



## Main points

- Maintaining or strengthening economic growth to 2030 will require a significant increase in investment, including an estimated cumulative US\$89 trillion of investment in infrastructure. A shift to low-carbon infrastructure will have an additional impact, changing both the timing and mix of infrastructure investment. A low-carbon transition across the entire economy could be achieved with only 5% more upfront investment from 2015-2030.
- From a broader financial perspective, the global economy could create value from the transition to low-carbon energy. Low-carbon infrastructure has significantly lower operating expenses and a longer expected lifespan than fossil fuel assets. Low-carbon infrastructure also has the potential to achieve lower costs of capital.
- We estimate that the full investment impact of a low-carbon transition in the electricity sector would be a net financial benefit of up to US\$1.8 trillion over the period 2015-2035. This accounts for all investment impacts including stranded asset costs, and refers to a transition to a 2°C scenario from “business as usual”.
- A global low-carbon transition will lead to a decline in value of some fossil fuel assets, or “stranding”. Clear policy signals can reduce this value destruction by discouraging new investment in fossil fuels that would be at risk of stranding.
- The potential stranding of investment in the coal sector is less than for oil and gas, because coal produces less economic value per tonne of CO<sub>2</sub> emitted, and there is comparatively less sunk investment in coal production, including coal-fired power plants. Over the next 20 years, reducing the use of coal can achieve 80% of the required energy-sector emissions reductions at only 12% of the total potential stranded asset cost, supporting a focus on coal in climate policy.
- There is sufficient capital available to finance a low-carbon transition. Accessing this capital will require the right long-term policies, however, including carbon pricing and regulation. Significant, near-term opportunities can reduce the costs of finance by up to 20% for low-carbon energy in all countries through a mix of financial innovation, greater use of national development banks and concessional debt, and increased development capital flows into low-income countries.

## 1. Introduction

Transitioning from a high-carbon to a low-carbon economy will require significant investment by all sectors of society. Industries, land owners and households will invest to improve efficiency. Energy producers will invest in low-carbon generation. Additionally, governments will invest in infrastructure to protect their nations against the long-term effects of climate change and to knit all of this new investment into a well-functioning, low-carbon economy.

Governments will play a dual role. First, they will invest directly in infrastructure to ensure an ordered transition to a well-functioning, low-carbon economy. Second, they will influence the direction of private finance through regulation, incentives and other policy measures. This chapter touches on both forms of government action, but focuses on the role of governments in shaping and motivating private finance.

Much of the needed investment in low-carbon infrastructure can be handled through existing structures and mechanisms, with the help of effective policy, regulation and market signals. Energy efficiency is an example where value is already created within the existing commercial environment for consumers and businesses, providing cash flows that can make these investments attractive.

Other investment requirements will need more intervention. In these cases, creating new, efficient finance structures and directing finance into these new industries becomes more challenging and may require dedicated policy to initiate and continue the transition. Energy supply is an important example, as the energy sector accounts for around two-thirds of global greenhouse gas emissions. A low-carbon transition in energy supply requires the highest near-term financing, and some of the most significant changes in financial and industry structures.

The good news is that between public and private sources, there is sufficient capital available globally to finance an energy transition. Many new industries and market structures are already emerging in both the developed and developing world. However, current industry and financial structures often allocate capital inefficiently, with risk, reward and geographic preferences that do not match well with an effective low-carbon energy transition. Some investors express concern that the transition will be unaffordable or will require capital that is not available. Others fear coal, oil and natural gas assets will suffer. The Commission has taken these concerns seriously and recognises that innovation in the financial sector will be as critical to the transition as innovation in the urban, land use and energy sectors.

This chapter focuses on financing in the energy sector, given risk-return characteristics which are likely to see the

most significant changes over the next decade. It begins by presenting estimates of the overall need for infrastructure investment between 2015 and 2030. Next, it discusses how to develop financing instruments and models which significantly cut the cost of investing in low-carbon energy assets, separately for high-income, middle-income, and low-income countries. Then it presents the likely additional investment and financial costs of an overall system shift to a low-carbon model that reduces the risk of dangerous climate change. Finally, it outlines how governments and private investors can minimise the risk of destroying the economic value, or “stranding”, of fossil assets during the transition.

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The chapter should not be viewed in isolation from the rest of the report. The focus here is the transition to a low-carbon energy system, with particular emphasis on investment in renewable energy. There are many other aspects of the low-carbon financing agenda which are touched upon throughout the report as a whole. Chapter 2: Cities describes some of the key instruments that will be needed to strengthen capital mobilisation at the city level, for investment in smarter infrastructure. Chapter 3: Land Use describes the forms of finance that will be needed to support tropical forest protection in the context of measures to increase overall capital mobilisation in developing country agriculture. Chapter 4: Energy addresses the challenge of mobilising capital for the more than one billion people who lack access to modern energy services. Chapter 5: Economics of Change considers the institutional and policy frameworks for mobilising the necessary capital. Chapter 7: Innovation more specifically addresses the funding of research and development and the early-stage, low-carbon innovation pipeline.

## 2. Overall infrastructure financing requirements

### 2.1 Infrastructure investment and global growth

The global economy will require substantial investments in infrastructure as the population and the middle class grow. An estimated US\$89 trillion of infrastructure investment will be required through 2030, based on data from the International Energy Agency (IEA), the Organisation for Economic Co-operation and Development (OECD), and analysis for the Commission (see Figure 1). This is chiefly investment in energy and cities. This estimate for the

required investment is before accounting for actions to combat climate change.

A significant shift in the composition of these infrastructure investments will be needed to move to a pathway consistent with a good chance of keeping global average warming below 2°C. This includes increased investments in energy efficiency, and the deployment of low-carbon technologies. Improvement in efficiency of energy end-use sectors such as buildings, industry and transport could alone account for an additional US\$8.8 trillion of incremental investment according to the analysis presented here (see Figure 1). Investment for the deployment of low-carbon technologies including renewables, nuclear and carbon capture and storage (CCS) could lead to an additional investment of US\$4.7 trillion.

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***Overall, the net incremental infrastructure investment needs from a low-carbon transition could be just US\$4.1 trillion, if these investments are done well.***

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At the same time, however, a low-carbon scenario could potentially also lead to savings in several components of infrastructure investment. Savings of US\$2 trillion to 2030 are estimated from reduced investment in fossil fuel power plants in a low-carbon scenario. Reduced demand for fossil fuels could potentially also lead to further savings of US\$3.7 trillion along the supply chain of fossil fuels. This includes reduced investment in the exploration and transport of fossil fuels.

Another source of savings could be from reduced investment in electricity transmission and distribution, by an estimated US\$0.3 trillion, as a result of greater energy efficiency and thus less demand for energy. The IEA projects that the savings from energy efficiency will outweigh the additional investment in the electricity grid needed to integrate intermittent renewable energy sources. Finally, the construction of more compact, connected cities, in an effort to reduce emissions, pollution and congestion and to rejuvenate the urban core, has the potential to reduce the overall infrastructure requirement for roads, telecommunications, water and waste treatment. Our estimates suggest that these savings could be worth cumulatively up to US\$3.4 trillion by 2030. Figure 1 understates the scale of the transition that would occur in such an economic transformation, as investments shift from higher- to lower-carbon.

Overall, the net incremental infrastructure investment needs from a low-carbon transition could be just US\$4.1

trillion, if these investments are done well. In this case, the infrastructure capital spent in a low-carbon economy would be 5% higher compared to a business-as-usual scenario of high-carbon growth. Given the additional infrastructure investments that would likely be needed under business as usual, to adapt to the impacts of climate change which are not included here, it is possible that investments in infrastructure in a low-carbon economy may be about the same as those in a high-carbon one. Other studies have suggested that, if done well, investment in low-carbon infrastructure could be even lower, given some of the potential synergies in fuel and infrastructure savings, for example in cities, indicated above.<sup>1</sup>

Financial considerations other than upfront investment, such as lower operational expenditures from low-carbon energy, were not included in this comparison exercise. Including them would make the low-carbon scenario even more favourable in terms of overall costs, leading to net savings of US\$1 trillion. Section 4 of this chapter provides an in-depth consideration of wider financial impacts of a low-carbon transition in the energy sector.

Given the uncertainties in projecting out to the future, these estimates are directional estimates, designed to provide orders of magnitude rather than precise figures. In addition, not all relevant infrastructure components and financial aspects were included in the comparison of the two scenarios. For example, the total investment needs for building infrastructure are not included in Figure 1, although the incremental costs of increased energy efficiency in buildings are reflected in the low-carbon scenario. Global construction spending on buildings in 2010 has been estimated to be on the order of US\$5.4 trillion (in constant 2005 US\$).<sup>2</sup>

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***Including full, longer-term impacts on investment under a low-carbon transition make such an outcome even more favourable, leading to net savings of US\$1 trillion.***

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## 2.2 Financing a low-carbon energy transition

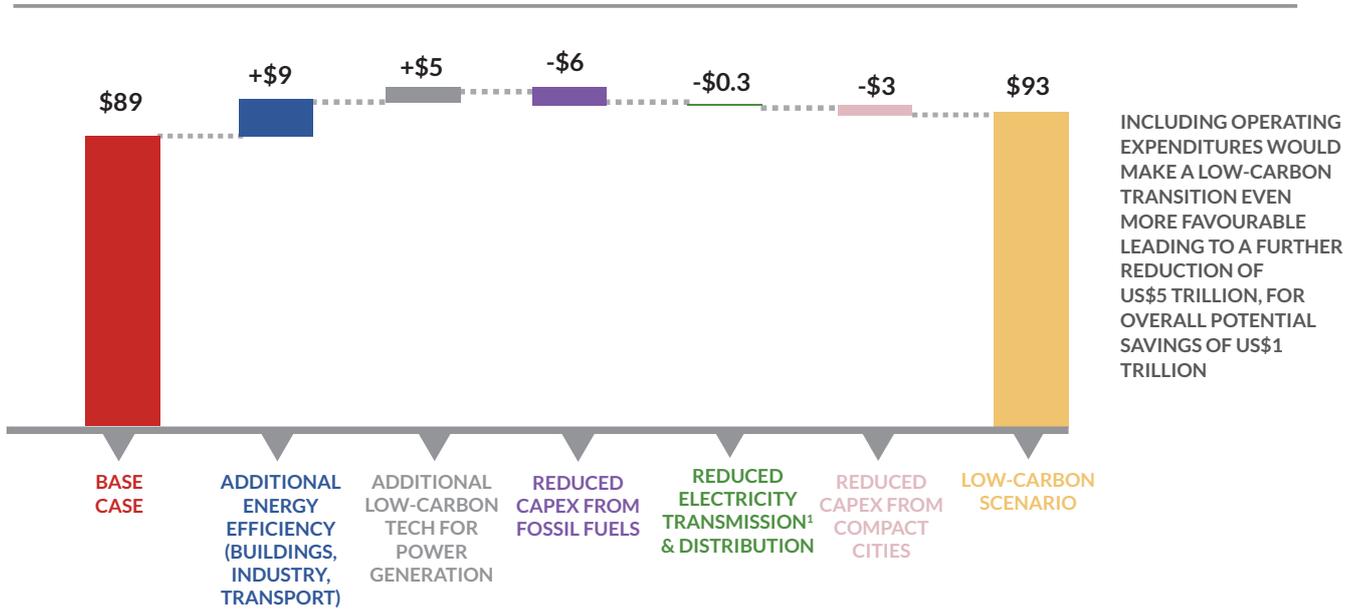
The energy sector is the backbone of the global economy. Investment in energy and related infrastructure will be important to support economic growth, whether or not nations transition to low-carbon economies. From a climate change perspective, the sector acquires even more importance, because reducing greenhouse gas emissions from the energy sector is crucial to reducing the risk of dangerous climate change. Energy supply and consumption represent approximately two-thirds of global greenhouse gas emissions.<sup>4</sup>

Figure 1

**Infrastructure capital spend is 1% lower in a low-carbon scenario**

**GLOBAL INVESTMENT REQUIREMENTS, 2015 TO 2030, US\$ TRILLION, CONSTANT 2010 DOLLARS**

Indicative figures only  
High rates of uncertainty



NOTE: For further details, see the *New Climate Economy Technical Note, Infrastructure investment needs of a low-carbon scenario*, to be available at: <http://newclimateeconomy.report>. [forthcoming].

Net electricity transmission and distribution costs are decreased due to higher energy efficiency lowering overall energy demand compared to base case. This efficiency effect outweighs the increased investment for renewables integration.

SOURCE: Climate Policy Institute and New Climate Economy analysis based on data from IEA, 2012, and OECD, 2006, 2012.

However, the transition to low carbon need not add substantially to the required energy investment. One way to illustrate the scale of the task to shift to a low-carbon energy economy is to measure investment as a proportion of fixed capital formation. The latter is a proxy for total investment across the economy.<sup>5</sup> IEA estimates of infrastructure investment suggest that a transition to a low-carbon economy would increase global energy investment from 9% to 12% of fixed capital formation.<sup>6</sup> Alternatively, this can be viewed as a shift in investment equivalent to less than 0.5% of gross domestic product (GDP), arguably a small shift given the scale of the risk and challenge at hand.

### 3. Financing the electricity sector over the next five to 10 years

#### 3.1 Power generation infrastructure

Since the beginning of the 20th century, electricity financing has been characterised by the need to create scale and efficiency. Large-scale capital was provided by the public sector or through investors in regulated companies under a de facto government guarantee. As the industry grew, the quest for the lower costs that scale could deliver led to large, integrated, monopoly providers. These integrated utilities capitalised on lower costs achieved through scale across a network that connected generation, transmission, distribution and end users, relying on whatever was the cheapest energy source – fossil fuels or hydropower – available in their region.

