverty line of US$1.25 a day. Health, education and other human development outcomes are weak. Low-income countries generally have low institutional capacity, relatively low (though fast-increasing) urbanisation, and a high reliance on agriculture and other primary sectors.

The key challenge in these countries is to overcome poor governance and low institutional capacity, and so spark rapid and widely shared economic growth and poverty reduction. These countries comprise 11% of the world population[21] and are exceptionally vulnerable to climate change and variability.[22] They are responsible for only 2% of world primary energy consumption and 1% of carbon dioxide emissions from energy use.[23] Changes in agriculture and land use could yield significant gains in terms of development and build climate resilience while curbing GHG emissions. Ensuring modern energy access for the poor is also a key development challenge.

Middle-income countries comprise 70% of the world population and were central to the boom in developing country growth, globalisation and urbanisation in the 2000s.[24] They account for around half of world energy consumption and carbon emissions from energy use, proportions which are rising rapidly. These are countries with a large and growing middle class. Many are grappling with complex problems of structural change and institutional modernisation. They are critical players in a transition to a resource-efficient, low-carbon global economy. Major development challenges include tackling dysfunctions and inefficiencies in urbanisation, industrialisation and energy use, where there is a high potential both to improve productivity and abate GHG emissions.

China and India stand out among middle-income countries by virtue of their size. Despite China's tremendous development over the last 30 years, its political leaders have remarked that the country's previous economic model is likely to prove "unbalanced, uncoordinated and unsustainable".[25] New approaches will be needed if the country is to avoid the "middle income trap" and reach high income levels in the next 15–20 years. The previous model entailed rapid growth in capital accumulation, exports, energy-intensive industry, and high levels of fossil fuel use (particularly coal); it also brought urban sprawl and severe local air pollution. A new direction will include a

shift towards growth driven by innovation, more efficient resource use, cleaner energy sources and reduced coal consumption, cleaner air to breathe, more compact and productive cities, and greater reliance on growth in domestic consumption and services. These structural changes offer notable "no-regrets" opportunities for decarbonisation as part of the country's efforts to achieve national economic and social goals.

In India, meanwhile, where growth has fallen below 5% for two consecutive years,[26] a new government has a strong mandate to accelerate development by boosting infrastructure, improving the business climate and strengthening public service delivery.

Countries that have abundant natural resources occur in all income groups. They saw a significant rise in revenues during the 2000s as a result of major new mineral discoveries and higher international commodity prices.[27] If well managed, these resources could accelerate growth and poverty reduction. If not, they could generate dysfunctional outcomes.

Global CO_2 emissions from energy use increased by about 3% per year in the 2000s, around twice the pace in 1981–2000.

However, these countries also face particular challenges. First, in the absence of strong governance, natural resource abundance tends to foster problems such as corruption, social strife over rents and other effects – collectively labelled the "natural resource curse" – that lead to worse development outcomes. In practice, faster growth associated with mineral booms has often had only weak links to job creation and poverty reduction. Second, many of these countries are not saving enough to replace the depletion of their natural assets with human capital, through skills development, health improvements and new infrastructure, for example. In such cases, the total stock of wealth is falling, and present prosperity masks the likelihood of a poorer future.[28] Third, if the rest of the world credibly commits to curbing fossil fuel use, these resource-rich countries face the prospect of reduced demand and lower prices for fossil fuels in the future. It is therefore crucial that they make the most of the boom they are enjoying today to build up their human and other capital and prepare for the transition that they will surely have to undertake in the coming decades.

2.2 Climate risks

While achieving rapid economic growth and poverty reduction in the run-up to the financial crisis, the world has also been accumulating immense climate risks. Global CO_2 emissions from energy use increased by about 3% per year in the 2000s, around twice the pace of the years 1981–2000.[29] CO_2 emissions from energy use are the largest component of global GHG emissions, accounting for two-thirds of total emissions in 2010.[30] A growth rate of 3% means that emissions increase by 55% in 15 years and double in 25 years.

Recent emissions trends differ strongly between developed and developing countries, decelerating in the former but accelerating in the latter. Figures 2a and 2b explain changes in CO_2 emissions according to three drivers: real GDP, energy intensity of GDP, and carbon intensity of energy. (Energy intensity is the energy consumed per unit of real GDP. Carbon intensity of energy is the carbon emissions per unit of energy.)

Figure 2a shows that in the developed world, CO_2 emissions began to decouple from economic growth, contracting by 0.3% per year in the 2000s. This decline partly reflects the recession and slower economic growth, but there were also more promising reasons. The annual decline in energy intensity reached nearly 2% per year. Carbon intensity also fell, reflecting a continued gradual shift towards cleaner sources in the energy supply mix.

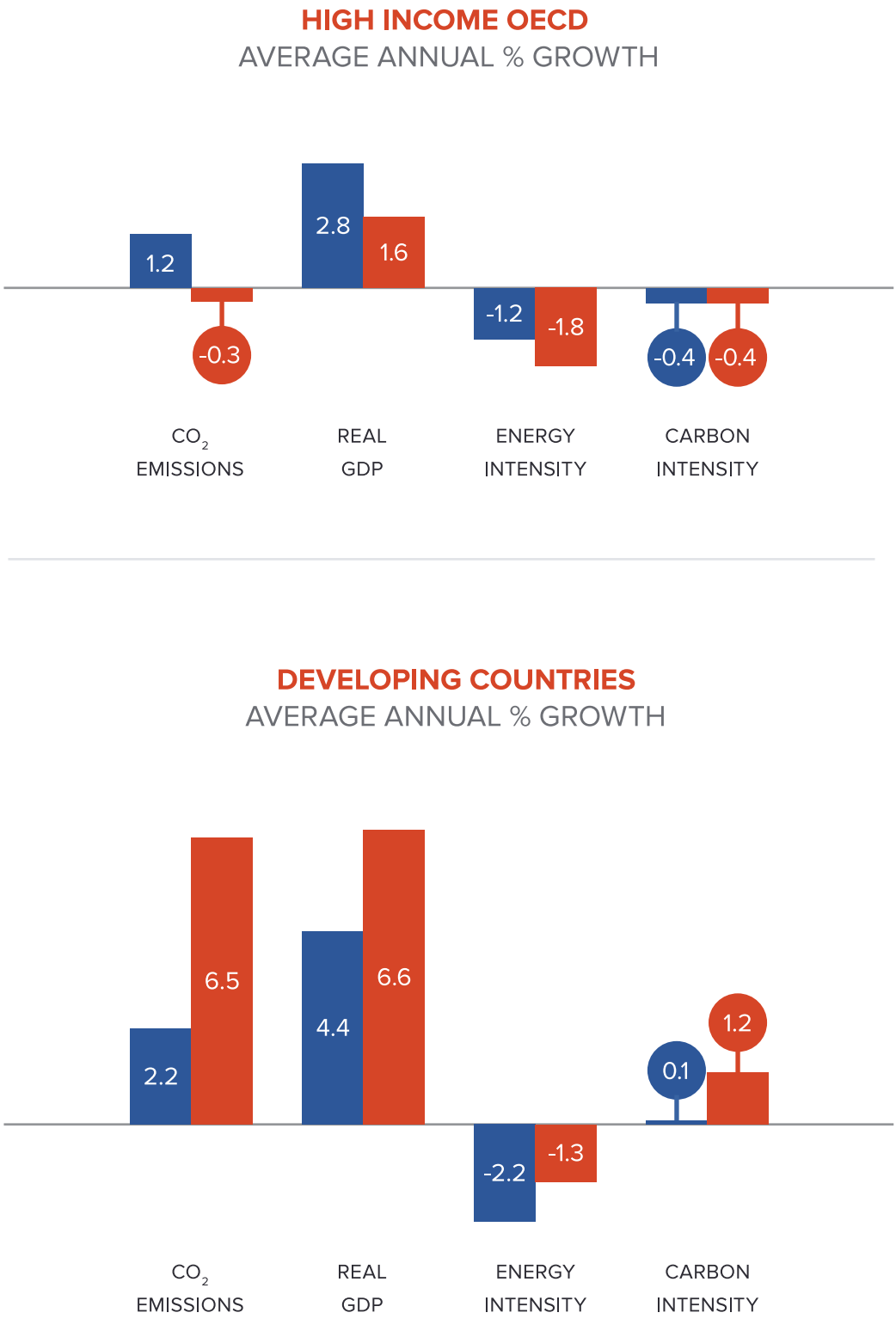
There was, however, no such decoupling in developing countries, where CO_2 emissions rose by 6.5% annually in the 2000s, in line with economic growth (see Figure 2b). Among other factors driving emission growth, the pace of decline in energy intensity slowed compared with the 1990s. Most seriously, the carbon intensity of the energy mix in developing countries, which was flat in the 1990s, rose by over 1% per year in the 2000s, reflecting a greater reliance on coal to meet rapidly growing demand for electric power generation.

Importantly, these carbon emission trends in developed and developing countries have not evolved independently. They reflect growing international trade in an increasingly integrated global economy. The 1990s and 2000s saw a shift in production of energy- and carbon-intensive goods from developed to developing countries, accompanied by a sharp rise in imports of such goods by developed countries from developing countries.[31] Key metrics for understanding this trend are "production emissions", which refer to the carbon dioxide (CO_2) emissions within a particular country's borders, and "consumption emissions", relating to the CO_2 embedded in the goods consumed by a country, regardless of the country where this CO_2 was originally emitted.

In developing countries, the fraction of production emissions which were ultimately exported rose from about 4% in 1990 to 11% in 2010.[33] Conversely, in developed countries, consumption emissions have grown faster than production emissions, reflecting rising carbon-intensive imports. High-income OECD countries saw

Figures 2a and 2b

Changes in CO_2 emissions, by key drivers, in high-income and developing countries



Source: Brahmbhatt et al., 2014 (forthcoming).[32]

Box 1

Climate change – concentration pathways, "lock-in" and impacts

Greenhouse gas emissions cause climate change. Carbon dioxide (CO_2) is the main greenhouse gas, and is emitted principally from the burning of fossil fuels for energy in the electrical power, transport, industry and residential sectors, and from deforestation and land use change. Other powerful GHGs include nitrous oxide (N_2O) and methane (CH_4), which are emitted from various agricultural and industrial processes and from waste. Fluorinated greenhouse gases such as hydrofluorocarbons (HFCs) are used as refrigerants and are less abundant but far more powerful than CO_2.

A broad definition of GHG concentrations includes so-called "Kyoto" GHGs (CO_2, CH_4, N_2O and three fluorinated gasses HFC, PFC and SF6) as well as "Montreal" GHGs (ozone-depleting substances such as chlorofluorocarbons, or CFCs). The concentration in the atmosphere of Kyoto GHGs is currently around 446 parts per million (ppm) of CO_2 equivalent (CO_2e), while including Montreal gases raises this to 470 ppm. Atmospheric CO_2e concentrations are rising by around 3 ppm per year, and that rate is accelerating.[34] A century of "business as usual" development might take us to a concentration of 1,000 ppm of CO_2e. Climate models suggest that such a rise could lead to a median temperature increase over the next century of 4°C or more compared with pre-industrial levels (see Figure 3).[35]

Action to reduce carbon emissions is made more urgent by long lag effects, both in atmospheric physics and human infrastructure, which mean that decisions today have their major impact on the climate for future generations.

First, there is a long atmospheric time lag, because it can take 25–30 years for CO_2 molecules to reach the upper atmosphere, and cause the "greenhouse effect" of trapping heat. Thus, moderating climate change in 2040–50 requires cuts in GHG emissions today and over the next 10 years. Note that CO_2 remains in the atmosphere for several centuries, and so avoiding emissions in the first place is the only sure way to limit their impact.

Second, GHG emissions come largely from long-lived assets. Once a power station, building, factory or car has been built, it will generate emissions at about the same rate through its life. This can be 40–50 years for a power station and even longer for some buildings (assuming constant use, and no "retrofitting" of new technology). This gives rise to the phenomenon of "lock-in". Once capital assets are built, their lifetime emissions are potentially irrevocable for decades.