A revolution in electricity system design began in the 1970s, '80s and '90s, as governments and regulators saw the benefits of scale begin to taper off, and sought to increase innovation and flexibility and reduce the inefficiencies of what had become a large and monolithic

sector. In 1978, the US Public Utility Regulatory Policy Act (PURPA) sought to promote energy efficiency and bring in non-utility generators and cogeneration in response to the oil crisis.

Over the following years, many countries and regions developed independent power producers (IPPs), competitive short-term energy markets, privatisation, innovative regulatory systems and innovative risk sharing and financing schemes to enhance incentives for generators and utilities to improve efficiency and lower costs. New generators appeared, in some cases costs fell, and new investors entered the market and corporate structures shifted, sometimes beyond recognition. However, whether governments chose to introduce competition or remain mostly regulated, in most regions both the market and operating systems were, and are, still largely based around large-scale, mainly fossil fuel-powered, generation.

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#### *Finance for low-carbon energy continues to evolve*

Within the electricity system transition, more can be done in all countries to increase low-carbon investment. There are several areas with potentially large investment requirements, but in the near-term, each of these have very different policy and financing needs:

- **Energy efficiency:** Improving the efficiency of energy use and production is an important element of nearly every plan to achieve a low-carbon system. According to estimates outlined in Figure 1, achieving a 2°C pathway will require US\$8.8 trillion in incremental investment in energy efficiency between 2015 and 2030, in areas like buildings, energy-intensive industry and transport. Financial incentives and loan programmes can be useful as a policy tool to accelerate investment in energy efficiency (see Box 3). However, the lack or high cost of finance are not the only impediments to most efficiency improvements. Demand for energy efficiency is constrained by other factors, including lack of information, transaction costs, agency problems, mispricing and a host of other barriers discussed in the energy efficiency literature. Energy efficiency investments also tend to be intimately wrapped into the operations of a business or household, and therefore are often difficult to finance independently of financing to the household or business in question.
- **Carbon capture and storage (CCS):** Removing the CO<sub>2</sub> from the exhaust gases of fossil fuel fired power plants can be an important strategy for reducing greenhouse gas emissions from the power sector. As discussed in Chapter 4: Energy, there were 21 large-scale CCS projects in operation or under construction around the world as of February 2014. However, since the technology is currently more expensive than other technologies examined here, the financing policy challenges are not explored in this chapter. For the purposes of the next 5–10 years, financing of CCS is likely to be dependent upon research and public support schemes and therefore more of an issue for innovation, energy and climate policy than financing policy.
- **Nuclear energy:** Like CCS, nuclear energy development will likely depend on public support mechanisms in many countries. In addition, however, nuclear energy could benefit substantially from many of the financing and industry structure arrangements to be discussed below with respect to renewable energy.
- **Transmission and distribution:** As natural monopolies, transmission and distribution is generally owned and operated by regulated or government-owned companies. While the specific assets requiring investment, and even the business models employed, may shift substantially in a low-carbon transition, total investment will be slightly less than under a business-as-usual scenario. For instance, increased investment to connect new renewable sources will be offset by the impact of energy efficiency and distributed generation in reducing demand for centrally generated electricity. Thus, with appropriate system policy and design, current financing arrangements could work adequately for the near-term transition.
- **Other associated infrastructure, including energy storage, information technology and advanced metering:** The transition will require continued innovation across several technology areas, particularly on the demand side. In the near term, these are areas for continued innovation, as briefly discussed in Chapter 7: Innovation.
- **Maintaining conventional generation during the transition:** In many countries, the transition will involve phasing out the building of new coal- and gas-fired generation, and could reduce life extensions for many existing plants. Nevertheless, conventional generation will be needed for many years to support the transition: to provide ongoing energy to meet

the demands of the economy; balance variable renewable power; and reduce the overall economic cost of a transition. In developing economies, some new conventional generation will be needed alongside low-carbon generation to support continued rapid economic growth. Thus, while investment needs for fossil fuel generation will decline, there will still be a need to ensure that this generation is financially viable. In developed countries, new capacity markets can value the flexibility and support that conventional generation offers, making these assets viable even at reduced output levels.<sup>7</sup> Further consideration will need to be given to the integrated utilities that may lose value in the transition, and find it difficult to support the required growth in transmission or distribution businesses.

The main, near-term financing concern lies in the growth of renewable energy investment and, to a lesser extent, nuclear energy. While costs were relatively high and falling, it made sense to finance and operate renewable energy sources, such as wind and solar, through existing corporate and financial structures, minimising industry disruption while concentrating on cost reduction and initial deployment. Today in some markets, the average cost of energy from many renewable energy sources is approaching that of new conventional generation, when

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levelised over the life of a new energy project, as detailed in Chapter 4: Energy. In some cases, the cost of renewable energy is lower than for conventional generation. With lower costs, a faster, larger scale roll out is more feasible and attractive, but the arrangements that helped when deployment was relatively small are inefficient at a larger scale.

The principal challenge many countries now face in financing low-carbon energy is therefore to reduce the cost of investment in low-carbon energy assets, and to identify mismatches between investor and finance needs. Solutions to these challenges are discussed in the following section.

### 3.2 New finance approaches for high-income countries

The utility companies and independent power producers that currently build and finance most power plants in high-income countries have developed their corporate and finance structures around fossil fuel generation. These structures are inappropriate for renewable energy for a number of reasons:

- Renewable energy has no intrinsic fuel price risk as fossil fuels do. In current markets wholesale electricity prices fluctuate with fossil fuel prices. This imposes fossil fuel price risk on renewable energy either directly through wholesale power markets, or more often through the investment return requirements of regulated or unregulated power producers whose business models are built on earning a premium to manage these risks. Fossil fuel price uncertainty thus raises risk, uncertainty and finance costs;
- Variable renewable energy such as wind power is not dispatchable (its quantity and timing cannot be easily controlled), but utilities must ensure reliability of the electric grid, and in competitive electricity markets will expect a premium to manage this variability. Such a premium translates into higher costs associated with renewable energy generation;
- The initial investment is a higher proportion of total costs for renewable energy than fossil fuel energy, making the finance costs that spread these initial costs over the life of the renewable energy plant much more important.

Many of these differences can be, and are, handled through policy. Feed-in tariffs (FiTs) or fixed price power purchase agreements (PPAs) can eliminate the price risk that would be experienced by a renewable provider attempting to sell renewable generation on wholesale electricity markets. Where these PPAs offer longer-term price guarantees – often up to 15 to 20 years or more – renewable energy projects can attract longer-term debt finance, which reduces the expected lifetime average finance costs for a project. Under current financing arrangements, extending the duration of a PPA by 10 years (say from 10 to 20 years) alone could reduce the average electricity generation costs over the lifetime of typical wind and solar projects by 11–15%, while employing a FiT rather than a premium to wholesale prices can reduce costs by 4–11%.<sup>8</sup> As the cost of renewable energy approaches that of market prices, the benefits of these policies will fall slightly, but the benefits in reducing risks remain.

There is, however, another impact of policy on financing. Uncertain or changing policy can raise risk perceptions and increase borrowing costs or even make it impossible

to borrow against a project without some sort of explicit or de facto government guarantee. Without debt, the cost of finance can increase markedly.

***New business models can attract long-term investors, reducing renewable energy costs by up to 20%.***

The following analysis of the impact of policy on financing costs assumes that projects are financed with the current industry structure and common project development arrangements. Typically, these projects are developed and owned by independent power producers and investor-owned utilities, and often use project finance to enhance returns to levels consistent with their business models. Investors in utility company shares expect certain levels of returns from their equity investments. Under current business and investment models, renewable energy returns have to rise to these expectations to make these investments attractive to utilities and to make utility shares attractive to the financial markets.

However, the key to optimising finance for any investment is to match the investment and the related regulatory and corporate structure with the investment pool that is most closely aligned with the financial characteristics of the investment. From this perspective, renewable energy is more similar to long-term infrastructure investments than fossil fuel investments, making renewable energy, if properly structured, particularly well-suited to three sets of investors:

- **Institutional investors**, like pension funds, seeking to match defined cash flow needs over a long period of time to service liabilities such as pensions and life insurance policies;
- **Municipalities** and other local and regional agencies, seeking to provide long-term infrastructure for themselves and their residents and companies;
- **Energy users** seeking long-term price certainty for energy, or a hedge against volatile energy costs.

As shown in Figure 2, solutions tailored to the investment needs of these types of investors could reduce the cost of renewable energy by up to 20%.

Once development and construction is finished, renewable energy projects are relatively simple investments. There are no fuel costs to manage, operating costs are relatively low, output is fixed by wind or solar conditions, and revenues are also fixed, assuming a fixed, long-term price contract or feed-in tariff. As simple investments, these projects remain attractive investments even when returns are low, and with the right structural changes they can remain attractive at lower returns still.

Utilities and IPPs have used project finance – where a stand-alone project company is formed that owns only the renewable energy project – to increase returns to

levels more in line with what their shareholders expect from utility investments. Project finance increases returns by allowing the owner to borrow more money directly against the asset, without otherwise affecting the company's finances. By borrowing more, project owners get their cash back earlier and thus enhance their returns. However, project finance can be expensive to arrange and banks charge higher interest on loans to project companies, thus increasing the cost of finance.

Policies can encourage the use of project finance despite its lower efficiency. For example, in the United States, tax credits used to incentivise renewable energy are often worth more with project finance, because they are realised earlier. Project finance can be used to transfer these credits to banks or other companies with immediate tax obligations to offset, thereby shortening the period over which tax credits are received by as much as several years. However, arranging the project finance and providing an

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***If the market for longer-tenor debt were to dry up completely, the cost of renewable energy could increase by 16% or more.***

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incentive for the investor with the “tax appetite” can be costly and inefficient. As a result, the use of tax credits can end up costing the government more than other types of policies.<sup>9</sup>

The financial crisis has made project finance less attractive. Longer-term loans are riskier for banks in general, and one response to the financial crisis has been to shorten the tenor of loans that they offer – that is, how long the loan lasts – in order to manage their own risks, and in anticipation of regulatory requirements under Basel III and Capital Requirements Directive (CRD IV). With shorter-term loans, project owners need to set aside more cash each year to pay the debt principal. The result is that the average debt over the project life goes down, and higher tariffs are needed to make projects attractive to developers. If the market for longer-tenor debt were to dry up completely, the cost of renewable energy could increase by 16% or more.<sup>10</sup>

Some utilities have responded by financing renewable energy on their balance sheets – that is, by borrowing against the entire company rather than just a specific project. Companies have lower debt costs than projects, since lenders have more assets to recover in case of default, and thus face lower risks. The lower debt cost would reduce the renewable energy costs by 6% for a well-financed utility. For many utilities, however, large renewable energy portfolios still offer lower returns than other investments, consume investment capital while

Figure 2

## New finance models could reduce renewable energy costs by up to 20%

### LEVELISED COST OF ENERGY UNDER DIFFERENT FINANCIAL STRUCTURES

TYPICAL WIND PROJECT 2013

#### 1. Typical Project Finance – Base Case

Most Wind Power is project financed with 12-20 year bank debt at interest rates 2% or more higher than corporate bonds

#### 2. Impacts of Financial Crisis

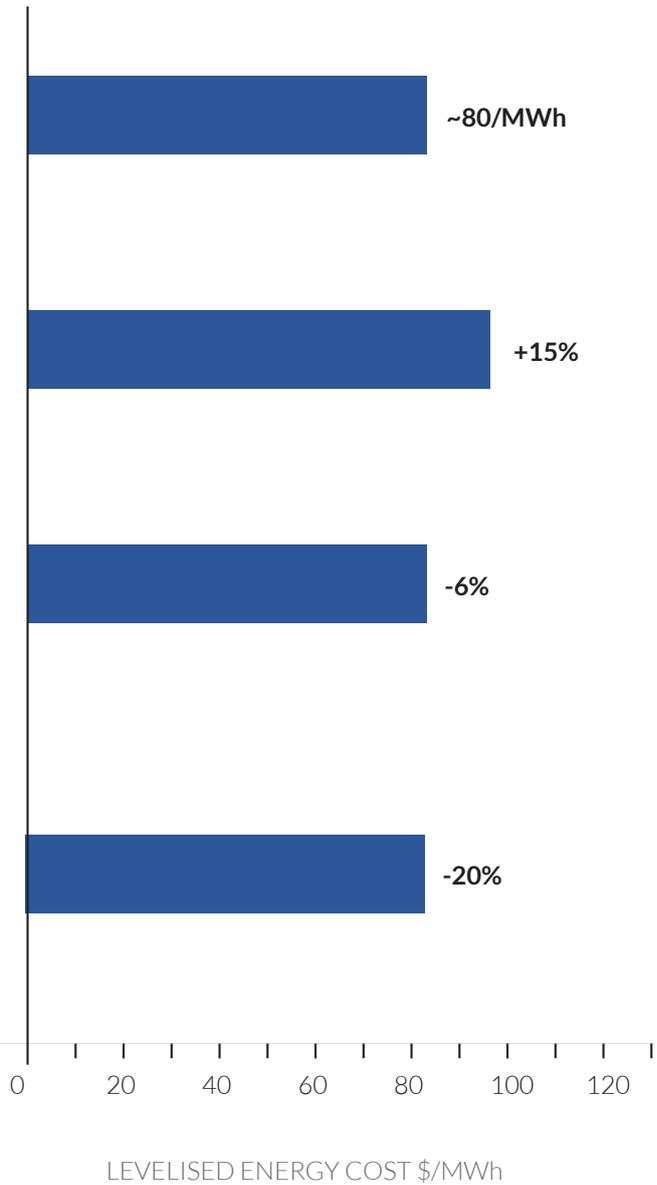
Some banks are reducing the time period over which they lend to reduce their own risk, limiting debt to 7 years raises lifetime energy cost 15%

#### 3. Utility Corporate Finance

Utilities can reduce renewable financing costs by using corporate debt and equity, but this reduces project leverage and offers lower returns than other corporate investments

#### 4. New Investment Model

Properly structured, a portfolio of renewable energy projects could attract corporate bond type investors for a large share of the investment lowering debt and equality costs, increasing leverage and accessing large pools of capital



Source: Climate Policy Initiative modelling, based on interviews with developers and investors and Standard & Poor's; company reports.

producing little growth, and thus make the companies less attractive to investors. That is notwithstanding the fact that the very best renewable energy projects, including many wind projects in Texas and Midwestern US, have very good wind conditions that can make projects competitive over their lifetime. An additional, emerging problem with utility financing in Europe is that these companies are seeing falling revenues and profits, and

many can no longer support additional debt.