The implications for climate action are profound. The infrastructure and technologies we install today will affect emissions both today and through this century. The next 15 years will be decisive in influencing the future climate. That is because of the greenhouse gas-emitting capital stock which already exists, plus the US$90 trillion worth of new infrastructure investment expected during this period across the cities, land use and energy systems where emissions will be concentrated.[37]

One way to understand the implications of lock-in for climate policy is through the concept of "carbon budgets". The Intergovernmental Panel on Climate Change (IPCC) calculated that for a two-thirds or better probability of limiting global average warming to 2°C, cumulative GHG emissions could not exceed 3,670 billion tonnes of carbon dioxide equivalent (Gt CO_2e).[38] Around half of that (1,890 Gt CO_2e) had been emitted by 2011. If the capital stock built over the next 10 years generated emissions at the same rate as that built over the last 25 years, the world would almost certainly exceed this carbon budget.

The IPCC's review of recent emission projections suggests that if current trends continue, global emissions in 2030 will be around 68 Gt CO_2e, compared with around 50 Gt CO_2e today, with cumulative emissions breaching the 2°C carbon budget by a significant margin in the long term.[39] There are several conceivable emission pathways consistent with a two-thirds probability of keeping warming below 2°C by 2100. A core 2°C scenario used in this report looks for a reduction in GHG emissions to 42 Gt by 2030 – an average decline of about 1% a year, with further reductions thereafter, including (in line with IPCC scenarios) a transition to negative emissions in the second half of the century.[40]

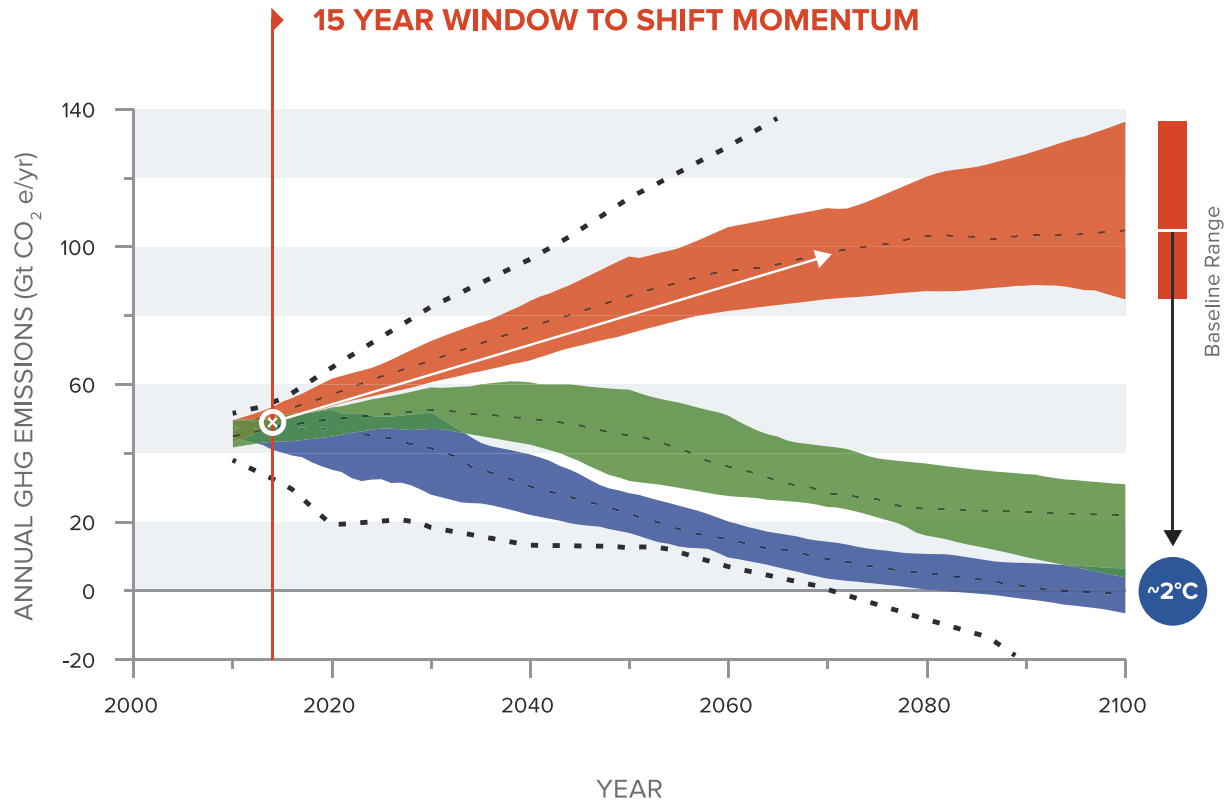
Such calculations show that delay in taking action makes it increasingly difficult to meet a 2°C target, raising climate risk. Delay is dangerous. Climate scientists have estimated how rising temperatures will affect different regions of the world over time, showing how warming above 2°C will lead to more dangerous effects.[41] In general, the frequency of extreme weather events, such as heat waves, droughts, floods, hurricanes and storm surges, will increase. Rising and more variable temperatures and changes in precipitation patterns will also take a toll, particularly in developing countries which depend on agriculture. Arctic sea ice and global glacier volume will shrink further, while sea-level rise and ocean acidification will continue. Ecosystems and "biomes" (biologically productive regions) will move polewards as temperatures rise.

Put in economic terms, the impact of about 2°C of warming could lead to global aggregated losses of 0.2–2.0% of income, the IPCC has said, synthesising the results of various studies.[42] Impacts and damages were likely to be significantly more severe in tropical regions and developing countries. Within developing countries, the poor are inevitably the most vulnerable group.

The IPCC reports that very few studies have examined economic impacts beyond a 3°C increase, which would represent an average global temperature not experienced

Figure 3

The world is currently on track for warming of around 4°C



Source: IPCC, 2014.[36]

for millions of years. While such studies have arrived at a very wide range of damage estimates, it is well understood that higher temperatures in this range increase the likelihood of reaching "tipping points" or "thresholds" in natural systems, setting off powerful, self-reinforcing climatic impacts and irreversible changes with severe economic and human costs. For example, the thawing of permafrost could lead to a large release of methane, which would drive additional temperature rises, risking runaway and catastrophic climate change and economic damages.

net carbon imports in 2010 rise to the equivalent of 18% of production emissions, from about 2% in 1990. Nevertheless, some OECD countries have managed to reduce both production and consumption emissions.

The comparison with financial risk

Climate risk can be usefully compared with financial risk before the 2008–09 financial crisis. Such comparisons include the steady accumulation of risk over time, the systemic nature of that risk, and its underlying incentives.

Before the crisis, financial risks increased as leverage and the use of high-risk instruments grew and spread through a globalised financial system. Climate risk is similarly cumulative, determined by the growing stock of GHGs in the atmosphere, rather than any one year's emissions. Such accumulation of risks creates the danger of a more severe outcome, especially since it is hard to know how close the system is to a tipping point. Even if most analysts thought a global financial crash was unlikely, there was clearly a possibility that it could happen, as transpired. Similarly, there is a clear possibility that climate impacts and damages could be even greater, or come earlier, than scientists' central scenarios, with very severe effects.

The financial risks that accumulated in the pre-2008 period were "systemic", in that all major financial institutions were exposed, making the entire global financial system vulnerable. Climate risk is also systemic: it cannot be isolated in one part or region of the world economy. Damage from warming above 2°C will affect all parts of the global economy.

> *Climate risk is large, systemic and accumulating, just as financial risk was before 2008.*

Climate and pre-crisis financial risk also exhibit similar incentives. Financial firms and households had incentives to take on excessive debt and risk, because of higher near-term profits and utility. Regulators and governments had little short-term incentive to stop the excess, since the credit boom was evidently boosting economic growth and voter satisfaction. Similarly, firms emitting carbon and consumers enjoying the benefits of fossil fuels have every incentive to enjoy their low costs today. Governments with short-term political considerations hesitate to get in the way.

These parallels are both disturbing and instructive. Climate risk is large, systemic and accumulating, just as financial risk was before 2008. However, climate risk is arguably much better understood, having been the subject of vast international research collaboration and discussion for decades. And, unlike financial risk, failing to act could have consequences that are irreversible.

The Commission believes that the world's governments, businesses and citizens at large possess an overwhelming case to act while they are still able to defuse the risks, if not to eliminate them.

Managing climate risk under uncertainty

One of the factors that makes climate change such an unusually difficult problem is that it entails policy-making under large scientific and economic uncertainties. While there is little doubt that climate change is occurring and that human activity is contributing significantly, there remain many large scientific uncertainties about the timing and scale of climate changes. The IPCC exhaustively documents these uncertainties in its latest major report reviewing the physical evidence, published last year.[43] As Box 1 notes, little is known about the scale of economic damages beyond a warming of 2–3°C, although the range of outcomes includes the possibility of very severe, long-run damage.

Uncertainty is not a reason for inaction given the evidence that climate change will inflict significant costs on average across the range of uncertainties. In addition, it is a standard assumption that decision-makers are risk-averse, and should therefore put even greater weight on the loss of welfare under a less optimistic outcome. The rational course of action is to manage climate risks, to take climate action today as an insurance premium against the real, but difficulty to quantify, possibility of severe or catastrophic outcomes.

Broadly speaking, there are two strategies to manage climate risk:

- **Mitigation** of climate risk aims to reduce the likelihood and extent of climate change by reducing GHG emissions. In risk management language, this can be called a self-protection strategy. The challenge facing the world is how to mitigate emissions substantially while maintaining rapid economic development and poverty reduction. In the remainder of this report we explore the potential for mitigation in terms of three drivers of change: improvements in efficiency in resource use; strategic investments especially in infrastructure; and, perhaps most important in the long run, innovation.
- **Adaptation,** on the other hand, is defined by the IPCC as "the process of adjustment to actual or expected climate effects", which "seeks to moderate or avoid harm or exploit beneficial opportunities" from climate change.[44] This is sometimes referred to as a self-insurance strategy. There is growing interest in broader strategies for transformative adaptation that help communities increase productivity, seek out lower-carbon methods and strengthen resilience to climate change. Box 2 notes some key aspects of adaptation. (See also Box 4, which describes transformative adaptation in sub-Saharan Africa.)

Box 2
Adaptation

Any sensible approach to managing climate risk will involve some investment in adaptation, alongside mitigation. GHGs already in the atmosphere will mean that 2016–2035 will be 0.9–1.3°C warmer than 1850–1900, on average, even if drastic action to reduce emissions is taken immediately.[45] Adaptation to at least that level of climate change will therefore be essential. Furthermore, without mitigation, emissions and temperatures will continue to rise, and so will the costs of adaptation, as the impacts of climate change become increasingly harsh. Beyond a certain threshold, climate change would overwhelm capacity for adaptation – for example, extreme heat and sea-level rise.

Adaptation is likely to be highly context-specific, but will in general involve complementary actions across all levels, from individuals to governments. Changes in patterns of resource allocation, investment and innovation will be needed to sustain and improve well-being in response to actual and expected climate changes. Increased investment will be needed in such areas as more resilient infrastructure and water supplies; stronger coastal defences and flood protection; new techniques in agriculture, forestry, fisheries and other sectors to maintain output under changing weather conditions; improved meteorological forecasting and early warning systems; and better risk management, insurance, social protection and health services.

Taking adaptation seriously further underlines the importance of efforts to strengthen institutions for public investment management, to ensure that public spending is well planned, carefully implemented and efficiently managed.

Initial estimates have indicated that the costs of adaptation to 2°C warming might be US$70–100 billion per year from 2010 to 2050, or about 0.2% of global GDP in 2009, but a much more significant cost relative to GDP in low-income countries, which are likely to suffer more from climate change.[46] Limitations in the evidence base also suggest that these estimates are incomplete.[47] Regardless, estimates of adaptation financing needs in vulnerable low-income countries, such as in sub-Saharan Africa and Small Island Developing States, far exceed actual flows. Improving financing for adaptation must be an important element in international cooperation to tackle climate change.

Alongside public investment, adaptation also requires institutional and policy reforms that facilitate adaptation by businesses and individuals. Rational, forward-looking individuals will normally undertake adaptation actions in their own self-interest, but such autonomous adaptation may be hampered by market and policy failures. For example, farmers in low-income countries may fail to shift to new, more resilient seeds and farming techniques due to some combination of credit market and information failures, and weak property rights. Solving such problems to promote more resilient farming methods can have multiple benefits by raising agricultural productivity as well as curbing emissions, by promoting more sustainably intensive farming methods.