The essential problem is that renewable energy investments have financial characteristics that are more akin to corporate bonds than the typical utility investment. A utility would make no money borrowing at a bond rate just to invest in another bond with the same return. Packaged appropriately, in structures that look like bonds rather than utility company shares, and then selling the

assets directly to bond investors could significantly reduce the cost of financing renewable energy.

Another issue is that many current renewable projects investments are relatively “illiquid”. That is, investors tie up their money in the investment and cannot easily sell the assets if their circumstances, or those of the market, change, or can only do so with substantial transaction costs or loss of value. Illiquidity imposes a significant cost on institutional investors, if it makes them unable to react to new investment opportunities that may arise in the market. They may have to retain extra investment in secure, very liquid, but low-return investments such as government treasury bonds.

Appropriate structures that provide both direct access to the bond-like risk reward profiles of renewable energy projects and some liquidity are already beginning to emerge, including “YieldCos” (described in Box 2). These new investment vehicles are tailored to the investment

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*The Climate Bonds Initiative and HSBC reported US\$11 billion in green bonds were issued in 2013 – a marginal portion of the total global bond market, but one that is growing rapidly.*

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needs of long-term, institutional investors, such as pension funds and insurance companies. They focus exclusively on owning and operating portfolios of renewable assets that are largely free of fuel, market, and technology risks, providing investors with steady, predictable revenues over 15 to 20 years, while creating an opportunity to sell the investment should the need arise. Based on interviews with long-term investors and rating agencies, the analysis for the Commission suggests that such low-risk structures could attract equity investment at costs 2% per year lower than traditional utilities, and could support more debt on their balance sheets. Alternatively, institutional investors could buy the YieldCos without debt as direct replacements for corporate bonds, essentially earning corporate bond rates for the entire investment. Renewable energy investments are more capital-intensive than fossil fuel power generation, and so are highly sensitive to the cost of capital. Financial modelling of typical wind and solar projects in the US and Europe shows that renewable energy-specific business models could reduce the cost of renewable energy by up to 20%.<sup>11</sup>

Other approaches, such as securitisation of loans to renewable energy and covered bonds rely on standardisation and pooling for diversification and aggregation. These can also be appealing to institutional

investors, which require large transactions and low transaction fees, high credit ratings, sufficient transaction data to assess risk and return, liquidity, benchmarks, and a defined asset category in which to invest. Institutional investors are also primarily interested in providing long-term debt investments that match their liabilities.

Green bonds (described in Box 2) could be a promising vehicle for institutional investors if renewable energy projects can be standardised and securitised. The Climate Bonds Initiative and HSBC reported US\$11 billion in green bonds were issued in 2013 – a marginal portion of the total global bond market, but one that is growing rapidly.<sup>12</sup> Institutional investors are very comfortable with bond investments. If green bonds can be used to finance renewable energy projects in a manner that delivers liquidity and high credit ratings (e.g. through pooling, credit enhancement and securitisation) this may be a promising path for increased institutional investment in renewable energy.

### *Creating national infrastructure banks*

Although the sophisticated financial systems of developed economies can cultivate innovative solutions to financing problems, they need an investment case to do so. The unfamiliarity and risks of new financial products can prevent their development, but, once the market is established, risks fall and financial actors join the market. In this context, national infrastructure banks can develop credible markets that will eventually bring in private capital.

For renewable energy and energy efficiency, there are a number of markets that a government infrastructure bank could help develop. These include:

- **Creating appropriately designed YieldCos:** Although YieldCos, as discussed above, are gradually entering the market, their design is not perfectly aligned with institutional investor needs. A government infrastructure bank could take on this role and develop the new, appropriately designed, asset class.
- **Lending to small-scale distributed generation and energy efficiency projects:** Infrastructure banks could extend loans to de-centralised, customer-generated electricity and energy efficiency projects with marginal credit risks, creating business opportunities both for the private sector and low-carbon investment. Examples of these programmes are discussed in Box 3.
- **Financing infrastructure that needs scale for rollout:** As an example, an infrastructure bank could lead investment in electric vehicle (EV) charging infrastructure, an investment that is difficult for individual actors to make due to scale up and timing issues, but one with significant public benefits. The

## Box 1

## How business models and financial regulations create barriers to scaling up low-carbon infrastructure

Current investor business models, accounting rules and investment restrictions established by financial supervisory bodies, may discourage institutional investors from investing in infrastructure and other “illiquid” asset classes. The motive of such rules is to ensure financial solvency of investors by not locking them into long-term investments that may be hard to exit from at short notice or at acceptable prices.<sup>13</sup>

Despite their long time horizon, institutional investors tend to invest overwhelmingly in liquid assets, so that they can maintain diverse portfolios and manage risks in a changing investment landscape. Large-scale funds are better positioned to increase investment in green infrastructure and other illiquid assets, because they can develop specialised knowledge on the risks and returns to these assets, increasing their confidence in the investment and reducing the need for liquidity.<sup>14</sup> For example, the largest of these funds, the Norwegian Bank for Investment Management, may be able to manage the risks of more investment in illiquid assets and emerging markets, consistent with its mission of investing for the benefit of future generations.<sup>15</sup> However, investors overall continue to favour shorter-term investment. The OECD has identified several reasons for this:<sup>16</sup>

1. Financial markets tend to reward short-term over longer-term investment. Although they are long-term investors in theory, institutional investors often face short-term performance pressures which can prevent them from investing in long-term assets.<sup>17</sup> Investment holding periods are declining among institutional investors, and allocations to less liquid, long-term assets such as infrastructure and venture capital are generally very low.
2. As part of the liberalisation of gas and electricity markets, “unbundling” regulations have been set up to prevent investors from owning a controlling stake

in both transmission and generation. This applies to renewable energy as well, and the OECD notes that given the attractiveness of transmission and pipeline-type infrastructure assets, “unbundling” regulations “may unintentionally force investors to choose between majority ownership in transmission and generation/production”. Similarly, the use of tax incentives may discourage investment by institutions that are already tax-exempt (such as pension funds in many countries), and instead can create a new class of “tax investor”, the OECD notes, “whose purpose is to accelerate the use of, and improve the value of tax credits, but whose presence can crowd out institutions”.

3. “Capital adequacy” rules designed to increase banks’ levels of capital and reduce their exposure to long-term debts can also discourage long-term investments, including green infrastructure investments. (Examples include Basel III for banks around the globe, and Solvency II for insurance companies in Europe.) In addition, the OECD notes, certain accounting rules that are meant to increase transparency and consistency in financial statements – such as fair value or mark-to-market accounting – can be hard to apply to illiquid investments with long holding periods.

There are policy initiatives underway to attempt to re-orient the financial sector toward longer-term, lower-carbon investments, including the United Nations Environment Programme (UNEP) Inquiry on the Design of a Sustainable Financial System.<sup>18</sup> A number of banks have made statements on the value to investors of taking a longer-term perspective or considering social and environmental risks. However, implementation of these principles has been sparse to date.

timing issue refers to a “chicken and egg situation” where widespread EV adoption requires a charging infrastructure in place, but without EV users charging infrastructure will fail to generate revenues.

- **Providing early-stage deployment support:** An infrastructure bank could take on some early-stage risk to accelerate deployment of newly emerging technologies that drive infrastructure productivity.
- **Supporting local municipal governments and aggregating small-scale projects to attract cheaper capital:** Securities backed by pools of diversified small-scale clean energy loans can attain much greater cash flow certainty than individual projects, making them attractive to institutional investors. Building such

projects portfolios have to acquire a certain scale, however, where a government infrastructure bank can provide initial support for example through first-debt loss guarantees.

Table 1 lists several examples of public green infrastructure banks in OECD countries.<sup>19</sup> These types of banks and other public finance institutions, the OECD notes, are currently being used to leverage private capital and support investment in low-carbon infrastructure, including from institutional investors.<sup>20</sup> There are also green investment banks (GIBs) or similar institutions in developing and emerging economies, such as South Africa (Green Fund), Malaysia (Malaysian Green Technology Corporation), and United Arab Emirates (Masdar).<sup>21</sup>

## Box 2

**Green bonds, infrastructure bonds, YieldCos and municipal bonds**

Financing costs are crucially important in keeping down the cost of infrastructure, given the high upfront investment. As discussed in Box 1, there are presently financial market barriers that restrict or raise the cost of finance to infrastructure.

A number of different financial instruments address this challenge, by attracting institutional investors.

Infrastructure bonds are primarily used in the project finance of infrastructure assets. Through these bonds, institutional investors can gain direct access to long-term, steady, low-risk investments. Bank deleveraging and Basel III capital restrictions have limited new investment from banks. Infrastructure bonds and other vehicles below here have the potential to fill the void by attracting institutional investment.

Green bonds are a type of infrastructure bond that provides debt to a project or a portfolio of projects that are certified as being environmental or “green”. The green character is the key enhancement over infrastructure bonds. By being green, these bonds may be able to access investors who prefer green investments or have restrictions or limitations to non-green investments when debt is scarce. By creating a distinct market and through competitive forces, green bonds could lower the cost of environmental infrastructure projects. Corporations and governments have also issued green bonds to back low-carbon projects, using their institutional creditworthiness to bring down financing costs for the projects.

YieldCos, which own portfolios of low-risk, long-term projects are equity vehicles that can go a step further than infrastructure bonds by effectively bundling equity and debt together in one package. By bundling projects together, the project finance premium for single projects can be avoided. Moreover, for a portfolio of projects with risks comparable to corporate bonds, the result for investors can be a higher-yielding, bond-like instrument that nevertheless reduces the overall financing cost for the projects in question.

Municipal bonds can serve the same purpose for renewable energy as YieldCos – that is, using high leverage for a project while keeping debt and equity costs down – if a municipal government is willing to bear the equity risk and role of investor itself.

Green investment banks have been established at both the national and sub-national levels.<sup>22</sup> Many have leveraged private capital, and engaged with institutional investors in a number of ways including: taking cornerstone stakes in funds or vehicles that attract pension and insurance

capital; providing debt financing; issuing green bonds; or designing products that have stable long-term cash flows which will be attractive to long-term institutional investors. Some green investment banks have a particular focus on financial sustainability and demonstrating that low-carbon investments can be profitable. The UK Green Investment Bank expects to earn taxpayers an average return of 8% per year, with every investment on track to make a profits.<sup>23</sup>

At the national level, green investment banks can be effective tools to mobilise domestic private finance and investment in low-carbon infrastructure when existing institutions are not already fulfilling this role. Some Public Finance Institutions (PFIs), such as Germany’s KfW, already have an explicit mandate and authority to invest in green infrastructure – often with established guidelines on which technologies or markets to address. “Greening” existing PFIs, where there is the necessary institutional and political support, might be preferable to creating new institutions.

Currently, these banks are a small portion of the financing landscape, but through their investments they may be able to kick-start liquidity in these assets, creating a virtuous circle whereby more investors are able to participate in financing low-carbon assets. As these begin to replace high-carbon assets, they shift the landscape of infrastructure investment needs. For example, energy efficiency investments bring down the need for renewal and expansion of the power generation, transport networks and building stocks.<sup>24</sup>

Apart from their role in funding and directing national infrastructure banks, governments also invest in low-carbon infrastructure themselves, both via direct investment and via companies that are fully or partially owned by the government.

### 3.3 Development banks and low-carbon investment in middle-income countries

Renewable energy can play a slightly different role in rapidly developing, middle-income countries. First, rapid growth creates a thirst for new energy sources to meet growing demand. Thus, competition for renewable energy comes from new plants that are yet to be built, rather than already existing facilities, as may be the case in developed markets. With good renewable resources, renewable energy could already be competitive, and in some cases, renewable energy might even have an advantage given the infrastructure that may be needed to support large-scale, centralised coal-fired generation. Second, the potential role of renewable energy is especially important in boosting energy security and improving balance of payments compared with importing coal, oil or gas. Third, some developing markets have viewed the manufacture

Table 1  
Examples of public green infrastructure banks in the OECD

Bank Name & Location	Capitalisation	Source of Capitalisation	Year of creation	Target rate of return	Scope	Instruments used
<b>Australia</b> – Clean Energy Finance Corporation	<b>AU\$10</b> billion	Government budget appropriation	2013	Commercial-level returns	Renewable energy, energy efficiency	Direct debt/equity investment and indirect (pooled) investment
<b>UK</b> Green Investment Bank	<b>GBP3.8</b> billion	Government appropriation	2012	Sufficient to offset losses, and create profit	Offshore wind, waste, non-domestic energy efficiency, with goal of market transformation	Direct debt and equity investment; indirect, fund-led investment
<b>Korea</b> Export - Import Bank (Kexim) Green Bonds	<b>US\$500</b> million	Bond issuance	2014	None provided	Low carbon and climate resilient growth, including clean energy, energy efficiency, emissions reduction, and waste filtering.	Direct debt investment
<b>Canada</b> – Ontario Financing Authority Green Bonds	<b>&lt;C\$500</b> million, planned	Bond issuance	2014 – 2015 planned	None provided	Environmentally friendly infrastructure including transit	Not specified
<b>Canada</b> Export Development Corp. Green Bonds	<b>C\$300</b> million	Bond issuance	2014 – 2015 planned	Sufficient to generate “modest profit to finance growth”	EProjects “aimed at the preservation, protection or remediation of air, water or soil or the mitigation of climate change.”	Direct debt investment
<b>USA</b> – New York State Green Bank	<b>US\$218.5</b> million	Utility bill surcharge, auction proceeds.	2013	Sufficient to offset losses	Commercially proven clean energy and energy efficiency	Credit enhancements, joint or pooled debt investment, loan warehousing
<b>USA</b> - Green Energy Market Securitization (GEMS)	<b>US\$100</b> million anticipated	Bond issuance	2014 planned	Not a key concern	Distributed solar, energy efficiency	On-bill financing, securitisation (proposed)

Source: Berlin et al., 2012; Booz&co, 2013; Clean Energy Finance Corporation, n.d.; Critchley, 2014; Export Development Canada, n.d.; Gutscher, 2014; Hawaii State Energy Office, n.d.; Kidney, 2014; Moore and Morrow, 2013; New York Green Bank, n.d.; Parliament of Canada, n.d.; UK Green Investment Bank, 2014; Wee, 2013.<sup>25</sup>

### Box 3

## Challenges and innovative policies for financing energy efficiency

### The priority

Increasing energy efficiency is a key part of developing better energy systems. Improving energy efficiency in buildings and energy-intensive industries accounts for US\$5.3 trillion of the US\$8.8 trillion of incremental investment in energy efficiency from 2015 to 2030, laid out under the low-carbon transition scenario in Figure 1. Efficiency is particularly important for those countries whose growth is constrained by unmet energy demand.

### The challenge

Energy efficiency poses specific financing challenges. Achieving investment at the scale needed will require new policy and financing vehicles.

While many energy efficiency investments generate substantial savings relative to the initial investment, few projects are large enough to attract the attention of financiers. Energy efficiency projects generally offer poor collateral, for example improvements to a building's shell have little value if removed and resold. Credit risk is the principal driver of financing costs for most energy efficiency projects, and that risk – being uncollateralised – is substantial enough that interest rates for small commercial and residential consumers are relatively high. In developing countries, where credit-based lending is rare, energy efficiency financing is often not available for small-scale borrowers. Even lending to large industrial actors with collateral is restricted to five years or less. Moreover, it may depend on targeted lines of credit financed by international institutions, such as the International Finance Corporation (IFC) and the European Bank for Reconstruction and Development (EBRD), both of which have prioritised funding for private-sector energy efficiency investment.

### New business models are emerging to deliver financing

Despite these difficulties, private-sector interest in energy efficiency financing is growing, with new business models emerging that shift risks in helpful ways. Public programmes that add security to investments by tying them to utility bills, mortgages, or property tax assessments may lower rates from financiers. Sales of securities backed by energy efficiency loans have begun to emerge, potentially making energy efficiency lending more liquid and attracting cheaper capital.

### Innovative policies are generating results

The HERO programme started in Riverside County, California demonstrates the potential benefits. With repayments secured on property tax bills (and therefore senior in obligation to mortgages), private lenders have provided more than US\$200 million in capital for efficiency and distributed renewables in residential and commercial buildings. One capital provider has securitised and sold bonds backed by the loans to raise additional capital. Demand has been strong and over 100 California municipalities have now joined the programme.

The German development bank KfW runs a residential energy efficiency programme that provides increasing amounts of principal reduction for projects with higher energy savings, and buys down local banks' interest rates to low (1%) levels. Almost 1% of German households participate annually – a considerably larger participation rate than most whole-home programmes of its kind achieve.<sup>26</sup>

Through its Sustainable Energy Financing Facilities (SEFFs), EBRD has offered credit lines and technical assistance to support development of energy efficiency financing among banks in Eastern Europe and Central Asia. Since 2006, the bank has provided over €2 billion in financing to local banks to establish new markets for lending for energy efficiency and small-scale renewable energy projects.<sup>27</sup>

In the developing world, risk-sharing programmes run by multilateral development banks have encouraged energy efficiency lending at more attractive terms. For example, under the China Utility-Based Energy Efficiency Finance Program (CHUEE), the IFC provided a loss reserve to participating banks, thereby inducing them to extend loan tenors and offer loans to smaller enterprises. Participating banks have lent over US\$500 million under the programme, and as of 2010 the programme had not experienced a single loan default.<sup>28</sup>

Most financial programmes, even those that offer substantial concessions, have struggled to motivate customers. The extent to which improved financing drives project uptake has not been well studied, and may vary substantially in different markets. That said, the approach clearly offers potential.

of renewable energy equipment as a potential national strategic objective.

To meet these goals, many middle-income countries have adopted policies and incentive schemes also used in developed markets, such as feed-in tariffs, power purchase agreements, auctions and green certificate markets. A distinguishing feature of some middle-income countries which can alter the effectiveness of these types of policies

is their greater cost of debt.

### *Low-cost debt can reduce the cost of renewable energy*

Middle-income countries tend to grow faster than high-income ones. Growth creates competing investment needs, particularly for infrastructure, and it can also

lead to inflation. The result is usually higher interest rate environments than in slower-growing developed countries. Additionally, generally younger populations and less well-developed pension and insurance industries limit the pool of long-term, relatively low-cost investment available for infrastructure.

Thus, in middle-income countries low-carbon energy may suffer in two ways. First, since low-carbon generation is often more capital-intensive than fossil fuel generation, higher interest rates and low debt availability have a greater impact. Second, since fossil fuel generation is often priced in dollars and has access to global markets, it can be financed on international rather than domestic markets. Yet for the developing country itself, renewable energy is often a direct substitute for the fossil fuel, replacing imported coal, gas or oil, and reducing foreign exchange requirements that go along with fossil fuel imports.

For developing countries there are a number of financial mechanisms that can bridge the difference between the high cost of financing in local currency and the benefits that should be priced in hard currency.

Countries such as China and Brazil effectively use subsidised, low-cost debt to finance renewable energy. National development banks, national sovereign wealth funds and investments made from national budgets or state-owned enterprises (SOEs) under administrative direction fund substantial percentages of the world's low-carbon investment, overwhelmingly in their own domestic markets.

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*The China Development Bank, for instance, is the largest development bank in the world and has supplied over US\$80 billion to renewable energy projects.*

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The China Development Bank, for instance, is the largest development bank in the world and has supplied over US\$80 billion to renewable energy projects.<sup>29</sup> In China, as of June 2012, 87% of wind projects and 68% of solar projects were built and owned by SOEs and their subsidiaries.<sup>30</sup> As such, they have access to capital at low, administered interest rates. In Brazil, the national development bank, Brazilian Development Bank (BNDES), sets a separate long-term interest rate that it uses as a basis on which to make loans to infrastructure projects. Nearly every major power project in Brazil has had access to BNDES funding, with around US\$50 billion committed so far into low-carbon energy.<sup>31</sup> The result is that renewable energy projects in these countries have access to low-cost financing that reduces the cost disadvantage

compared with fossil fuel alternatives. Recent auctions in Brazil, for instance, achieved average prices for energy from wind projects at the comparatively low price of US\$58/MWh.<sup>32</sup>

The accomplishment of state banks in funding low-carbon energy at tolerable debt rates is substantial. In China, it may be that the combination of China Development Bank debt, SOE equity funded by retained earnings, and secure power purchasing agreements in administered markets creates the functional equivalence of municipal finance, energy user finance or YieldCos in high-income country, market-based finance systems. However, it is important to note that there are active reform movements in China, Brazil and other middle-income countries with strong development banks that would liberalise the existing financial system, changing the supply of low-carbon debt financing.

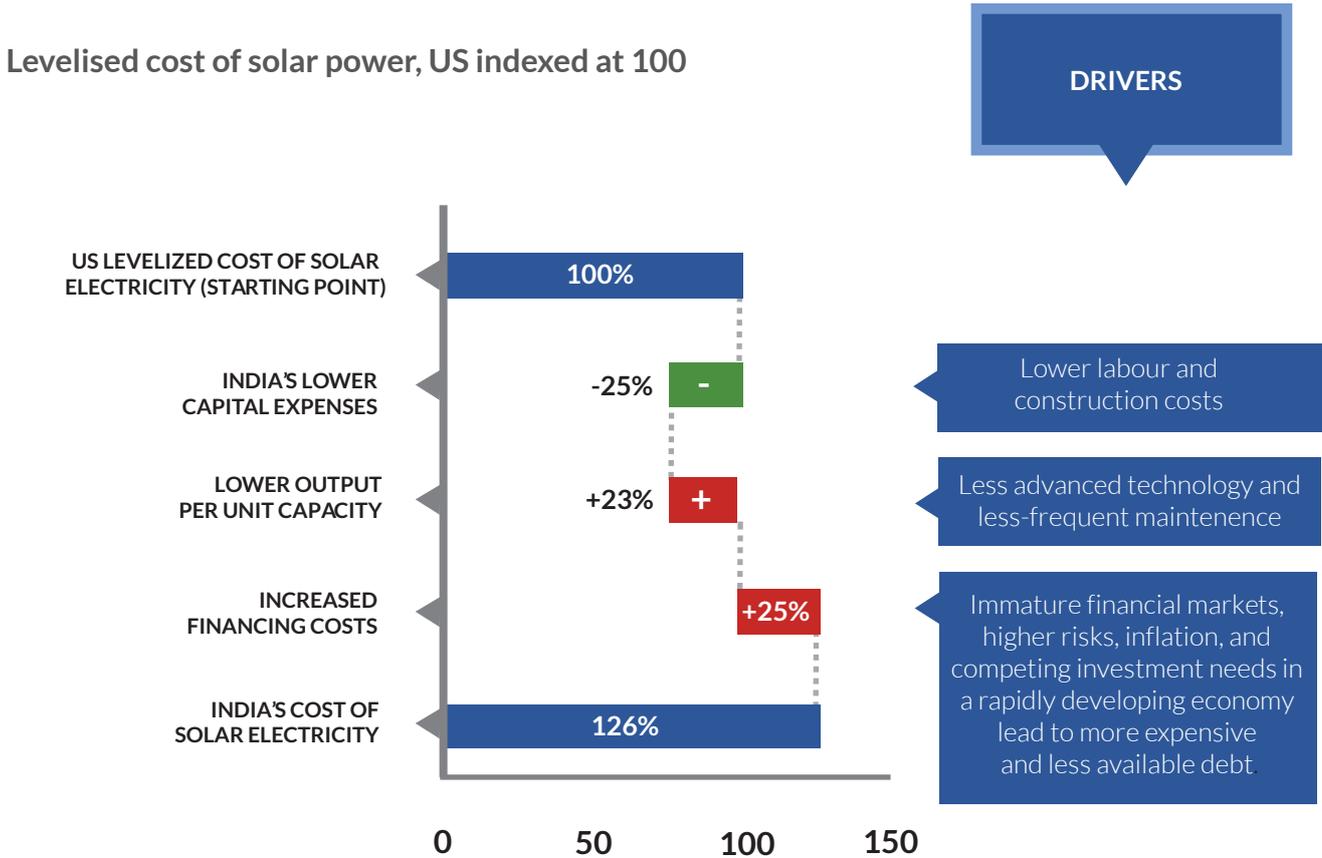
Middle-income countries such as India, Mexico, South Africa and Morocco use a variety of national niche and multilateral solutions to finance low-carbon projects, but are constrained by an absence of low-cost debt necessary for such capital-intensive investments. In this analysis, those countries are labelled as MIC2, in contrast to middle-income countries with access to low-cost debt through development banks, such as Brazil and China (MIC1).

MIC2 countries often pay as much for renewable energy as the US and Europe, and sometimes much more, despite potential labour, land and construction cost advantages. Figure 3 shows how increased financing costs could impact a typical Indian solar project. Lower initial capital expenditures for this plant were almost 25% lower than a US counterpart. Less advanced equipment, lower solar radiation and dust were expected to decrease its output, but even then, costs were slightly lower than in the United States. However, financing costs due in large part to wider capital market factors in India, pushed lifetime cost per unit of energy well above the US counterpart.