As these examples suggest, many of the reforms needed to facilitate adaptation are also likely to increase the development options and carbon abatement choices available to individuals and countries. A systematic use of cost-effective adaptation measures could increase resilience and reduce losses from climate change by up to two-thirds through 2030, while also making insurance more cost-effective for the remaining third, according to one study.[48]

In conclusion, there is an urgent need for a development model, across all types of countries, that first slows and ultimately reverses the accumulation of climate risk, while continuing to yield rapid gains in human well-being.

3. Opportunities to tackle growth and climate challenges

3.1 Some strategic considerations

A central insight of this report is that many of the policy and institutional reforms needed to revitalise growth and improve well-being over the next 15 years are also key to tackling climate risk. There is considerable scope for countries to press forward with reforms that both energise development and grapple with climate risk.

Market and policy failures, multiple benefits and the scope for "win-win" reforms

The potential for countries to make immediate progress on both development and reducing climate risk rests partly on what the Commission sees as the substantial scope for what are sometimes called "win-win" or "no-regrets" reforms.

"Win-win" reforms arise because real-world economies are rife with market and policy failures. In contrast to the theoretical economic model of competitive general equilibrium, where the demanding conditions for a welfare optimum are satisfied, real economies are typically operating well below their potential to improve welfare. Correcting these failures can generate multiple benefits, including gains in economic efficiency and the

environment. Such reforms still entail costs and trade-offs. But the case for vigorous reform is substantially strengthened by taking proper account of the full range of market and coordination failures, and the potential multiple benefits (and costs) of correcting them.

Box 3 lists some of the more important market and coordination failures that are relevant to this discussion.

This report documents numerous opportunities for reforms which deal with both development and climate risk. These reforms yield both significant near- to medium-term net improvements in welfare, economic efficiency and development, as well as mitigation of GHGs. One important example we illustrate here is reform to reduce the negative environmental externalities from burning fossil fuels to reap multiple benefits, including both lower global climate risk and reduced local air pollution.

Climate change itself is, of course, the biggest of all global externalities. The economic case for undertaking some immediate action to mitigate climate change is well established.[50] But actual action has been limited. One concern among policy-makers is that while the costs of climate interventions are incurred today, they will produce benefits mostly over the long term. In addition, the size of these benefits is uncertain. And the climate benefits produced as a result of actions by any individual country will largely accrue to other countries, in the absence of a global agreement.

There is considerable scope for countries to press forward with reforms that both energise development and grapple with climate risk.

The benefit-cost calculus of climate action can change substantially when fuller account is taken of the multiple benefits that arise as a joint product of actions to reduce emissions of GHGs.[51]

The classic example of multiple benefits is the reduction in local air pollution associated with climate mitigation policies that reduce the use of fossil fuels.[52] Fossil fuel burning generates not only greenhouse gases but also local air pollution that has an immediate harmful impact on the emitting country itself. The most important type of air pollution involves tiny particles called particulate matter (PM). These particles are defined according to their size; the smallest, $PM_{2.5}$, which often come from burning fossil fuels, are the most dangerous. They increase they prevalence of lung cancer, chronic obstructive pulmonary disease, ischemic heart disease (from reduced blood supply) and stroke.[53]

Box 3

Anatomy of market failures – a world of imperfections and opportunities

Externalities occur when a product or activity affects people in ways that are not captured in its price. A firm burning coal as an input in manufacturing creates local air pollution, which damages the health of people nearby. This damage is not captured in the price of the final product, which is then over-consumed, reducing overall welfare. The firm's activity also creates a global externality in the form of climate change, which will adversely affect people all over the world.

Network effects occur when the value of a product or activity depends upon its wider adoption. Electric cars are less valuable if there are only a few users, because it is unprofitable to create a network of charging stations. And without charging stations, the number of electric car users remains low. As a result, electric cars may fail to take off and achieve an alternative possible equilibrium with many users and a profitable charging network. Extension of recycling initiatives and the electricity grid provide other examples.

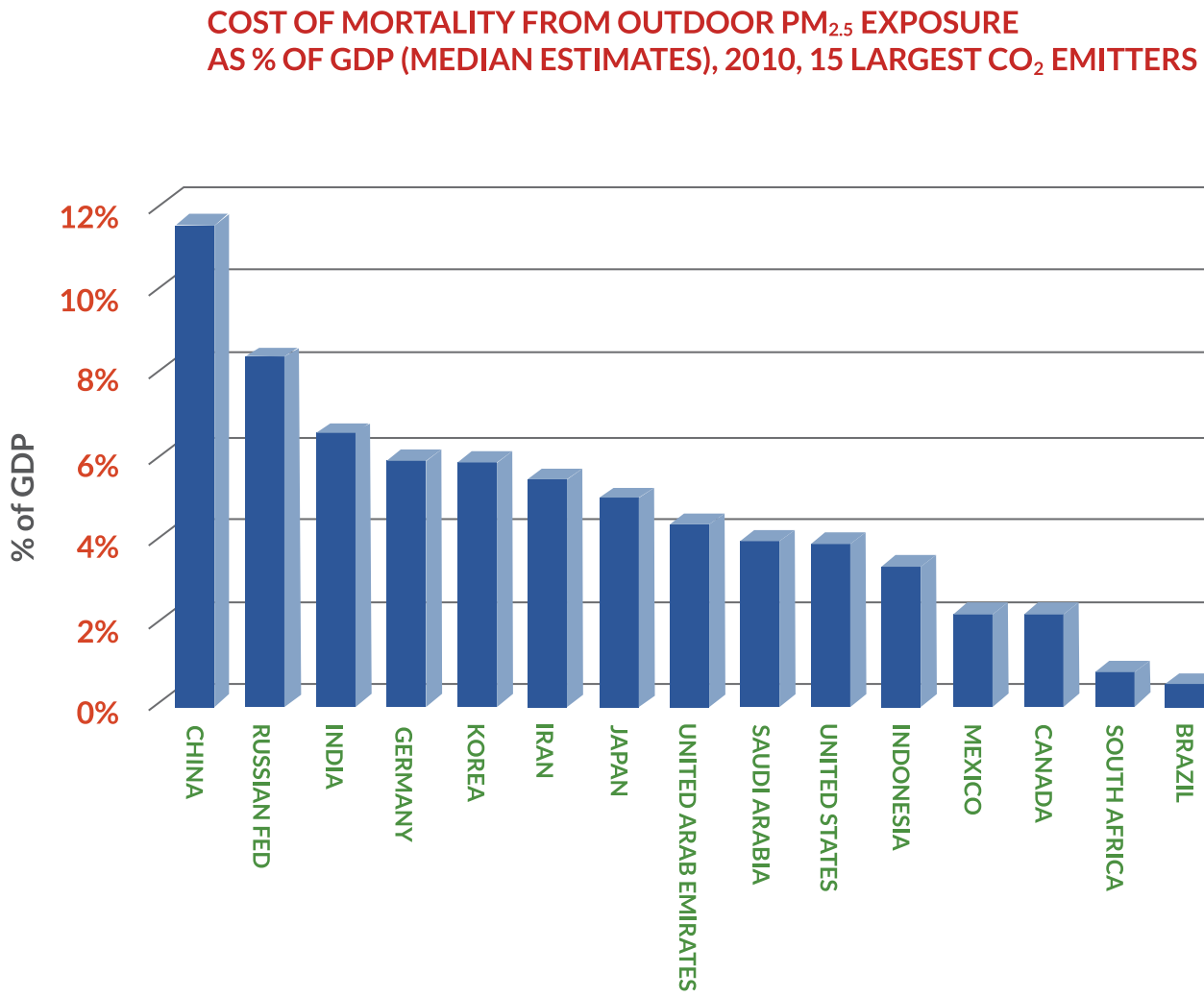
Agglomeration effects are close cousins of network effects, and are important in the economics of cities, where the value of deciding on a particular location depends on the number of other people deciding the same.

Innovation externalities occur where an inventor is inadequately rewarded for the time and resources invested to create a superior product or process. For example, once developed, the innovation's advantages may be relatively cheap to copy. Knowing this, the inventor may simply not take the trouble to innovate. Similarly, firms may under-invest in education and training, as trained workers can be "poached" by other companies. Network externalities and asymmetric information effects also hinder the creation, diffusion and financing of innovations.

Imperfect information. Many imperfections in capital markets and financial systems, such as moral hazard, adverse selection and principal-agent problems, result from imperfect information. In addition, firms and consumers do not have complete information about available goods and services – for example, the energy efficiency of appliances or cars – and so may not recognise their economic benefit.

Behavioural aspects. Economies may also perform inefficiently because of the psychological features of economic agents, whether consumers, workers, savers, managers or policy-makers, reflecting various biases and constraints in human decision-making.[49]

Figure 4
Cost of mortality from outdoor air pollution, 2010



Note: The estimate is for mortality from particulate matter ($PM_{2.5}$) exposure in particular Source: Hamilton, 2014.[55]

The health damages caused by local air pollution are often very large. In China, $PM_{2.5}$ pollution has been linked to 1.23 million premature deaths in 2010 (median estimate) – or, put in monetary terms, damages equivalent to 9.7–13.2% of China's GDP. The problem is so severe that curbing local air pollution has become one of the major items on the government's policy agenda, driving plans to curb China's coal consumption.

In India, $PM_{2.5}$ pollution is associated with more than 627,000 premature deaths in 2010 (median estimate), equivalent to 5.5–7.5% of GDP. Figure 4 shows median estimates of the costs of mortality from $PM_{2.5}$ exposure for the 15 largest emitters of CO_2 from energy use.[54]

It is sometimes useful to express the monetary value of health damages from local air pollution per tonne of CO_2 emitted from fossil fuel combustion. With some caveats, this indicator also provides an estimate of the potential health benefits per tonne of CO_2 abatement. A recent study calculates the median value of such health benefits for the 15 largest CO_2 emitters at US$73 per tonne of CO_2 abated in 2010.[56] Illustrating the significance of these numbers, they are more than double US government estimates for the climate benefit of reducing CO_2 emissions. The US Interagency Working Group on Social Cost of Carbon estimated this climate benefit at US$32 per tonne of CO_2 abatement in 2010.[57] Adding the median US$73 benefit from reduced air pollution in the 15 largest emitters would triple the overall benefit from cutting carbon emissions. Furthermore, and importantly from the perspective of policy-makers, the air quality benefits are enjoyed in the near term; accrue locally, mostly to the country itself; and are more certain compared with climate change benefits.

This discussion of avoided local air pollution provides a specific example of the importance of accounting for multiple benefits when evaluating climate actions. In practice, it would be important to look carefully at how the size and time paths of the various benefits and costs differ across countries. Many aspects of the links between greenhouse gases and local air pollutants, including synergies and trade-offs, need to be better understood.

From the perspective of policy-makers, an important complication is that there may be alternative policies that generate a different set of benefits. For example, a significant volume of local air pollution can be mitigated by so-called "end of pipe" methods that do not reduce GHG emissions, such as sulphur scrubbers fitted to the smokestacks of power plants. If countries pursued more ambitious air pollution reduction targets, however, then "end of pipe" methods are unlikely to be enough. It would still then be necessary to adopt methods that also reduce GHG emissions.

One of the few model-based studies to estimate the scale of GHG reductions from ambitious air pollution policies considered an illustrative scenario in which countries sought to reduce premature air pollution-related deaths in 2050 by 25% compared with 2005. This ambitious air pollution target also yielded large GHG reductions by 2050, falling by 38% in the OECD, 61% in China and 42% in India, compared with a baseline without mitigation policies.[58]

Fossil fuel combustion, especially from coal, is the major source of PM pollution in China, causing severe smog and haze problems in major cities. In 2013 only three Chinese cities met a so-called "Grade II" air quality standard (equivalent to less than 35 micrograms of PM per cubic metre). Research for the Commission suggests that even with the most advanced end-of-pipe technologies, only 50% of Chinese cities would be able to achieve the Grade II air quality standard by 2030. Instead, it will be necessary to adopt upstream methods which replace fossil fuels to ensure that most Chinese cities meet these air quality standards. Such transformational policies would also generate GHG reductions and help China peak its emissions by around 2030.[59]

In a full cost–benefit analysis, policy-makers could compare the total multiple benefits (net of costs) of a GHG mitigation policy against those of an air pollution reduction policy. An optimal policy would seek a combination of GHG and air pollution measures, to maximise total multiple benefits net of costs. One study finds that an optimal, combined policy achieves air quality benefits as large as an air pollution-only policy, while also achieving climate benefits larger than in a GHG-only mitigation policy.[60] The net total benefits of the combined policy are larger than either of the separate policies. Clearly, this is an important policy theme which deserves to be explored more thoroughly going forward.