More specifically, the difference is the cost and terms of debt. In India, our modelling of a range of projects shows that the cost and terms of debt alone can add 24–32% to the cost of utility-scale wind and solar photovoltaic (PV) projects.<sup>34</sup>

The high cost of debt creates other problems. Policy solutions such as stable long-term contracts or reliable feed-in tariffs can reduce the cost of renewable energy in other countries by allowing a larger share of a project to be financed with debt, which carries lower financing costs than equity. But in many rapidly developing countries, the cost of debt is so high that there are virtually no savings to be gained by growing the share of debt in a project. As a result, those same policy solutions are much less effective at bringing down renewable energy

Figure 3  
**Financing costs for solar power eliminate natural cost advantages in India**



Source: Climate Policy Initiative, 2012.<sup>33</sup>

costs and driving deployment.<sup>35</sup> More expensive debt can limit the availability of upfront equity capital, given uncertainty over the cost of refinancing the completed project. Developers may not be willing or able to refinance completed projects with debt. Discussions with stakeholders in India reveal that the difficulty in securing debt may already be causing developers to run out of equity to invest in the next set of projects.

*In India, our modelling of a range of projects shows that the cost and terms of debt alone can add 24-32% to the cost.*

High debt costs are not unique to renewable energy. Rather, they reflect the high interest rate environment, which itself reflects the higher inflation, large infrastructure needs, heavy government borrowing, and a less developed financial system typical of rapidly growing economies.

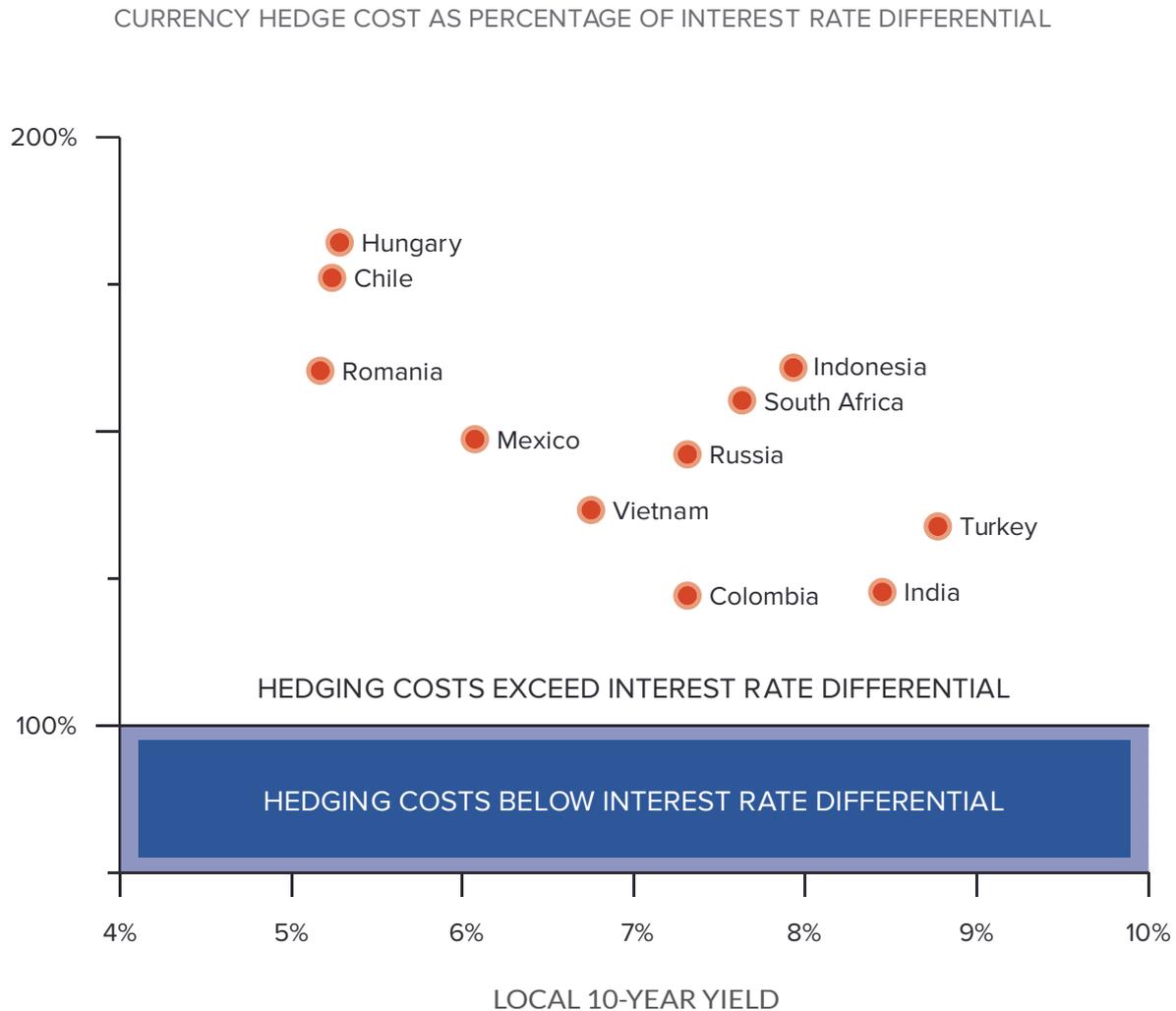
**Cheaper foreign debt is not an easy solution for middle-income countries because of exchange rate risk**

One option would seemingly be to use lower-cost debt from developed markets. The first question is, then, whether the loan should be denominated in, say, US dollars, or in the local currency. If it is denominated in US dollars, then the borrower must take the risk that the local currency falls and the debt becomes much more expensive. The lender will likely refuse to make this loan because the default risk associated with unfavourable currency movements will be too high. Alternatively, the loan could be priced in local currency, but then the lenders need much higher interest rates to compensate them for the currency risk.

As a result, most loans require currency hedges that convert one currency to another over the life of the loan. In fact, unless they have offsetting liabilities, most dollar investors require hedges for euro investments and vice versa. Hedges cover relative currency movement risk that results from differences in inflation, economic growth, government policy, and so forth. The cost of these hedges depend on market conditions, trade flows

Figure 4

## The cost of hedging more than eliminates the advantage of lower foreign interest rates



Source: Adapted from CPI, 2014.<sup>36</sup>

and relative country risks, but often they can take up all of the difference in interest rates between dollar-based loans and local currency loans. In fact, Figure 4 shows that as of January 2014 the cost of hedging for a number of developing countries was 20–80% higher than the difference between base interest rates in each country. In other words, foreign debt that was fully hedged against currency risk would have been more expensive than local debt, meaning that foreign debt is not a viable option for renewable energy project in these economies.

One solution for MIC2 that does have promise for increasing scale is national or local debt subsidies, which can reduce the total cost of subsidising renewable energy. Analysis for this report shows that if debt were available at terms and interest rates similar to those found in developed countries, the cost of renewable energy would be as much as 22% lower.<sup>37</sup> Debt subsidies can be used alongside feed-in tariffs or power purchase agreements,

partially or wholly replacing the subsidy element within these mechanisms. Modelling conducted for the Commission shows that this switch could reduce the total cost to government and energy consumers of subsidising renewable energy, including the cost of the debt subsidy, by up to 30% for the same amount of renewable energy. Lowering debt costs can allow the government to support greater renewable energy deployment with scarce subsidy resources, compared to providing the same rate of subsidy through higher guaranteed revenues.

A key challenge for incentivising renewable energy through concessional debt will be the administration of the debt and selection of projects. These arrangements must allow project developers to receive adequate incentives while ensuring that the value of the lower-cost debt flows through into lower energy prices. Project selection mechanisms must also target the most economic projects, to minimise inefficiencies through poor project selection including failed projects.

## Box 4

**The finance challenge for cities**

As discussed in Chapter 2: Cities, cities are likely to play a central role as drivers of low-carbon economies and low-carbon growth. Municipal financing is a common instrument to finance public transportation and efficient city infrastructure, and analysis in this chapter suggests it is also a useful vehicle for investment in renewable energy and energy efficiency. But in many countries, cities have limited authority to make decisions on major infrastructure investments. They also have limited financial resources and may not be able to provide sufficient collateral to finance investments themselves.

In order for cities to be able to deliver on the recommendations in this report, it will be necessary to resolve these issues of authority and financial resources. Further work is needed to better understand these challenges in each nation, and to develop financing vehicles that provide security for investors while helping low-carbon cities grow.

Many countries already have institutions which can perform part of the task, such as renewable agencies, energy ministries, treasuries or development banks. But careful design will be needed to ensure efficient project selection and development in coordination with national energy policy. In some cases, multilateral development banks may be able to help build the necessary institutions. In other cases, existing institutions may serve as a conduit for multilateral financing. Once these arrangements are in place, projects that receive concessional debt in lieu of subsidies should remain just as attractive to developers, while costing 30% less in terms of subsidies from governments or higher tariffs from consumers.

*Other creative financing solutions for middle-income countries need to be scaled up*

Rapidly developing, middle-income countries are in the process of quickly expanding their energy supply systems, and niche solutions for MIC2 countries abound, but need scaling up.

Examples of such creative niche solutions include private wind parks to supply off-grid power to high value firms in Mexico and India, which are willing to pay extra for a more secure electricity supply and can finance the project off their own balance sheets. Another is the case of large conglomerates which can access low-cost debt from commercial banks with which they have long-term relationships. A third is concessional financing from multilateral trust funds like the World Bank's Clean Technology Fund for early vintage concentrated solar plants in India, South Africa and Morocco and geothermal plants in Indonesia. Still, these solutions are, at the

moment, limited in scale and do not compare to levels of low-carbon investment financed in high-income countries and MIC1 nations.

### 3.4 The role of development finance institutions

Development finance institutions (DFIs) have a significant role to play in the expansion of energy efficiency and renewable energy in both MIC2 nations and in low-income countries (LICs). These include global and regional multilateral banks such as the World Bank Group, national development banks with international portfolios, and bilateral development agencies. They can provide support through equity investments, loans (concessional and non-concessional), guarantees and insurance products, principally to MIC2 recipients.<sup>37</sup>

DFIs can provide a layer of risk protection and capital cost reductions beyond what can be provided by host governments. Historically, international concessional financing has formed a substantial share of financing in low-income countries. Official development assistance in low-income countries averaged 54.9% of gross capital formation in 2012,<sup>39</sup> and those with lower GDPs had even larger shares of foreign assistance.

Concessional loans are known to be an effective tool to support governments in the development of large projects that might not garner private sector participation, such as large hydropower plants or binational/regional high voltage transmission lines to transport electricity from renewable sources.

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*Projects that receive concessional debt in lieu of subsidies should remain just as attractive to developers, while costing 30% less in terms of subsidies from governments or higher tariffs from consumers.*

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Equity and non-concessional loans can attract the private sector to invest equity and debt in utility-scale renewable power generation plants. The return on equity and the financing cost of the loans of DFIs are similar to private-sector investors and so do not directly reduce financing costs. However, the participation of DFIs as co-lenders or equity partners is regarded as positive with respect to reducing regulatory and other risks, and so still attracts private investors.

Recent OECD analysis shows that both bilateral and multilateral external development finance has a positive

and significant effect in mobilising private finance flows to developing countries, with a more pronounced effect in attracting domestic over international financial flows. These results are robust across different models and estimation approaches. Interestingly, the results suggest that the effect of multilateral public finance is greater on the decision over whether to invest at all, than on the volume of investment once the decision to invest is taken.<sup>40</sup>

The same analysis shows that raising the ambition of domestic policies in developing countries to incentivise renewable energy investment, such as through feed-in tariffs and renewable energy quotas, is vital to attracting private investment at scale. Evidence shows that external official development finance operates on at least two levels to support green investment: first, to directly attract private co-financing and investment for green infrastructure; and second, to work with MIC governments to support policy reform processes and build local capacity and conditions so as to make green investment viable in the longer term.<sup>41</sup> Delivered through bilateral or multilateral development cooperation channels, external official development finance often has a catalytic role in shifting and scaling up green investment.

In addition to direct equity and debt investments in infrastructure projects, DFIs offer risk-bearing instruments for investors in MIC2 and low-income countries, such as insurance protection and guarantees. With additional improvements and innovation, these instruments, could help address finance needs for low-carbon assets at larger scale.

Some institutions offer political risk insurance that can partially cover the impact of policy change, provided that the change qualifies as an expropriatory breach of investor's rights. For example, the Multilateral Investment Guarantee Agency (MIGA), a World Bank Group agency established in 1988 to offer political risk insurance to investors in developing countries, can cover a tariff reduction for the equity and debt provider. Similarly, the Overseas Private Investment Corporation (OPIC) provides policy risk coverage to US investors when the policy change causes a breach of the power purchase agreement (PPA) and constitutes an expropriation of investors' rights (or regulatory taking) originating from the contract.<sup>42</sup>

While these are useful steps forward, there are still significant gaps in the supply of instruments to address these risks. Existing instruments (such as those offered by MIGA and OPIC) have costly compliance requirements, which limit their application to large and well-resourced projects only. They may also not be fully visible under international official development assistance accounting rules, which measure assistance on a cash flow basis.

Because these instruments are largely unaffordable for smaller projects and programmes covering widespread, small-scale installations,<sup>43</sup> due to high costs as a result of complex negotiating and drafting processes, other dedicated programmes are needed to seek justice locally and keep investments solvent before compensation is paid.

A number of factors have limited a more widespread adoption of partial risk guarantees, which have only been issued 23 times since their inception and eight times for renewable energy projects.<sup>44</sup> The World Bank has in the past promoted the use of partial risk guarantees mainly for large and complex projects, such as large hydro investments and cross-border projects, and required an indemnity agreement from the host government. This has increased a market perception of product complexity, lengthy procedures and high transaction costs. Furthermore, partial risk guarantees directly cover only debt holders, while tariff reductions usually affect many other parties including equity owners, providers of operations and maintenance services. This last issue can be addressed by complementing the instrument with other insurance tools and guarantees, such as MIGA insurance, albeit at increased complexity and transaction costs.