Scope for reforms: some qualifications and limitations

We have used the term "win-win" to refer to the potential for reforms which tap multiple benefits by tackling numerous market and policy failures. It is important to describe some qualifications and limitations.

First, such reforms still entail costs and various trade-offs. To illustrate, consider a common example of a "win-win" reform, to reduce fossil fuel consumer subsidies. Such a reform can reduce fiscal pressures, improve economic efficiency, and yield multiple benefits in reduced local air pollution and GHG emissions. However, it also entails costs, including human costs and loss of output that occur as workers and equipment in some sectors become unemployed for some time, before finding employment in rising sectors. Costs and trade-offs exist in all cases, and need to be carefully examined and dealt with in undertaking reforms.

In developing countries, an important concern is that attempts to tackle climate change will derail their immediate and overriding objective of rapid economic growth and poverty reduction.

Second, there is the "problem of the second best". In an economy with multiple imperfections, an attempt to correct one imperfection could reduce rather than increase overall welfare.[61] Here there are no easy formulas. Each situation would need to be analysed carefully on its merits, and policy might need to proceed through step-by-step experiment and learning-by-doing to discover the right combination of instruments to advance overall welfare over the course of time.

Third, there are often deep political economy or institutional reasons why governments do not undertake reforms to eliminate a market or policy failure. Government failure can lead to reforms themselves introducing new distortions or inefficiencies that leave the country worse off than before. Such failures can occur, for example, when governments are mainly responding to influential special interests or rent-seekers; lack credibility with the public; or are mainly driven by short-term political objectives. As a result, the hard and poorly understood problem of improving governance and institutions is an essential element of reform strategies to tackle development and climate objectives.

Some of these limitations may represent daunting challenges for reform. But this should not discourage a well-considered, bold and persistent effort to act, given the potential for immense gains in human welfare and

poverty reduction, and the severe climate losses that could accompany inaction.

Is climate action too costly?

There is never a good time for major change, especially one which involves complex political dynamics and deep institutional reform. To make progress, it is crucial to examine the many thoughtful and reasoned concerns about potential adverse effects of climate action. Here we briefly discuss some of the main concerns that are sometimes raised against taking immediate action on climate.

The most widely held concern is that climate action is simply too costly. In developing countries, an important concern is that attempts to tackle climate change will derail their immediate and overriding objective of rapid economic growth and poverty reduction. In all countries there are concerns about potential effects on employment and competitiveness in the global economy.

In evaluating such concerns, it is important to take into account the full costs and benefits of all available options. Sometimes a policy may appear too costly because not all its benefits are accounted for. The appropriate metric for judging an economic policy is its impact on overall welfare. In this report, we have tried to focus on policies and reforms which improve overall national welfare, productivity and efficiency, and which also help reduce climate risk.

Developing countries may worry that environmental policies will hinder their industrialisation. They may argue that it is better to "grow dirty and clean up later".

Often the analysis focuses only on the costs to a particular sector – for example, the pollution or carbon-intensive industries in the economy – while ignoring broader effects on the welfare of the public at large, such as improvements in health from reduced local air pollution. A lack of environmental regulation is in effect a form of subsidy to highly polluting firms at the expense of a less healthy public, and less polluting firms. Environmental policy improves overall economic efficiency and welfare by removing the implicit subsidy for polluting firms, and by causing a reallocation of resources towards cleaner activities.

The exclusive use of GDP as a yardstick to measure the welfare effects of reform can also be misleading. The effect on GDP might include a potential loss in measured output of goods and services, but not other types of changes in welfare, for example in improved health. Policy-makers should supplement GDP effects with estimates of broader welfare gains, which can also be estimated in monetary terms, albeit sometimes only roughly.[62]

If policy-makers do want to focus solely only on GDP effects, however, several points are relevant. First, the assumptions of models used to make such estimates need to be carefully scrutinised. Models often start from the assumption of an economy where resources are already efficiently allocated, for the good reason that we do not yet know how to model the real world of multiple imperfections and numerous inefficiencies. The effects of reform are therefore judged against the assumed starting point of an efficient economy. Such results, while interesting, need to be used cautiously as a guide to policy, when one is judging the results of reform versus non-reform in a highly imperfect and inefficient world.

Second, as Chapter 5: Economics of Change discusses in more detail, the estimated global costs of efficient climate policy, such as a carbon tax, are usually rather limited, perhaps in the order of 1–4% of global consumption in 2030, with a median value of 1.7%, according to the IPCC's review of recent studies.[63] Such costs are fairly small in relation to the much larger underlying increase in consumption that would occur by 2030. Assuming consumption growth of 3% in 2015–30, a little less than average world GDP growth since 1980, a median 1.7% cost would represent a delay of about six months in achieving the level of consumption that would have been reached in 2030 without climate policies. This does not seem an excessive insurance premium to pay to start reducing the possibility of dangerous climate change. Note that the cost estimates discussed here do not include the kinds of multiple benefits discussed above, nor the benefits of averted climate damages. Such model-based cost estimates can also be significantly reduced by optimal recycling of revenues from a carbon tax – for example, to cut labour and capital taxes.

Third, adopting a somewhat costlier option today may make sense in a highly uncertain world where there is a value in keeping options open and avoiding getting locked into courses that might turn out to be very expensive in the future. This point is especially relevant when building large, long-lived infrastructure such as transport networks or power systems.

Fourth, the cost–benefit ratio for climate action depends greatly on the international context. There is a disincentive for governments to undertake reforms with climate trade-offs, because climate action creates a global public good. The benefits from a single country's efforts to reduce GHG emissions will accrue to all countries. But if countries act together to reduce emissions, then the climate benefits for each country are much larger. Chapter

8: International Cooperation explores approaches for enhancing global cooperation on climate action, including the need for climate finance to help developing countries make progress.

Will climate action lead to loss of competitiveness?

The particular focus here is the potential harm caused by climate action to the international competitiveness of a country's industries. The concern is that higher costs relative to foreign competitors will cause a shift in pollution-intensive industries to other countries with less strict regulation.

Empirical studies have found this relocation effect to be small, where it is found at all, reflecting the fact that pollution abatement costs are only a small proportion of total costs in most industries. In addition, environmental regulations can induce firms to increase innovation as a way to offset such higher costs. Governments may nevertheless consider providing carefully designed transitional assistance to vulnerable sectors.[64]

Developing countries may worry that environmental policies will hinder their industrialisation. They may argue that it is better to "grow dirty and clean up later". Developing countries indeed face numerous coordination and market failures that may hamper structural change and the success of tradable goods industries, which, even if they are polluting, might well be important for long-term growth and structural change. As noted earlier, "growing dirty" implies subsidising polluting industries at the expense of less polluting firms and the public at large, who suffer from pollution and ill-health. Lack of environmental regulation can then be a form of industrial policy to support polluting tradable sectors, one that is relatively easy to implement, as it does not make heavy demands on institutional capacity. Developing countries should, however, be able to reach a better outcome if they combine tighter environmental policy with more focused government interventions in support of structural change, backed by a sustained effort to strengthen institutional capacity. To encourage such approaches, developed countries could consider providing greater flexibility under international trade rules to accommodate well-managed industrial policy interventions by developing countries.[65]

Will climate action hurt the poor?

Whether climate actions such as removing fossil fuel subsidies or a carbon tax are regressive (having a greater relative negative effect on the poor) depends to some extent on country circumstances. There is some evidence that they tend to be regressive in developed countries, but less so in developing nations, where the upper and middle classes may be the major consumers of energy.[66] Regardless of this relative impact, policy-makers are concerned about the absolute impacts of higher energy prices on the poor. Well-designed and targeted safety net measures to help vulnerable groups are an essential element in the political economy of reforms.

Will climate action cost jobs?

Linked to concerns about competitiveness are fears that environmental policies will significantly increase unemployment. Others have argued that such policies will, on the contrary, be a source of "green jobs".

A good starting point is to note that the aim and effect of environmental and climate policies is to induce a substitution between different types of production and consumption, away from more polluting to less polluting activities. There is no special reason to expect any overall net job gains or losses from this adjustment. While there is a clear finding in the research that any overall employment effects of environmental policies are small, there is no consensus whether those small effects would be positive or negative.[67] (See Chapter 5: Economics of Change for further details.)

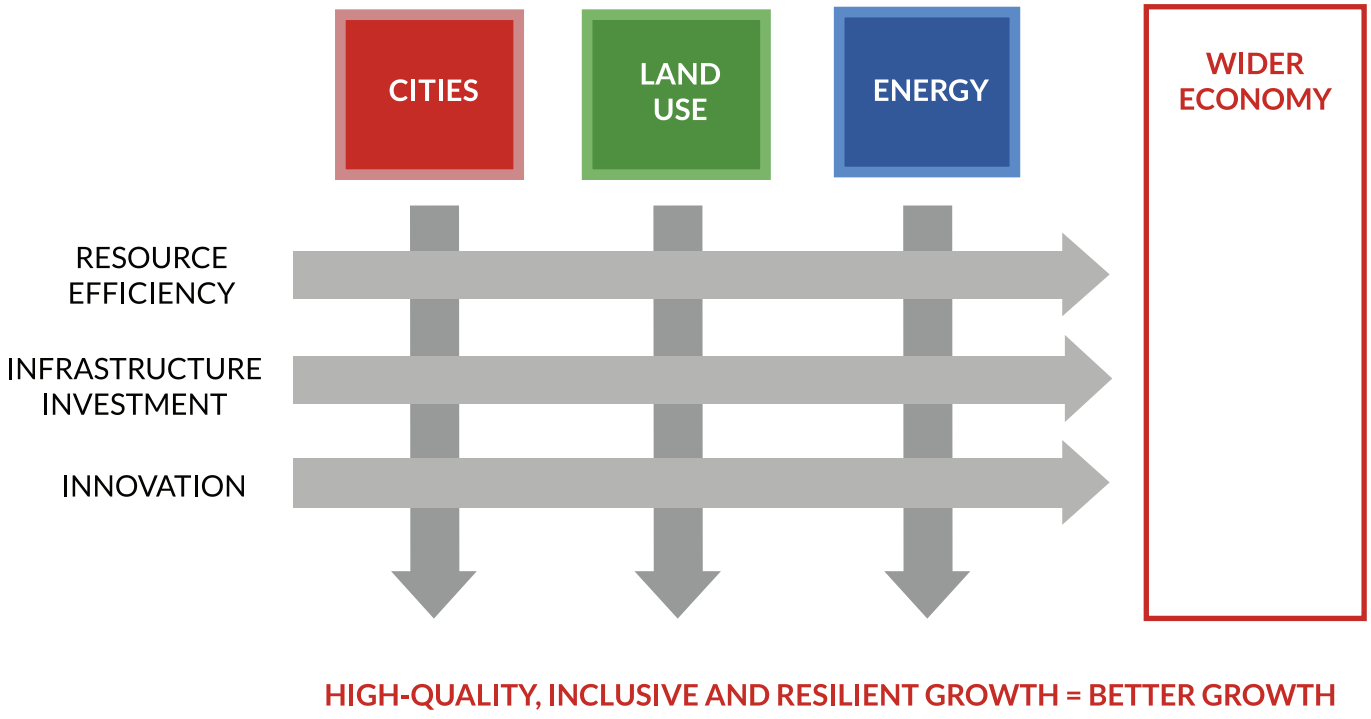
Investment in infrastructure is a fundamental mechanism to expand the productive capacity of the economy.

There will, however, be changes in the numbers and types of jobs across and within economic sectors, and there could be significant adjustment issues, as workers need to move from declining to expanding sectors, firms and job types. This will require specific policies to shape a just transition. The amount of such "churn" or job destruction and job creation linked to climate mitigation is expected to be about 0.5% of total employment – quite small compared with the overall "churn" that normally occurs in a market economy. Job effects may be larger in economies with larger labour market imperfections. The recycling of revenues from carbon taxes or emissions trading schemes can mitigate job impacts. For example, studies suggest that recycling of carbon tax revenues to reduce labour market taxes could offset or more than offset all adverse impacts of climate action on employment.[68]

3.2 Enabling change through resource efficiency, investment and innovation

Policy efforts to promote rapid development and tackle climate risk will draw upon and work through three fundamental mechanisms or drivers of change that affect every sector of the economy: efficiency of resource use; investment, particularly in infrastructure; and innovation.

Figure 5
Three critical economic systems and three key drivers of change



Note: Cities include urban transport, and land use includes forests; innovation includes economy-wide innovation.

Resource efficiency

The discussion in the preceding section has stressed the presence of numerous market and policy failures which result in an inefficient allocation of resources and lower levels of welfare. Fossil fuel consumer subsidies are an important example. They result in multiple resource misallocations, including excessive capital and labour employed in pollution-intensive sectors. Within sectors, firms use more fossil fuel- and pollution-intensive methods of production. Consumers' shopping baskets are biased towards fossil fuel- and pollution-intensive goods and services. There is too much local air pollution, damaging citizens' health and productivity, and too high GHG emissions, storing up climate risks for the future.[69]

> *Innovation and technological progress are by far the most important drivers of long-term growth in productivity and output.*

Reforms of fossil fuel subsidies, discussed in more detail in Chapter 5: Economics of Change, can stimulate improvements in efficiency of resource use in all these dimensions. Various instruments can improve resource efficiency by tackling market failure, including price-based instruments such as carbon taxes or emission trading schemes, as well as regulations and standards, and information-based instruments, among others.

Infrastructure investment

Infrastructure refers to the large interconnected physical networks – transport, communications, buildings, energy, water and waste management – that provide critical services to and raise the productivity of the economy as a whole. Investment in infrastructure is a fundamental mechanism to expand the productive capacity of the economy.

Recent economic research has provided much evidence on the high, economy-wide returns to efficiently allocated and well-managed infrastructure capital.[70] As Chapter 6: Finance indicates, almost US$90 trillion infrastructure spending (in constant 2010 dollars) is projected to be needed in 2015–30 across the cities, land use and energy systems, especially in developing countries. Ensuring that this new infrastructure does not lock countries into a high-carbon path, but rather supports the transition to a low-carbon economy, is expected to have a net additional cost of about US$4 trillion. The latter does not include

longer-term operational savings in a low-carbon transition, as a result of burning less fossil fuels.

Increased investment is a means of increasing consumption in the future. When the economy is operating at full capacity, it will, in general, demand some sacrifice of present consumption. But that is hardly the case in large parts of the world today, which are continuing to operate at below their potential output in the wake of the Great Recession. Investment is hardly constrained by a shortage of savings, as suggested by low long-term real interest rates. Yet world gross fixed investment relative to GDP has fallen to around 21% in the years since the crisis, the lowest level in 50 years, entirely due to a fall in developed countries, to around 19%.[71] The present macroeconomic context thus provides a particularly favourable opportunity for policies to foster stronger global growth through increased infrastructure investment, including in low-carbon systems.[72] Chapter 6: Finance further explores policy approaches to boosting infrastructure spending on low-carbon assets, in particular through institutional innovations to encourage private-sector financing and engagement.

Innovation

Innovation and technological progress are by far the most important drivers of long-term growth in productivity and output.[73] It is also becoming clear that innovation is likely to be the most important long-term driver to mitigate climate change, in particular by fostering new technologies that can supply energy that is not only clean but also cheap and abundant. The latter condition is critical if the world is to satisfy rapidly growing energy demand in developing countries while also abating GHG emissions and climate change.

The clustering together of individuals and firms in urban areas facilitates innovation, productivity increases and economic growth through a variety of agglomeration economies.

A broad definition of innovation includes not only cutting-edge research and development (R&D), but also deployment, diffusion and adoption of existing technologies, the latter being especially important in developing countries. It includes not only development of new products and production processes, but also institutional innovation and new methods of business organisation, marketing and distribution. Relatively simple innovations can have enormous impacts: the introduction of the humble shipping container revolutionised global freight transport and is estimated to explain a 700% increase in industrialised country trade over 20 years.[74]

There is a large role for public policy to foster innovation. As Box 3 indicates, innovation is subject to its own specific market failures, such as knowledge spillovers, network externalities and asymmetric information. These failures mean that private incentives alone are generally

Box 4

African agriculture – a case for transformative adaptation and multiple gains[80]

High poverty makes Africa's rural populations acutely vulnerable to climate risk. It also closes down opportunities for productive investment and reinforces land use policies that contribute to climate change.

Low productivity is at the heart of the problem. Grain yields are between one-third and one-fifth of those in South Asia. Much of Africa's agricultural output growth over the past half-century has come from land and labour increases. Crop-intensification, minimum tillage and agroforestry projects could all boost yields. Farmers in Malawi have doubled maize output per hectare through more intensive cropping. However, climate risk is itself a barrier to investment, one which is gradually ratcheting higher. Studies show that inability to manage risk is a major deterrent to the adoption of new technologies and investment in crops offering higher (but more variable) returns.

Transformative adaptation strategies could help change this picture. For example, support for social protection and the development of insurance can provide a safety net that reduces the threat of severe losses. Investment in infrastructure can have a similar effect by strengthening resilience.

African governments themselves could do much to reduce risk and raise productivity. On one estimate, Africa's farmers typically receive around 20% of the value of food crops, reflecting the poor state of rural roads and the operation of transport cartels. Some 10–20% of food staple production is lost through post-harvest losses. Non-tariff barriers restrict opportunities for participation in regional trade. One effect is to decouple agriculture from fast-growing urban markets. Currently, intra-regional trade accounts for less than 10–15% of the US$35 billion in food imports.

Ethiopia is exploring a more ambitious approach to adaptation. The 2011 Climate Resilient Green Economy strategy provides a single funding mechanism and institutional framework linking all government departments. The strategy combines public investment in infrastructure with incentives for private investment to mitigate climate risks and raise productivity.

inadequate to generate an optimal amount of innovation. Market incentives for climate-friendly innovation are further reduced by the failure to price externalities related to GHG emissions, which boost the profitability of polluting relative to clean technologies. The introduction of environmental pricing on fossil fuels would improve the price incentives for innovators to seek out new cleaner technologies, in addition to improving the efficiency of existing resource allocation.

Chapter 7: Innovation discusses various public policy responses, including public-sector R&D, fiscal incentives, public procurement, intellectual property rights and other instruments. Innovation market failures also provide a rationale for policies tailored to promote innovation in clean technologies more specifically. That is because market failures affecting innovation also promote path dependence.[75] The large existing base of research in fossil fuel technologies, for example, has given them a large "head start", and favours further innovations on that path. This path dependence, or bias in favour of existing dirty technologies, could hinder or prevent the creation of a clean energy innovation complex and path that might otherwise generate new clean technologies that are ultimately even cheaper than their dirty competitors.

3.3 Opportunities to tackle growth and climate challenges in three critical systems

The Commission has focused on three socio-economic systems that hold the key to yield multiple economic, social and environmental benefits: cities, land use and energy systems. These systems are crucial for change in a meaningful 10- to 20-year horizon because they are so important for the overall economy and emissions, are already undergoing rapid change, and generally have institutions and policy frameworks that can support reforms and contribute to improved outcomes. Other sectors such as heavy and light industry and services are also enormously important, of course, and are examined throughout the rest of the report, for example in the discussions of energy, innovation, competitiveness and restructuring.

Building more productive and cleaner cities

As Chapter 2: Cities discusses, urbanisation and economic development are mutually reinforcing. The clustering together of individuals and firms in urban areas facilitates innovation, productivity increases and economic growth through a variety of agglomeration economies. Such effects include spillovers and diffusion of knowledge between firms; increased productivity due to a wider variety of specialised inputs and types of labour; better risk-sharing; better matching of workers to firms; and greater feasibility of infrastructure projects with economies of large scale.

The geographic density of economic activity is found to be a powerful influence on productivity, broadly confirming the role of agglomeration economies, and showing that more compact cities can have economic development advantages. Employment density is found to explain over half of the variation in labour productivity across US states, for example.[76] At the same time, cities are also drivers of energy consumption and GHG emissions, generating about 70% of the global total of each.[77] Crucially, more compact, more connected city forms allow significantly greater energy efficiency and lower emissions per unit of economic activity.

In developing countries, especially, the traditional model of agriculture and land use is under pressure due to growing land and water scarcity, deforestation, over-grazing and soil degradation.

Unfortunately, there are few automatic guarantees that urban form will necessarily evolve in ways that maximise agglomeration economies and productivity while curbing GHG emissions, local air pollution and congestion. The dominant growth pattern in many urban areas is characterised by unmanaged sprawl and increasing car use. The fact that individuals and firms do not take into account the collective benefits of density creates a bias towards more urban sprawl. Other market failures also contribute, such as the lack of pricing for air pollution, congestion, or road traffic accidents (a major source of death and injury, particularly in developing countries[78]). Lack of city-level institutional and planning capacity tends to work in the same direction. Policy failures include infrastructure financing or urban tax models that implicitly subsidise sprawl, and motor fuel taxes that are too low to fully cover the cost of building and maintaining roads. Once a city starts to sprawl, it creates its own logic for further sprawl, by shaping household expectations about dwelling space and commute time; and building up a political economy of property developers and transport providers. Beside climate change, urban sprawl is one of the biggest examples of a market failure worldwide.

The Commission concludes that the type of urbanisation that unfolds in the next 15 years will have a major bearing on whether the world can exploit the opportunity for achieving economic growth while managing climate risk. How urban planners shape urban form and long-lived infrastructure in these coming few years will largely determine whether the world gets locked into a traditional model of sprawl and conventional motorisation, with lower productivity and spiralling emissions, or moves onto a better path, with more compact, connected and liveable cities, greater productivity and reduced climate risk.

Improving land use

Agriculture and land use systems will play an important role in dealing with development and climate risk challenges, as elaborated in Chapter 3: Land Use. These systems are central in meeting rising demand for food, driven by fast-rising incomes in developing countries and a still growing world population. They remain a major source of employment and income in low- and lower-middle-income countries, where they are also highly vulnerable to climate change.

In developing countries, especially, the traditional model of agriculture and land use is under pressure due to growing land and water scarcity, deforestation, over-grazing and soil degradation. These are also regions where agricultural productivity is already being affected by existing climate variability and will be most seriously reduced by climate change.

Chapter 3: Land Use argues that there are significant reform opportunities that raise farmers' incomes, strengthen resilience to climate change and abate GHG emissions. Such gains can be achieved by the application of modern agricultural technologies and practices that boost crop and livestock productivity, and that economise on inputs such as land, water and fertilisers. Landscape approaches to land and water management, which look beyond individual farms to improve resource use and protect ecosystem services, and often involve planting trees, can increase productivity and help stop and reverse land degradation. This, in turn, can reduce pressure on adjacent forests.[79]

Developing countries need to re-evaluate traditional assumptions about the inevitability of fossil fuels and coal and to study the full range of options that are now becoming realistic.

Exploiting such opportunities will require policy reforms, coordination and institution-building to overcome market failures that hinder farmers from pursuing them individually. One key problem to address is weak property rights, which create "tragedy of the commons" problems, contributing to overgrazing, deforestation, overuse of water resources and soil degradation. Weak property rights, credit market failures, imperfect information and other market failures contribute to inadequate uptake of new agricultural technologies, products and logistics capacity, which together could improve living standards, reduce food losses, and create greater flexibility and resilience to climate variability. Government failures, including inadequate provision of public goods such as roads, human security, information and agricultural extension services, also contribute.

Transforming energy systems

Energy is a crucial enabler of development. World energy use has increased by more than 50% since 1990,[81] and it is clear that developing-country demand for energy services will continue to increase as these countries industrialise and as hundreds of millions more people move out of poverty. Many of these people will be gaining access to electricity for the first time. Securing access to abundant energy services will remain a major preoccupation for policy-makers everywhere.[82]

Important approaches for meeting energy demand and reducing climate risks will include boosting energy efficiency, and exploiting rapid changes in energy supply technologies, as discussed in Chapter 4: Energy.