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*Delivered through bilateral or multilateral development cooperation channels, external official development finance has often a catalytic role in shifting and scaling up green investment.*

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MIGA aims to provide compensation within six to 14 months following the date of loss.<sup>45</sup> Historical evidence made available by the Agency<sup>46</sup> shows that so far claims have been paid after two to three years from the event date, and no later than one year from the date of claim's submission.

OPIC data based on 13 available observations, from a total of about 70 projects determined under total expropriation clause, show that claims are resolved on average 3.5 years after the event date and 1.5 years from the submission of the claim. Timing of the reimbursement process is uncertain and varies significantly from case to case. These delays and uncertainty have a large impact on the viability, and the perception of viability by investors, of these schemes.

Guarantees are another financial instrument offered to reduce and mitigate investment risks. They are mostly offered by the World Bank and have proven to be an effective tool to attract private investment to the energy sector. Guarantees are particularly well suited

for use in MIC2 and low-income countries, as they are focused on reducing the risk associated with payments due from governments or state-owned enterprises to investors (equity or debt) under contractual or regulatory commitments. These payments can be of a diverse nature such as those due monthly under a power purchase agreement, payments due as compensation resulting from a change in law, or payments due from SOEs under loan agreements with commercial banks. The World Bank has approved 19 guarantees in the past three years for an aggregate amount of US\$2.9 billion.<sup>47</sup> These guarantees have enabled US\$11 billion of investment, mostly in the energy sector, in highly challenging markets such as Cameroon, Ivory Coast, Kenya, Mali, Mauritania, Nigeria, Pakistan, Senegal and Uganda.

### 3.5 Addressing the energy financing challenge of low-income countries

Across low-income countries (LIC), even those now exporting oil and other natural resources, the challenge of capital mobilisation for investment in energy assets, whether low or high-carbon, is still very severe. Infrastructure investments typically depend on government involvement in the form of partial ownership, subsidies or credit guarantees, or contracts with a government-owned utility. As in all countries, a stable regulatory system and enforceable, long-term power purchasing contracts is a major component of an investment case. However, lack of government credibility and/or financial capacity is a potential barrier for investment in infrastructure assets.

Given the lack of long-term domestic or international private capital for these classes of investment, multilateral banks and development finance institutions, including the Global Environmental Facility, the Green Climate Fund, and the United Nations Framework Convention on Climate Change (UNFCCC) Adaptation Fund, continue to play a central role in financing infrastructure in low-income countries.

The extra up-front capital costs of low-carbon energy present a challenge to the multilateral banks, given many other demands on their balance sheet capacity. Fortunately, new initiatives, funding vehicles and programmes, special purpose funds and institutions with particular dedication to low-income countries energy provision are expanding.

Examples include innovative distributed, off-grid energy solutions such as community-inclusive local area networks, anchored on an agricultural or mining producer with substantial base demand, or small-scale mechanisms such as prepayment cards as used in mobile telephones or securitised microfinance. Multilateral platforms such as the Green Climate Fund, Sustainable Energy for All, and the Climate Finance Innovation Lab assign leading

emphasis to the particular demands of low-income countries, including funding adaptation and the design and implementation of specific equity funds, project development facilities and the private refinancing of multilateral banks' energy development budgets. Finally, it is worth noting the growing significance of funding of energy infrastructure in low-income countries by Chinese development banks (see Box 5).

## 4. Financing energy system transformation

While the emerging strategies described in the previous section can reduce the cost of capital and increase the availability of finance for a low-carbon energy transition, these measures by themselves would not achieve the full investment necessary to reach an ambitious climate goal, often benchmarked at a 2°C rise in global average temperatures. The Commission therefore decided to explore just how much additional capital might be required to achieve this goal and what impact that those additional capital needs could have on global finance.

The headline financial impact of the low-carbon transition is the incremental investment required. Incremental investment is important because it can describe how much of the available global investment capital would need to be “crowded out” and shifted to the low-carbon energy investments. If, for example, a doubling of investment into the power sector were required (relative to a “business as usual” scenario), it would be hard to reconcile this with the imperative to grow global energy supplies in an affordable way. But incremental investment tells only a part of the story.

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*These guarantees have enabled US\$11 billion of investment, mostly in the energy sector, in highly challenging markets such as Cameroon, Ivory Coast, Kenya, Mali, Mauritania, Nigeria, Pakistan, Senegal and Uganda.*

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First of all, the mix of assets will change beyond just incremental investment, since there would be a reduction of investment in fossil fuel assets like coal mines, oil production facilities and coal-fired power stations. Furthermore, incremental investment does not adequately capture the effect that this shift in investment will have on other costs that then feed back into financial markets, for investment in an energy transition can create or destroy value in a number of ways, in so doing freeing up (or consuming) additional cash to the economy that

## Box 5

## The emergence of new international financial institutions

Infrastructure in developing and emerging countries will require a step-change in investment levels over the next decade, even before accounting for climate action. Estimates indicate that investment in developing and emerging markets, in order to sustain projected growth paths, will need to more than double from the current US\$1 trillion a year invested in electricity supply, transport, telecoms and water.<sup>48</sup>

At the moment, the majority of investment in infrastructure in developing and emerging markets is provided by the public sector. Given the budget constraints faced by these countries, and the projected needs, the private sector will need to participate more strongly in the future. Private-sector money is not flowing to developing and emerging countries at the pace and scale required. Political risk, macroeconomic instability, lack of well-developed projects all contribute to the reluctance of the private sector to invest.

A number of new public funds and banks are being created or strengthened in developing countries to respond to the new government demand. The latest two are the Asian Infrastructure Investment Bank (AIIB) and the BRICS (Brazil, Russia, India, China and South Africa) Bank. The AIIB was proposed last October by Chinese President Xi Jinping during the Asia-Pacific Economic Cooperation Summit in Bali. It is expected to be established within the year with an operating capital of US\$50 billion to start with, and the perspective to grow quickly to US\$100 billion. To date, China has invited Japan, South Korea and other countries to join. The BRICS Bank, an initiative of Brazil, Russia, India, China and South Africa, was proposed at the BRICS summit in Delhi in 2012, and was formally launched at the BRICS Summit in July 2014. The bank would begin with a subscribed capital of US\$50 billion, divided equally between its five partners, with an initial total of US\$10 billion in cash and US\$40 billion in guarantees.<sup>49</sup>

While the total subscribed capital of these institutions is not insignificant, it is still fairly limited in comparison with the International Bank for Reconstruction and Development (IBRD), at about US\$200 billion, or the Asian Development Bank, at about US\$160 billion.

The real potential of these institutions derives from their shareholding, formed by key emerging and developing countries, and their focus on infrastructure. This puts these new institutions in a strong position to leverage and blend their finance with national development banks and funds, such as the China Development Bank or the Brazilian National Development Bank (BNDES), both able to mobilise substantial investments.

Some smaller regional development funds, such as the Development Bank of Latin America (CAF), are also increasingly influential. With one of the highest credit ratings of debt issuers in Latin America (AA-), the CAF is now lending more than the World Bank and the Inter-American Development Bank together in the Latin American region. As developing and emerging countries' domestic financial markets deepen and savings are increasingly recycled through their domestic banking system, these new banks and funds will be in a strong position to blend their finance with private sector funds.

An important question is to what extent these institutions will recognise the opportunity to invest in infrastructure that lays the foundations for a more sustainable, low-carbon future, particularly when investing in energy infrastructure. The nascent Green Climate Fund, which is meant to provide global climate change finance in the context of delivering on the commitment of mobilising US\$100 billion a year by 2020 to support emerging and developing countries on adaptation and mitigation options, can play an important role in blending its finance with other infrastructure funds. While US\$100 billion is a small part of the total financing needs for sustainable infrastructure, and can be raised in rich countries through current and future fiscal instruments, used wisely these funds can be a catalyst for further public and private funds.

Using innovative financial instruments to address multiple issues including policy risk and affordability of infrastructure in poorer countries, will be key for these institutions to invest at scale in sustainable infrastructure. BRICS countries have explored how their new bank could support sustainable infrastructure, but the outcome will only be clear once the bank starts lending at scale.

could then be recycled into other investments in the future. Four adjustments must be made to incremental capital investments to understand the true impact on the economy and financial markets:

- **Operating expenses:** Capital investment will replace some operating expenses freeing up cash for further investment. For example, wind turbine investment reduces the cost of transporting coal from mine to power station. The money saved in transportation would then be available for investment elsewhere in the economy.
- **Asset life:** Both high- and low-carbon energy systems have a mix of long and short-term assets. In general, the average life of the assets of a low-carbon system is slightly longer, particularly when considering the short amortisation periods of some upstream fossil fuel assets. Longer-life low-carbon infrastructure may require more initial investment, but will delay future investment to replace capacity. For example, an investment made in 2025 with a 20-year life will still have half of its production remaining in 2035.

- **Risk and required return:** Lower-risk assets require smaller incentives to meet a given return. Investors in a project could require double or more incentive – that is return – to invest in a riskier project. Reducing risks in the energy portfolio could free risk capital to invest in risky, value producing, ventures elsewhere in the economy.
- **Stranded assets:** On the other side, a low-carbon transition can create “stranded” fossil fuel assets which lose value when they are no longer needed. Valuable assets can be used as security for future investments, so such a loss of asset value can take value directly out of the potential investment pool.

The next section analyses the required incremental investment in a low-carbon transition, with an initial estimate that is then adjusted according to the wider influencing factors described above.

#### 4.1 Investment needs are large and well investigated, but will depend on policy ambition and choice

The IEA uses a number of models and analyses to estimate future energy investment needs. Included in these estimates are scenarios that reflect current perspectives on “business-as-usual case” investment needs and scenarios with substantial carbon abatement, including the IEA’s 2°C scenario, or “2DS.”

Both scenarios define the investment requirements for: power generation (fossil fuel and low-carbon power generation, plus transmission and distribution), building energy efficiency, industry (energy efficiency and other measures), and transportation (vehicles and mass transportation). They exclude the upstream energy investment requirements in oil, gas, and coal and non-energy infrastructure investments (roads, railways, bridges, agriculture, etc.).

The difference between these two scenarios is an estimate of the *incremental* investment required to achieve substantial carbon abatement. It is only an estimate, since there are multiple possible scenarios, with very different investment implications. Nonetheless, the IEA investment figures provide a credible starting point from which to evaluate the impact of a transition on financing and financial markets. Analyses that specify less ambitious climate goals, for example to stabilise atmospheric greenhouse gases at 500 or 550 parts per million, could reduce substantially the incremental costs incurred by low-carbon systems and associated value stranding. However, the analysis of what such less ambitious transitions would mean for the average cost of capital, how these costs were distributed, and what political reactions might be expected would be logically similar.

The IEA estimates that about US\$36 trillion of investment will be needed in 2015–2030 in the energy sector, as well as in energy end-use sectors such as buildings, industry and transport, regardless of climate goals. A 2°C scenario, the IEA estimates, could require about US\$12 trillion of incremental investment over the same time period in comparison with a scenario with zero climate action, leading to up to 6°C of warming.<sup>50</sup> This is mainly because additional investments to improve energy efficiency and for the deployment of low-carbon technologies are only partially offset by reduced investment in fossil fuel power generation and in electricity transmission and distribution. (Note that savings from compact cities and reduced investment in fossil fuel exploration and transport, included in Figure 1, were not considered here.)

During that time, however, the world economy will grow substantially, and investments will be made in a variety of forms of capital stock. Analysis for the Commission shows that roughly US\$400 trillion of new investments will be made into fixed capital (that is, total global investment in the economy) over the same time period. This is based on World Bank data on the historic ratio of Fixed Capital Formation to GDP, and OECD projections of GDP growth.

In comparison, the above IEA estimates imply that the total investment needs for energy are 9% of fixed capital formation without taking any climate action, and 12% including the extra costs of low-carbon investments. While these are significant additional capital requirements, our assessment is that 3 percentage points additional investment in energy, as proportion of total investment, is modest relative to the overall scale of capital formation likely to occur over the next 15 years. The challenge will be to generate the required quantity of attractive investments, through technology improvements and supporting policy, and to direct available sources of capital into such investments.

Table 2 breaks down incremental cost for a 2°C scenario for high-, middle-, and low-income countries.

#### 4.2 Lower-risk, low-carbon energy investments

Earlier we outlined how incremental investment needs to be adjusted for operating expenses, asset life, risk and stranded asset to assess the full financial impact of an energy transition. Figure 5 makes this adjustment for one of the key components of the transition, the transition in electricity to move to low-carbon energy to replace fossil fuel-fired generation.

This analysis is based on a comparison of the IEA’s business-as-usual and 2°C (2DS) scenarios, as well as additional market and financial analysis undertaken by the Commission. As such, it represents just one

Table 2

## Energy investment needs as a proportion of total fixed capital formation, under a 2°C scenario

		OECD	Middle-income				Low-income	Total
			China	India	Transition economies	Other		
<b>2015-2030</b> Fixed Capital Formation (trillion US\$)	Households	41.3	n/a	n/a	n/a	n/a	n/a	41.3
	Government	24.4	51.8	7.1	1.2	65.7	0.6	150.9
	Private	84.8	54.8	24.8	7.3	17.6	1.3	190.6
<b>2015-2030</b> Investment needs in energy (trillion US\$)	Baseline investment	14.1	8.5	2.5	2.6	4.8	1.4	33.8
	Incremental investment	5.4	2.1	0.6	1.1	1.8	0.2	11.2
Ratio of investment needs to fixed capital formation	Baseline % of fixed capital formation	9%	8%	8%	31%	6%	72%	9%
	Incremental % of fixed capital formation	3.6%	2.0%	2.0%	12.5%	2.1%	11.8%	2.93%

example of how low-carbon investment needs would translate into an actual financial impact on the economy. Many different paths could be taken to a low-carbon future, and the Commission believes that policy-makers will follow this type of analysis in evaluating policy paths for a low-carbon transition.