First, there is substantial scope to meet demand for energy services by increasing energy efficiency. Numerous low-cost ways already exist to increase energy efficiency in transport, power, heating, lighting, buildings and industry, a potential which is growing rapidly as a result of innovation. Uptake of these solutions is hampered by energy subsidies, lack of environmental pricing and market failures such as innovation externalities, learning-by-doing effects, imperfect information, credit market failures and principal-agent problems, as well as behavioural effects such as inattentiveness and myopia.

Policy interventions such as subsidy reform, carbon pricing, product efficiency standards, better information and behavioural "nudges" can significantly boost energy efficiency and, in particular, prevent inefficient energy models being locked into long-lived infrastructure.[83] Such interventions can also prevent lock-in of a high-carbon mix of fuels, in particular excessive use of coal. Section 3.1 above has explored the large health and economic benefits of curbing local air pollution from fossil fuel burning. The most effective way to reduce these damages is through corrective fuel taxes. A recent study by the International Monetary Fund (IMF) finds that fuel taxes would also raise substantial fiscal revenues that could be used to cut other distorting taxes, or to raise other development spending.[84]

Second, global energy supply technology is changing rapidly. Renewable energy has seen unexpectedly fast cost declines. These changes are overturning many previous assumptions about relative energy costs and broadening the set of cost-effective low-carbon energy options available to countries, as Chapter 4: Energy elaborates.

Developing countries need to re-evaluate traditional assumptions about the inevitability of fossil fuels and

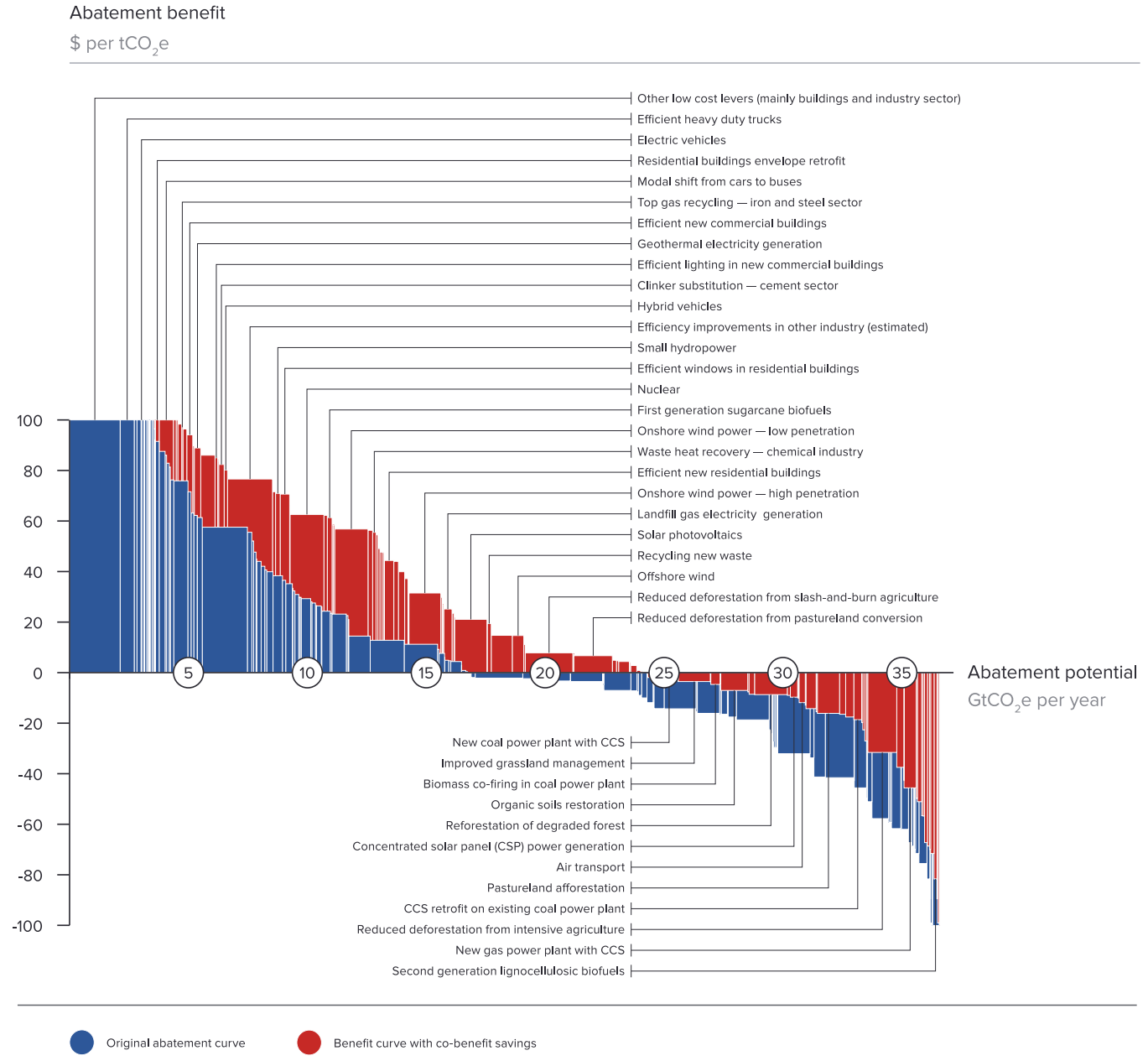
coal and to study the full range of options that are now becoming realistic. Middle-income countries that want to absorb new technologies and become technology leaders should avoid locking themselves into coal-based pathways. Broadly speaking, high-income OECD countries have been the pace-setters in exploring low-carbon paths, through research and development, deployment, and policy and institutional innovation. Innovation market failures mean that there is a clear rationale for a strong public sector role to support overall energy R&D and deployment. A major, expanded push on fundamental energy research, development and innovation should be a priority in all developed countries, both individually and through international cooperation.

3.4 Quantifying multiple benefits and emissions reduction potential from low-carbon actions

Analysis for the Commission has developed preliminary estimates of the value of multiple benefits likely to result from the reforms and investments discussed in this report. The analysis focuses on actions in the three key economic systems discussed in the preceding section: cities, land use and energy systems. Surveys of relevant technical literature were used to make monetary estimates of the multiple benefits per tonne of CO_2 abated.[85]

The focus is on multiple benefits from the following actions: reduced coal use, leading to lower local air

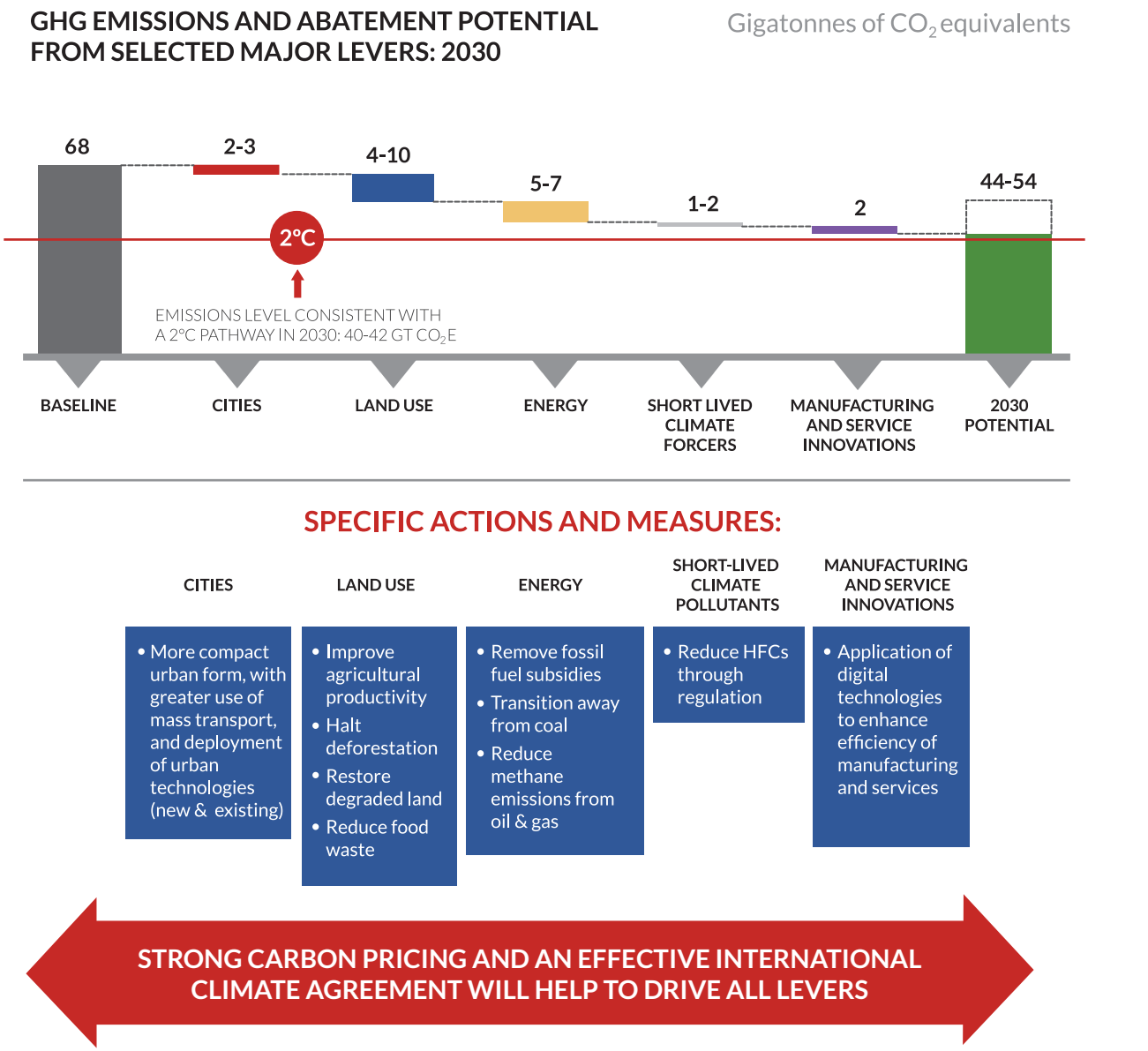
Figure 6
Marginal abatement benefits curve for 2030



New Climate Economy project analysis.[87]

Figure 7

Abatement potential of measures proposed in this report up to 2030



Source: New Climate Economy analysis.[90]

pollution and improved health; rural development arising from better land management and the restoration of forests and degraded land, linked with policies reducing emissions from deforestation and forest degradation (REDD+); reduced volatility of energy prices as a result of less reliance on fossil fuels; and reduced air pollution, avoided accidents and lower congestion due to shifts in transport modes, including greater use of bus rapid transit.

The results are illustrated with a version of the Marginal Abatement Cost Curve (MACC) developed by McKinsey & Company.[86] Each of the blue bars in Figure 6 shows the estimated incremental cost in 2030, relative to the high-carbon alternative, of abating an extra tonne of CO_2 through a specific technique or action, and the total technical abatement potential it offers. The incremental cost estimate per tonne in 2030 is based on the difference in operating and annualised capital costs between the low- and high-carbon alternatives, net of any potential savings associated with the shift to low carbon. The original McKinsey cost curve is inverted, so that methods with net benefits appear above the axis and those with net costs below, and the value of the multiple benefits is included where relevant. Thus, the chart becomes a "marginal abatement benefits curve". The red bars in Figure 6 show the additional co-benefit associated with

various abatement options, such as the health benefits from reduced local air pollution.

Figure 6 shows that many abatement options have a positive benefit even in narrow financial terms, which become substantially larger and more numerous once multiple benefits are included. A number of options with net costs swing to net gains when multiple benefits are taken into account, for example reduced deforestation, recycling of new waste or offshore wind. For energy efficiency options, the inclusion of multiple benefits could as much as triple their overall benefit.

This quantification of co-benefits is exploratory. On one hand, the coverage of co-benefits does not incorporate all possibilities, and, on the other, the proposed reforms do not include various potential programme and transaction costs. Nevertheless, this analysis clearly strengthens the case that countries have available a broad array of reform and investment options to improve the well-being of citizens while abating GHG emissions.