#### Amortisation and operating expenses

As shown in Figure 5 (“Increased Low-Carbon Expense”), our analysis shows that US\$2.8 trillion<sup>52</sup> of additional capital will be used, or amortised, between 2015 and 2035 for renewable energy, nuclear energy, carbon capture and sequestration and transmission under the IEA’s 2DS scenario compared to business as usual. Our analysis also indicates that by the end of 2035, an additional incremental US\$4 trillion of low-carbon assets (not pictured) would have been invested and be on the books and available for continued production after 2035. Thus, although US\$6.8 trillion of capital is invested, only US\$2.8 trillion of this capital is amortised during this period. Amortisation is lower than total capital investment during this period because a mortisation is spread out over the entire lifetime of the asset.

The incremental costs of operating the additional plants, including nuclear fuel, will consume an addition US\$1

trillion between 2015 and 2035. These estimates are based on the IEA investment paths, and on Commission modelling for upstream gas, oil and coal, based on commercial databases, including the Rystad oil and gas production economics database and a variety of industry and government data sources (see the discussion on stranded assets for further detail). Table 3 shows an application of various return and amortisation assumptions to different types of investment, based on industry and company analysis.

Coal mining is less investment-intensive than low-carbon energy, but it requires substantial operating costs to mine the coal and transport it to the power station where it will be used. Coal-fired power stations themselves also have higher operating expenses than comparable renewable energy generators. Our analysis shows that reducing coal and gas consumption in power plants will avoid about US\$1.7 trillion of capital investment from 2015-2035 (and avoid a further US\$2.8 trillion on the books in 2035). Meanwhile, operating expenses – excluding fuel use in power plants which is already accounted for in the fuel production expenses – will fall by US\$5.5 trillion.

Thus, while the transition will consume US\$1.1 trillion more capital during the period, total costs, after including amortisation and operating expenses, actually fall by US\$3.5 trillion.

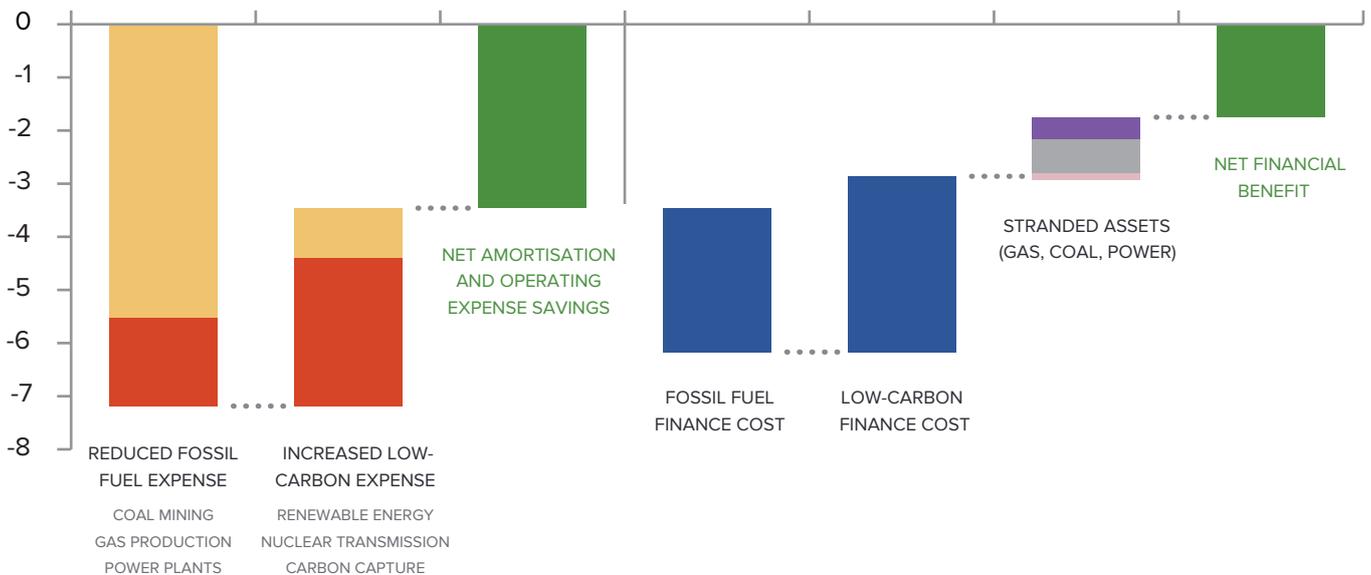
Figure 5

## Increased investment in low-carbon technology is offset by avoided operating and financing costs

### Financial Impact of a Coal to Renewable Energy Transition (2015-2035)

#### IMPACT ON FINANCIAL COSTS (US\$ TRILLION)

NEGATIVE NUMBERS IMPLY NET BENEFIT TO THE ECONOMY



- Amortisation of capital investment during period
- Financing cost
- Stranded coal
- Operating expenses (excluding fuel for power plants)
- Stranded gas
- Stranded power

Source: Climate Policy Initiative analysis, using data from IEA, 2012; IEA, 2014; Platts, and Rystad.<sup>51</sup>

#### Financing costs

However, the story does not end there, for assets require investment returns – that is, they incur financing costs – based on the entire value of the investment, not just the portion that is used (amortised) during a given period. The total amount of investment will be much larger for the low-carbon asset group, and therefore financing costs are higher as well. Nevertheless, the differences in returns required are not as large as the differences in total investment because the low-carbon assets are generally lower-risk than the high-carbon assets they replace.

While fossil fuel generation technologies are well-established, fossil fuel investment must still manage substantial risks across the supply chain, including exploration and transportation of the fuel. The riskiness of fossil fuels can be observed in their historically volatile prices. Fossil fuel power-generating assets are exposed

to this risk, as fossil fuels have to be purchased as inputs. This is particularly true when the fossil fuel generator is participating in a competitive electricity market and is not guaranteed a fixed return for the power it sells.

Renewable energy investments, by contrast, are not exposed to volatile inputs, and deliver electricity over the life of the investment at low operating costs (up to 90% of the total cost of a wind or solar plant is in the initial investment) and with a high degree of predictability. Thus, renewable energy sources can supply electricity at lower risk, if not at lower cost, than fossil fuel generators.

Whether the inherent low risk of renewable energy translates to a low cost of capital depends on the policy and market structures in place. If renewable energy generators participate alongside fossil fuel generators in a competitive market, they will receive a market price based on fossil fuel costs – and will still be exposed to fossil fuel

Table 3

## Return requirements and amortisation periods for different categories of high- and low-carbon assets

	Average investment life in years (Amortisation)	Return on investment (weighted average cost of capital)
Coal mining – internationally traded coal, or domestic markets in countries with lower financing costs	15	9%
Coal mining – domestic markets in countries with high financing costs	15	12%
Gas upstream investment	10	12%
Gas transport investment – global markets	25	6%
Fossil fuel generation – countries with low interest rates	25	10%
Nuclear generation	30	6%
Transmission	25	6%
Carbon capture and storage	20	10%
Renewable energy – countries with low interest rates	20	6%
Renewable energy and fossil fuel generation – countries with high interest rates	20	10%

price risk. However, if renewable energy generators can sign long-term contracts to provide power to a credible off-taker, they are not exposed to fuel price risks.

The lower risk of renewable energy sources could lead to lower overall financing costs as equity investors require a lower rate of return, and more of the total investment can be financed through debt. The lower financing costs reduce energy prices and free capital for savings and investment. From the investor side, relatively risk-tolerant capital is then freed to invest in new businesses elsewhere in the economy.

Once the incremental cost and relative risk of investments

is considered, modelling for the Commission suggests that the transition will require US\$600 billion of additional investment return to investors over the twenty year period.

### Stranded assets

Stranded assets are the final piece. Owners of fossil fuel assets would find that the value of their assets might fall in a transition. Valuable assets and the cash flows that they generate are used to underpin future investments. Reducing the value of these assets removes investment potential from the economy. Unlike capital and operating expenses, declining asset value does not represent a cost, but a one-time hit to the financial system. Therefore, this

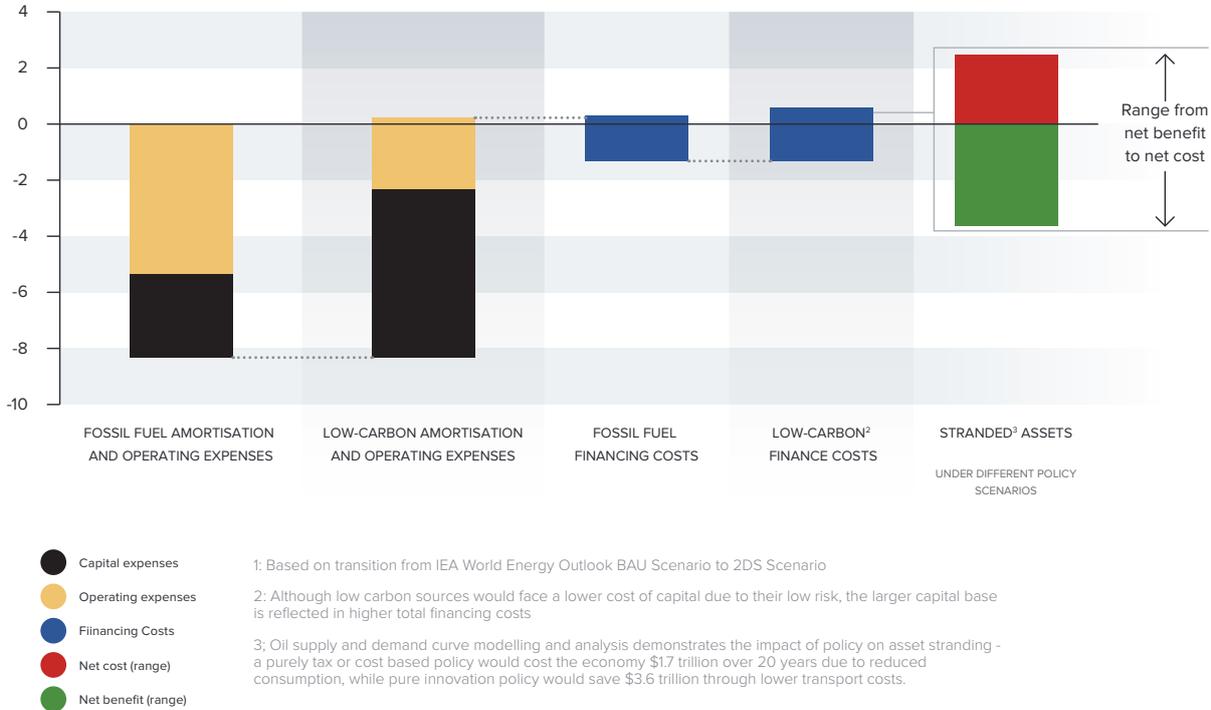
Box 6

The financial consequences of another transition – reducing oil use in transport and the central role of policys

FINANCIAL IMPACT OF REDUCING OIL IN TRANSPORT (2015 – 2035)<sup>1</sup>

IMPACT ON FINANCIAL COSTS (US\$ TRILLION)

NEGATIVE NUMBERS IMPLY NET BENEFIT TO THE ECONOMY



Source: Climate Policy Initiative, using data from IEA, 2012; IEA, 2014; Platts, and Rystad.<sup>54</sup>

The electricity transition is not the only one that involves a trade-off between higher capital expense, lower risk and lower operating costs. The same story plays out in an oil transition to higher electric vehicle penetration, fuel substitution, more mass transit and higher efficiency.

In this case, the analysis again used a combination of the IEA 2DS and business-as-usual scenarios with modelling for the Commission. It was found that a combination of lower operating costs, savings from reduced oil production, refining, transport and fossil fuel powertrains, and lower price risk almost entirely offset the higher capital investment, compared with the business-as-usual scenario. In total, before considering stranded assets, the global transition would cost around US\$750 billion cumulatively for 2015–2035.

Regarding asset stranding, oil supply and demand curve modelling and analysis were used to demonstrate the impact of different policies. The impact of the transition on consumers as well as producers and the government was explored. The impact that lower demand would have

on benchmark, wholesale oil prices is far more important to producers as a group than lost production. But when prices fall, consumers benefit. The net cost or benefit to the economy is the net of costs or benefits to producers, consumers and government tax receipts.

The result depends on the chosen policy. If customers lose value through reduced consumption or from being forced to switch transport due to costs – for instance through higher consumption taxes – the economy loses out because of consumers’ loss of value. However, if innovative new and lower-cost transport options – perhaps developed through innovation policy – attract consumers away from oil-based transport, the economy wins. Including all of the cost elements, a purely tax or cost-based policy would cost the economy US\$2.5 trillion over 20 years while pure innovation would save US\$3.5 trillion. In practical terms, a mix of policies will be needed as higher prices are a major spur to innovation and tax receipts can be used to invest in innovation. Meanwhile, the more successful innovation is, the lower taxes will be needed to reach a low-carbon trajectory.

investment loss to 2015 was discounted to reflect the impact on the system.<sup>53</sup> For the power transition, asset stranding – or the decline in asset value which reflects potential reduced prices for ongoing production, as well as delayed or curtailed production resulting from the transition – is estimated at approximately US\$1.1 trillion.