This analysis raises the question of the extent to which the actions discussed in this report would contribute to significant cuts in greenhouse gas emissions. As noted in Section 2.2, on current trends, with no climate action, GHG emissions could reach around 68 gigatonnes (Gt) by 2030, from around 50 Gt CO_2e today. While a number of emission pathways are consistent with limiting warming to below 2°C by 2100 with over 66% probability, a core scenario used in this report looks to reduce emissions to 42 Gt by 2030.[88] In other words, the world would have to cut GHG emissions by 26 Gt by 2030, compared with a baseline of no climate action. Further reductions would be needed after 2030, including negative emissions in the second half of the century.

Analysis for the Commission shows that the most significant measures and actions set out in this report relating to cities, land use and energy systems, plus specific forms of innovation in manufacturing and services, would yield some 14 Gt CO_2e of emission reductions. That is at least 50% of the median level of emissions reductions needed in the core 2°C scenario.

In the best circumstances, with early, broad and ambitious implementation, with rapid learning and sharing of best practice, these reforms and actions could achieve as much as 24 Gt of emissions reductions, or 90% of what is needed for a 2°C path.[89] That, in turn, would require decisive policy change and leadership, combined with strong international cooperation, particularly to support developing countries' efforts.

These actions would deliver multiple economic and social benefits. As a result, governments have good economic reasons to implement these actions even without accounting for their climate change benefits.

Calculations of this kind cannot be precise, which is why the figures come with a broad range. They depend on assumptions about what happens in the "base case" scenario, how far specific kinds of measures can be implemented and at what cost, the level of emissions they will generate, the underlying economic conditions (including growth rates and energy prices), and how rapidly technological changes may occur. They also depend on judgements of how the multiple economic benefits of these measures and actions should be valued. But with all these caveats, the figures do provide an indication of the scale of reductions potentially available.

On their own, these measures would likely not be enough to achieve the full emission reductions needed by 2030 to put the world on a 2°C path. The additional low-carbon measures needed would likely have net economic costs. For example, buildings will have to be more deeply retrofitted with energy efficiency measures than could be justified otherwise. Coal- and gas-fired power stations will have to be retired early, or fitted with carbon capture and storage (CCS) technology whose sole purpose is the reduction of GHGs. Industrial, agricultural and transport emissions will need stronger curbs. The likelihood that these more costly actions will also be required suggests that investment in research and development on key technologies such as CCS should be scaled up significantly today.

The low-carbon transition will not end in 2030. Deeper reductions will be required after that, to achieve near-zero or even net-negative emissions in the second half of the century. The measures in this report would nevertheless begin to put in place the institutions and policies – in terms of urban design, land use patterns, energy systems, environmental pricing and technological innovation – that would lay the foundation and create options for the more ambitious low-carbon policies and actions needed throughout this century.

4. Addressing growth and climate challenges in different country realities

The best approaches for dealing with development and climate challenges will depend on countries' vastly different realities and circumstances. Differences in levels of economic, human and institutional development, in social and political structures, in history, geography and natural endowments, profoundly shape the development and climate challenges that countries face, the capacities they can bring to bear, and the manner, timing and speed with which they can make progress on tackling these challenges. In this section we briefly consider the differing realities and challenges in low-, middle- and high-income countries.

4.1 Low-income countries

Low-income countries are characterised by high absolute poverty and low levels of human development and institutional capacity; limited industrial development; low access to energy; and a high reliance on foreign aid and concessional financing to support infrastructure investment and the public budget. As noted earlier, they account for negligible proportions of world energy consumption and GHG emissions.[91] Large fractions of the population are typically rural and derive their livelihoods from agriculture. Along with geographic issues that may expose them to more natural hazards, socio-economic conditions in these countries make them particularly vulnerable to climate risks.[92] The key challenge in these countries is to overcome poor governance and low institutional capacity, to spark rapid, widely shared and sustainable economic growth and poverty reduction.

Cities: Urbanisation is still in its early stages in low-income countries, with only 28% of the population living in cities, compared with 39% in lower-middle- and 60% in upper-middle-income countries.[93] Cities are growing rapidly, but still at an early stage of development. City authorities in low-income countries have a great opportunity to shape urban development in a desirable direction at relatively low cost, although they tend to lack the institutional capacity to use more sophisticated instruments of urban planning. Basic infrastructure choices can nevertheless fundamentally shape a city's character and footprint even at this stage; for example, they can ensure that scarce infrastructure resources go to smart choices such as bus rapid transit (BRT) rather than "business-as-usual" choices such as urban motorways (see Table 1).

Agriculture and land use, including forests, are much more important for people's livelihoods and well-being in low-income countries, and they are vulnerable to pressures of land and water scarcity, deforestation and soil degradation. Agricultural productivity will be more seriously reduced by climate change than in other countries, in part because of lower capabilities and investment in preparedness and infrastructure ranging from weather forecasting to irrigation.

In most cases, agriculture, forestry and land use are the biggest contributors to GHG emissions in these economies.[94] Carbon emissions related to energy are relatively unimportant because of limited industrial, power and transport development. Methane (CH_4) and nitrous oxide (N_2O) emissions related to livestock digestion and waste and various agricultural processes are far more important, as are carbon emissions related to deforestation, which is driven by expansion of agricultural lands, consumption of wood for cooking fuel and logging.

As Chapter 3: Land Use argues, there are substantial opportunities for low-income countries to intensify agriculture and to adopt "climate-smart" practices that can achieve "triple wins": higher farm incomes, increased resilience to climate change, and reduced GHG emissions

Table 1
Addressing growth and climate challenges in low-income countries

	Cities	Land use	Energy
Resource efficiency	Reduce incentives and hidden subsidies for embryonic urban sprawl in smaller towns	Reform tax and other policy distortions	Reform fossil fuel subsidies, with well-designed safety nets to protect the poor. Strengthen power sector management
Investment and finance	Use smart infrastructure such as mass transit to guide early-stage city development. Improve tax administration and public investment management	Strengthen rural credit and risk markets. Boost investment in rural infrastructure, including water management and agricultural logistics, together with forest protection	Boost concessional finance and domestic tax capacity to support rapid expansion of grid and distributed electricity capacity
Innovation		Strengthen property rights and extension services to speed diffusion of modern farming technology and practices	Support diffusion of distributed solar and other cost-effective new low-carbon technologies

(including greater carbon storage in soil, plants and trees).[95] From a policy perspective, this requires not a single technological solution, but rather a broad range of reforms and investments to promote better soil and water management, more efficient use of inputs, and the use of agroforestry techniques and other practices, and, more generally, to promote widespread diffusion and adoption of modern agronomic knowledge.

Reforms should improve incentives for farmers to adopt new technologies and practices, and tackle supply constraints that arise because of inadequate rural public goods and infrastructure. Reforms should strengthen farmers' property rights; boost rural credit and risk markets to increase adoption of new technologies by poor farmers; and increase rural extension services to provide better information and technical support. Public investments in rural transport and logistics infrastructure can vastly strengthen incentives by linking farmers to international markets and supply chains. The specific mix of reforms and investments will depend on the circumstances of the country. Ethiopia, for example, has adopted an "Agricultural Development Led Industrialisation Strategy". The country has also initiated a Climate Resilient Green Economy strategy, with measures to boost yields, improve soil management, curb agricultural GHG emissions and curb deforestation.

Energy: Ensuring modern energy access is a major development challenge in low-income countries. About 1.3 billion people or 26% of the population in developing countries still lack access to electricity. The International Energy Agency (IEA) defines modern energy access as "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time".[96] The thresholds for electricity access in this definition are low: 250 kilowatt-hours per year for rural households and 500 kWh/year for urban households; for comparison, the average US household uses about 11,000 kWh/year.[97]

Rapid expansion of public and private investment in power-generating capacity is key to improving energy access. Such scaled-up finance will come both from international sources – for example, concessional lending from development banks, and strengthened domestic taxation and financial capacity. Support for cost-effective, low-carbon energy sources will be an important part of long-term, external, concessional financing. Nevertheless, given the overriding priority for rapid growth and poverty reduction in these economies, there will undoubtedly be trade-offs between low-carbon and fossil fuel options. Given the relatively small size of low-income economies, a push to achieve minimum energy access levels in these countries would have a negligible impact on global CO_2 emissions.

In addition to efforts to scale up power generating capacity, demand-side, efficiency measures and opportunities will also play an important part in helping to satisfy energy needs in low-income countries – aided, for example, by reforms of fossil fuel subsidies.

Drivers of change: In addition to reforms in these three key systems – cities, land use and energy – it is also important to pursue broad, economy-wide reforms that can enhance or stimulate resource efficiency, infrastructure investment and innovation.

Regarding innovation, the rapid spread of mobile phones shows the potential for low-income countries to achieve widespread adoption and diffusion of appropriately adapted and priced new technologies. A similar rapid diffusion of appropriate new technologies should be encouraged in agriculture, energy, the digital economy and financial services, among others. Governments in low-income countries can facilitate rapid and continuous absorption of new technology by maintaining low barriers to foreign trade and investment, including through "South–South" interactions with middle-income countries which may have invested in adapting high-income technologies to developing country conditions. A business-friendly investment climate encourages local entrepreneurs to take on the risks of adapting imported technologies. Strengthening education broadly increases the capacity of the population to absorb new technologies. Financial support and technical assistance from foreign partners are also important.

Regarding investment, a key priority in low-income countries is building and strengthening the basic institutions of public financial management, such as tax administration, budgetary management and execution, accounting and auditing. There is an urgent need to improve public investment management capacity, given that there is little point in mobilising resources if new investments have poor returns because of mismanagement. External finance from multilateral development banks and other development partners for major infrastructure projects needs to be substantially expanded. This will also help encourage private capital flows.

4.2 Middle-income countries

Middle-income countries account for about 70% of the world population[98] and are at the heart of global development and climate challenges. Poverty is less widespread than in low-income countries, but still substantial, with 38% overall living on less than US$2 a day. Rapid growth and poverty reduction thus remain central development objectives, implying rapidly rising demand for energy services and, with it, continued GHG emissions growth.

Growth itself, however, is creating new pressures in middle-income countries. Industrialisation and urbanisation are generating substantial local air

Table 2
Addressing growth and climate challenges in middle-income countries

	Cities	Land use	Energy
Resource efficiency	Tax congestion and air pollution damage from auto use. Eliminate incentives for urban sprawl	Reduce subsidies that waste fertiliser, water and power; increase spending on key public goods	Reform fossil fuel subsidies; increase fuel taxes to reflect local pollution damages. Recycle tax revenues to boost development
Investment and finance	Secure major infrastructure savings by re-orienting spending to promote compact urban forms	Strengthen rural credit and risk markets; boost investment in rural infrastructure and logistics	Develop medium-term plans to peak coal consumption and boost investment in lower-carbon energy portfolios
Innovation	Develop strong, city-level governance to guide urban development	Strengthen domestic agricultural R&D, in particular to adapt modern agricultural technologies to local conditions	Boost domestic R&D to facilitate integration of low-carbon energy technologies; strengthen efficiency standards

pollution, congestion and other stresses. Expanding middle-class populations are becoming more vocal in demanding solutions to these problems. But these countries also have institutional advantages that differentiate them from low-income countries: more effective governance, more educated populations, more diverse economies and greater private-sector capacity, on average. Thus, they have a growing capacity to tackle complex and institutionally challenging economic and environmental reforms.

Cities: Middle-income countries are at the heart of a global urbanisation trend. The decisions that these cities make today about their size, shape, density, land use and infrastructure will effectively lock in – for better or worse – the potential pathways for economic prosperity, and emissions for decades and even centuries to come. For example, some 70–80% of the built infrastructure that India will have in 2050 is not yet built.[99] Already many middle-income countries are suffering the unintended costs of a "business-as-usual" model of urbanisation, at the heart of which are urban sprawl and conventional motorisation. These costs include lost productivity and innovation as a result of squandered agglomeration economies, as well as excessively costly transport infrastructure, air pollution and traffic congestion.

With their greater institutional strength, middle-income countries can adopt a variety of more sophisticated urban planning instruments. Strong city-level governance with financial autonomy, control, transparency and accountability is an important pre-requisite. Strong metropolitan authorities can deliver strategic infrastructure such as mass transit systems, for example, and can impose motor fuel taxes or congestion charges to help price the pollution and congestion damages caused by private vehicle use (see Table 2).

Industrialisation and urbanisation are generating substantial local air pollution, congestion and other stresses.

Agriculture and land use: Lower-middle-income countries, in particular, share many agricultural and land use characteristics with low-income countries. Around 70% of the population of India, for example, is still based in rural areas, with 50% relying on agriculture for their livelihoods.[100] As a result, these economies share the same problems of land and water scarcity and soil degradation as low-income countries. Many of the reforms to achieve so-called "triple wins" remain relevant here.

Given their greater institutional capacity, education levels and resources, however, middle-income countries also have the opportunity to undertake more ambitious initiatives – for example, to strengthen domestic agricultural innovation. Brazil's Agricultural Research Corporation (Embrapa)[101] has shown how a strong research and development (R&D) capability can boost the adaptation of foreign farm technologies to local conditions, for improving crop and livestock yields and

making better use of degraded lands. Sometimes the greater resources of middle-income countries are also put to wasteful uses, such as in agricultural input subsidies that cause excessive use of fertilisers, irrigation and electricity. Countries like China and India can improve resource productivity in agriculture by cutting input subsidies and using these savings to strengthen rural public goods including transport and other services.

Energy: Middle-income countries have been the driving force behind the sharp acceleration in global energy consumption and energy-related CO_2 emissions in the 2000s.[102] This acceleration has been driven by rapid economic growth and a greater share of coal in the fuel mix of these countries.

There are many self-interested reasons for middle-income countries to shift their energy strategies towards a greater focus on energy efficiency and low-carbon sources. Such a shift can avoid large health and economic damages from local air pollution and congestion, and growing energy insecurity as a result of rising net imports of coal and other fossil fuels. In China, air pollution has become so severe that the National Action Plan on Air Pollution in September 2013 banned construction of new conventional coal-fired power plants in major economic areas such as Beijing-Tianjin-Hebei (JingJinJi), the Yangtze River Delta and the Pearl River Delta, requiring them to sharply reduce coal consumption by 2017.[103]

The most efficient way to implement such reform is to eliminate fossil fuel subsidies and end the under-taxation of fossil fuels, to reflect local air pollution and other local damages, and recycle the resulting taxation revenues for poverty reduction and development. Recent estimates suggest that such corrective fuel taxes would generate revenues in the range of 6–8% of GDP in China and India, and cut pollution-related deaths in these countries by 50–70%.[104]

Institutional reforms and regulatory measures can also improve the adoption of energy efficiency. India's power transmission and distribution losses are around 20% of production, compared with 5–7% in the United States.[105] More ambitious standards to promote the uptake of existing low-cost energy-efficient products and technologies could reduce such losses and associated energy-related carbon emissions dramatically.

Countries can learn from one another. For example, the emergency measures to slash coal consumption in China could have significant economic adjustment costs. Other middle-income countries could take steps to prevent their economies becoming as coal-intensive in the first place, drawing on available policies and emerging low-carbon energy technologies.

Drivers of change: Middle-income countries have a much greater capacity to undertake innovation, compared with low-income countries, both in absorbing and adapting frontier technologies from abroad, and undertaking innovation themselves. This capacity can help middle-income countries adopt a more proactive approach to promote innovation and efficiency in key sectors such as electricity and energy, transport, buildings, manufacturing, agriculture, and the digital economy. The Republic of Korea provides a model example of a middle-income economy which was able to make a transition to high-income status through an unwavering focus on strengthening domestic human capital and technological capability.[106]

Middle-income countries can also access a deeper pool of resources to pursue development and climate challenges, as a result of their greater institutional capacity. They have more sophisticated systems of public finance, deeper domestic capital markets and engage more extensively in international private capital markets. Such institutional capacity is important to reshape domestic public finance, using environmental taxes to reduce labour and capital taxes and boost productive investment.

4.3 High-income countries

Developed economies are still struggling in the aftermath of the Great Recession. Five years after the crisis, unemployment and output gaps remain high. Medium- to longer-term problems loom, including the impact of ageing populations on public finances and growth, as well as problems of rising income inequality and climate change.

The challenge facing developed countries is to modernise public finance, enhance innovation and boost growth and employment in ways that accelerate progress on decarbonisation.

The challenge facing developed countries is to modernise public finance, enhance innovation and boost growth and employment in ways that accelerate progress on decarbonisation. The OECD argues that policies will need to focus on four key areas in the decades ahead: accelerating global integration; making institutions more resilient to shocks; curbing emissions; and exploiting a knowledge economy, which will be the main driver of global growth.[107]

Cities: In developed countries, the strategic focus is the re-densification and revitalisation of existing urban cores, alongside a shift from industry to services and innovation

in megacities and mid-sized cities. London, Brussels and Tokyo are examples of cities that are reversing urban sprawl and re-densifying. Strong, well-established city governments are important to drive adoption of more sophisticated high-tech infrastructure and energy-efficient buildings, and to use more sophisticated spatial planning and regulation instruments such as urban growth boundaries and maximum density standards. Sophisticated multimodal metropolitan transport authorities can be established, like "Transport for London",[108] which can drive productivity of the whole transport system through both pricing (e.g. congestion charging) and capacity allocation mechanisms (e.g. bus lanes, downtown parking capacity).

Agriculture and land use: Developed economies are at the forefront of agronomic research and development and innovation. Further public support should be provided for fundamental research and development, under a general high-income country strategy for economic revitalisation through increased innovation. Support should also be increased for multinational institutions and partnerships, such as the Consultative Group on International Agricultural Research (CGIAR),[109] among others, that specifically focus on agricultural innovation and dissemination targeted at developing countries. Forestry and land use in developed countries are now a net sink for CO_2 emissions, and this trend can be enhanced. The Republic of Korea provides an outstanding example of a country that has dramatically increased its forests, increasing from about one-third to two-thirds of its land area since the mid-1950s.[110]

Energy: High-income countries are the pace-setters in developing paths to a low-carbon future, both in research, development and innovation, and in policy and institutional innovation, including efforts at international coordination. A resolute push to introduce carbon pricing will yield multiple benefits, in terms of reduced local air pollution, as well as generate significant revenues that can play an important role in facilitating pro-growth fiscal reforms. A major push on fundamental energy research and development and innovation should also be a priority in developed countries both individually and through international cooperation. Institutional experimentation and learning from trial and error will also be crucial, especially around power system reform where more distributed generation technologies challenge traditional utility business models. Some developed countries are facing significant fiscal and other problems related to support for and integration of renewables. Careful study of lessons from these experiences and redesign of institutions as appropriate will be an important contribution in developed countries.

5. Conclusion: Why now?

Decision-makers will never have all the information they would want to make perfect decisions about the future. However, they do have three vital pieces of information that can guide their choices now.

First, the world is only halfway through its urbanisation journey. The next 15 years will hugely increase the footprint of urban infrastructure and shape the consumption patterns of about 1 billion new urban dwellers.[111] Choices over the pattern of urban development and associated energy and transport systems will shape how future societies function. These choices will also disproportionately affect the speed with which nations move from low- to middle-income status and from middle- to high-income status. The expected infrastructure investment of about US$90 trillion per year in cities, buildings, energy and transport systems over the next 15 years provides an unparalleled opportunity to build the world we want.

Second, deferring decisions for another decade will mean locking into high-carbon infrastructure. This will significantly increase the probability that future generations will have to contend with global warming of 4°C or more. Without immediate action, we will soon be committed to a minimum of 2°C warming, with adaptation costs likely to increase non-linearly beyond that point.

Third, many "no-regrets" opportunities exist to improve economic growth and climate risk performance together. Our economy is not operating at the "efficient frontier". Tackling multiple market failures and policy distortions will create both more growth and less climate risk, through integrated reform. Driving productivity in land use, by bringing degraded land back into production, meets the goals of increased rural incomes, greater food security and better climate risk management. The same is true for driving energy efficiency, cutting wasteful resource subsidies and tackling urban air pollution. Many of these opportunities are available with today's technologies, but need policies to encourage investment in better management systems and business models. We are just at the start of an innovation journey where advances in digitisation, energy technologies and biological and materials sciences can create new industries and reinvent old ones, generating new jobs while reducing greenhouse gas emissions.

There is also a crucial role for international cooperation on climate action. While this chapter and report stress opportunities for self-interested national action, it is well understood that – given the nature of the climate problem – countries working cooperatively will have incentives to accomplish a good deal more than the sum of uncooperative national actions.

Table 3
Addressing growth and climate challenges in high-income countries

	Cities	Land use	Energy
Resource efficiency	Congestion pricing and other fiscal reforms to remove subsidies for urban sprawl	Reform inefficient bioenergy policies; eliminate remaining input subsidies	Modernise public finance systems, drawing on carbon pricing to facilitate pro-growth tax reform.
Investment and finance	Infrastructure and systems investments to promote densification and revitalisation of urban cores	Scale market-based instruments for green infrastructure and ecosystem services	Develop short- and medium-term plans to peak coal consumption and boost investment in low-carbon energy; drive regulatory reform especially in the power sector
Innovation	Institutional innovation to strengthen city governance, including through greater digitisation. Multimodal transport authorities to promote mass transit. Deregulation to support new asset-sharing business models	Boost funding for international agricultural R&D, advanced bioenergy, and diffusion to developing countries	Boost fundamental energy R&D including "game changers"; create market-pull mechanisms; strengthen public-private risk-sharing partnerships (e.g. for CCS) including IPR models

As Chapter 8: International Cooperation argues, future cooperation will benefit from an approach that promotes development while helping countries to steadily move away from carbon dependence onto low-carbon trajectories. Such an approach would focus on agreed common norms and standards, and developing institutions that promote investment, trade, technology and expertise to support decarbonisation, both from richer to poorer countries, and among developed and developing countries. The Commission recognises that international cooperation is required not only for a transition to a low-carbon economy that is dynamically efficient, but also for one that is just.

Building the new climate economy will not be an easy journey. It is certainly not the "path of least resistance", and will require constant adjustment of policies, economic structures and institutions. But it is our opportunity to choose and shape a better economy, where equitable growth and a safer climate are not in opposition. This report also highlights actions that create flexibility and increase countries' options in an uncertain future through 2030 and beyond. The Commission is well aware that the transition to an economy which delivers better growth and climate performance is a 30- to 50-year journey. It is also a journey on which path dependencies mean that steps taken over the next 5–15 years may prove to be disproportionately important.

As finance ministries, central banks and the world's leading companies know, good growth and good risk management go together. Growth that takes no account of climate risk is unlikely to be sustainable for investors who know that their future assets could be adversely affected. Climate risk reduction that comes at the expense of growth or that hurts poor households will never be politically sustainable. The trick, and central purpose of this report, is to learn how to put the two sides of the equation together.

Endnotes

1 World GDP in 2012 was US$73.3 trillion, up from US$36.3 trillion in 1990, in constant 2005 international dollars, purchasing power parity (PPP).

See: The World Bank, 2014. World Development Indicators 2014. 11 April 2014 release. (An updated release, not including constant 2005 international $ PPP figures, is available at http://data.worldbank.org/data-catalog/world-development-indicators.)

2 The World Bank, 2014. World Development Indicators 2014. Data cited are for GDP (constant 2005 international $ PPP), 1990–2012. In 1990, middle-income countries' share of global GDP was 27%; in 2012 it was 42%. Share of global GDP calculated by the authors.

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Specifically, the estimates are that actions with multiple economic benefits to improve transport and building efficiency in cities could deliver 2–3 Gt CO_2e. In land use, a combination of forest protection, restoration of degraded landscapes for forestry and agricultural purposes, improved yields and lower food waste could deliver 4–10 Gt CO_2e. In the energy system, phasing out fossil fuel subsidies, combined with cost-effective reductions in coal use and more effective measures to tackle methane emissions, could deliver 5–7 Gt CO_2e. Phasing out of hydroflurocarbons (HFCs), chemicals used largely for refrigeration and air-conditioning, could deliver the equivalent of a further 1–2 Gt CO_2e. Finally, innovations in the manufacturing and services sectors could generate a further 2 billion tonnes.

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