Coal mining investments comprise the majority of lost value, with gas production assets accounting for a smaller part of the impact. The impact on power plants is relatively small, as there are available policies to manage coal plant stranding risk. The US\$1.1 trillion estimate is likely to significantly overstate the impact on financial markets as valuations currently seem likely to reflect some action towards reduced fossil fuel use, as discussed in Box 6.

Summing the above calculations, after accounting for the cost of finance and the one-time cost of asset stranding, the analysis shows that the transition would have a net financial benefit of about US\$1.8 trillion. However it should be noted that this is based on just one scenario, and that the IEA scenarios assume a significant increase in energy efficiency in the 2DS. The analysis has not attempted to value either the investment or operating costs of energy efficiency, except to note that much energy efficiency, if it can be achieved, has a net financial benefit, some, but not all, of which is reflected in the US\$1.8 trillion figure.

## 5. Addressing stranded asset risk and the cost to fossil fuel asset owners

### 5.1 Stranded assets and the capacity finance growth and investment

While capital expenses, operating expenses and even financial expenses have easily visible, tangible impacts on the flows of money within an economy, the effect of the final element of our impact analysis – stranded assets – can seem less obvious. The term “stranded assets” comes from the regulatory and economic concept where a change to technology, regulation or markets can leave assets “stranded”, reducing their usefulness and reducing or even eliminating their economic value.<sup>55</sup>

When the value of an existing asset falls, there is no obvious immediate cash impact on the economy. However, there is still an important impact on the ability of an economy to finance its growth and investment needs. Take the example of a homeowner whose house value falls 50%. After the price drop, the owner may no longer be able to borrow against the house to finance home improvements or even buy additional properties, and in the worst case, may no longer be able to pay off the debt. For the energy industries, stranded assets related to the transition could be particularly important if the very companies that are expected to finance the transition, such as electric utilities, are the ones who no longer have the financial firepower to

make new investments.

For the purposes of evaluating the impact of stranded assets on the financing of a transition, several concepts should be highlighted:

- **Value rather than output:** The financial impact of stranded assets is not about lost production, but lost value. For example, under our evaluation scenario, even oil producers whose output is unaffected by the transition could see the value of their oil production fall by up to 60% due to falling wholesale oil prices that result when demand declines.
- **A loss in wealth, not an ongoing cost:** Stranded assets are a one-time hit to expected or perceived wealth rather than an ongoing drain in expenses. It is this loss in wealth that could make it more difficult to finance the transition. The impact on the ability to finance the transition is thus roughly the same as a one-time, unexpected cash cost.
- **Expectations matter:** Since stranded assets affect markets through declines in expected wealth against which financing can be secured, expectations matter. If the market already expected the policy changes that would lead to a full transition, and further had included the impact of these changes in asset valuations, there would be no asset stranding impact on financial markets.

### 5.2 Economic modelling and scenario analysis to inform better policies

The impact of a low-carbon transition on asset stranding will depend on the starting point, the end point, and the process and trajectory of getting there. Thus, current market expectations, the ultimate shape of the transformed economy, and the policy, technology and economic paths followed during the transition determine the stranded asset impact, for it is these three elements that will define the surprise or adjustment that investors will need to make.

Describing these three more fully, it is possible to guess, but never fully know, what market participants are thinking based on interviews, asset prices and analysis. The set of assets and industries that comprise a future low-carbon economy can be envisaged, but many versions of that economy are possible, and new possibilities will continue to develop over time as new technologies develop and unforeseen advances and costs reductions are made. As for policy change and the shape of the transition, the Commission sees the evaluation of potential policy paths, including their impact and consequences, as one of the critical responsibilities of policy-makers worldwide.

To begin this process of evaluation and quantification of stranded assets and their impact, two scenarios are used

as starting points. The first scenario is based on business-as-usual, where no additional climate relevant policy action is taken. The second is based on the IEA's following – broadly consistent – low-carbon scenarios; the 2°C scenario (2DS) from the Energy Technology Perspectives 2012 modelling,<sup>56</sup> the 450 ppm scenario from the World Energy Outlook 2013,<sup>57</sup> and the 450 ppm scenario from the 2014 World Energy Investment Outlook.<sup>58</sup> The term 450 ppm refers to the level of greenhouse gases, in parts per million of carbon dioxide equivalent in the atmosphere, consistent with avoiding more dangerous climate change. Both of our scenarios are likely to overstate the impact of stranded assets:

- **The business-as-usual scenarios** are likely to imply higher asset valuations than current market expectations, as investors assume at least some policy action to curb greenhouse gas emissions. For example, major oil companies such as Exxon and Shell typically use reasonably high carbon prices in their investment evaluation process.<sup>59</sup> Furthermore, metrics that investors typically use to value companies, including price-to-earnings<sup>60</sup> (forward PE) and five-year growth expectations, show that markets expect industries like integrated oil and gas companies and electric utilities to grow more slowly than the market in general.
- **The scenarios based on IEA 2DS and 450 ppm** reflect a feasible path to a low-carbon economy based on current technologies. However, as technology and the economy evolve, new, low-cost carbon-reducing opportunities are likely to emerge, while existing ones will become cheaper. By reacting and selecting the set with the lowest cost, even the path all the way to 2DS is likely to become less costly, with different sets of asset stranding. For example, the rapid decline in solar PV pricing has exceeded expectations from just two years ago.

Thus, the business-as-usual and 2°C/450 ppm scenarios are not used as definitive numbers. They are used as guides with the following aims: to help quantify the potential impact of stranded assets; understand how asset stranding costs could be distributed; and identify the potential impact of policy on stranding and implications for policy-makers. For example, the results would be quantitatively but not directionally different had we modelled scenarios more consistent with 2.5°C or 3°C of global warming (i.e. 550 ppm rather than 450 ppm stabilisation levels).

### 5.3 Governments bear the biggest risk of value loss due to an energy transition

Stranded assets are often viewed solely from the perspective of investors and investor-owned companies. It is these investors, after all, who may not be able to invest in new assets once they find their balance sheets

weakened by declining asset values.

However, when assessing the impact on the global economy, governments and even consumers have an important part to play. A government that could no longer rely on oil exports earnings might find it harder to borrow money or invest in infrastructure. Thus, when examining stranded assets, producers, both investor- and government-owned, are considered first, and then in the case of oil, the analysis is extended further to consumers. After all, falling prices may impact an oil producer, but depending on how these flow through to retail prices they could benefit a consumer. A consumer with more cash in their pocket could spend or invest the money that could then flow back into more investment.

Beginning with producers, governments and government-owned companies own well over half of global fossil fuel assets by output and reserves. Even for those assets produced by commercial enterprises and owned by investors, governments typically extract significant value through royalties or taxes. Therefore, it is hardly surprising that governments, rather than investors, face the greatest risk of stranding, as shown in Figure 6.

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*Summing the above calculations, after accounting for the cost of finance and the one-time cost of asset stranding, the analysis shows that the transition would have a net financial benefit of about US\$1.8 trillion.*

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These figures only include the value that governments receive from exports and the taxes and royalties they garner from commercial enterprises operating in their own country. These numbers do not include the profits that governments make on their own consumers, as this is, essentially, just another form of taxation that could be replaced with other taxes with the same economic effect. In fact, many countries choose not to collect all of this profit, instead subsidising their consumers (by comparison with the world price). While they face 70% of the risk as measured by the difference in value between a business-as-usual scenario and a 2DS scenario, if the value that governments could make on their own consumers were to be included, the figure would be well above 80%.

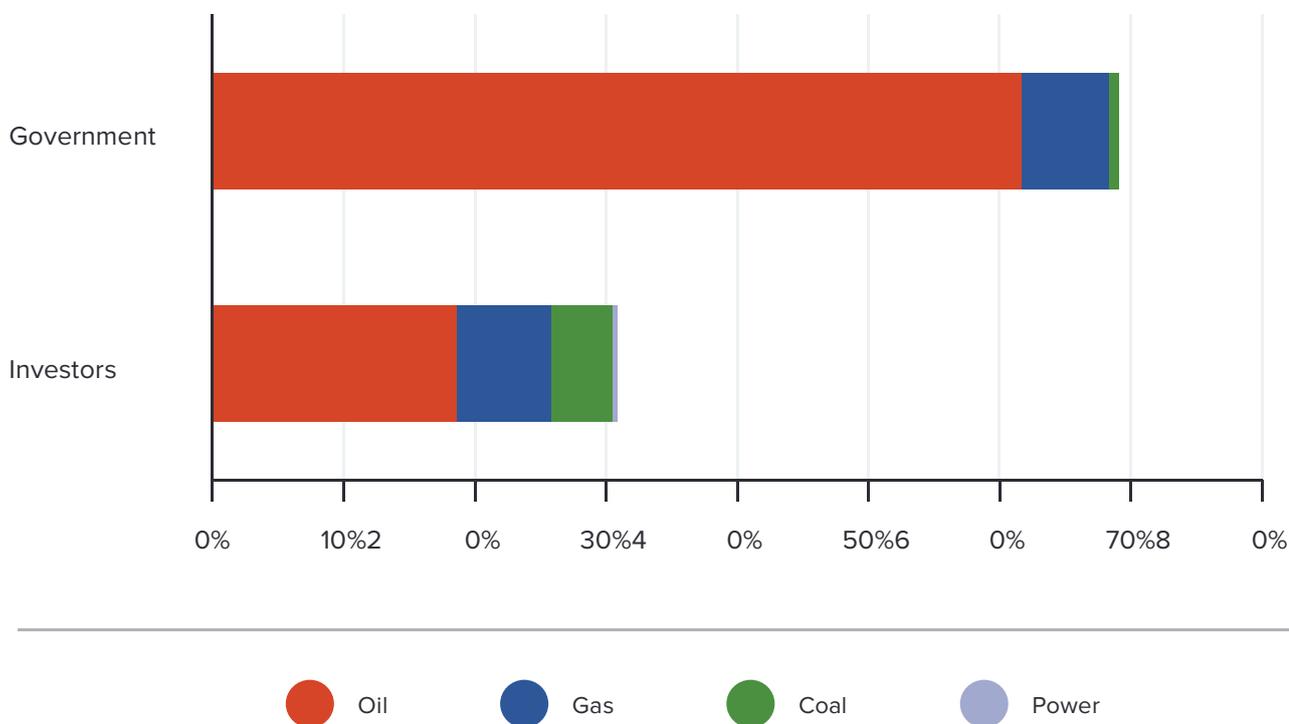
### 5.4 Stranding of coal: more carbon reduction for lower stranding risks

- Based on the stranded assets modelling conducted for the Commission, nearly 80% of the fossil fuel-related

Figure 6

## Governments lose more than private investors if fossil fuel consumption is reduced

SHARES OF FOSSIL FUEL VALUE AT RISK<sup>1</sup> FOR GOVERNMENT AND PRIVATE INVESTORS, 2015-2035



Source: Climate Policy Initiative modelling, based on data from Rystad and Platts.

CO<sub>2</sub> emissions reductions in low-carbon scenarios come from the reduction in coal production and use. This refers to the reduction in carbon emissions required to stay on a 2°C pathway. At the same time, coal only represents approximately 12% of the potential stranded asset cost. Therefore, if asset stranding is a major concern, then focusing on reducing coal use makes economic sense. Furthermore, approximately 70% of coal consumption is in the power sector. As outlined above, a low-carbon transition in the power generation sector could yield a net benefit to the global economy.

### 5.5 Coal-fired power plant risks compared with oil, gas or coal

Regarding the coal sector, coal-fired power plants may be stranded in addition to coal reserves. Here, asset stranding costs to meet the IEA low-carbon scenarios are comparatively even smaller, at just over US\$32 billion. All of this risk is in the developed world, as the IEA low-carbon scenarios include a modest amount of growth in coal-fired power plants in developing countries.

The risk for power plants is small for a number of reasons:

- Unlike coal, gas or oil there are no reserves to strand, only production assets.
- In the developed economies, recent air pollution legislation, such as the Large Combustion Plant Directive (LCPD) in Europe and the Mercury and Air Toxic Standards (MATS) in the US, has led to the retirement, or pending retirement, of coal-fired power plants. In these cases of retirement, the plant owners decided to close plants rather than invest in upgrades to reduce pollutants like SO<sub>x</sub>, NO<sub>x</sub> or particulates. This impact is shown in Figure 7.
- Some of the remaining plants in developed countries are old and without investing in life extension could be nearing retirement. It is assumed that all plants that have pollution control retire “early” at 60 years, while those that do not retire at 40 years. Based on the prevalent market prices for power, coal and other costs, it is calculated that the value that these plants forgo by not operating an additional 20 years, once life extension and maintenance costs are considered. In Europe, the additional value of these plants is

## Box 7

## Evaluating stranded asset risk for fossil fuel assets

Five data sources influence the calculation of the potential value at risk in any given sector: price, quantity, production cost, ownership and taxes. Below is a description of how the data were sourced for the analysis:

- Production cost, ownership and taxes are allocated based on commercially available data sources, such as the Rystad database of 66,000 global oil and gas fields and various other cost and ownership data sources.
- For the price and quantity of coal, gas and oil production, supply and demand modelling was developed to forecast which production would be curtailed because it is too expensive to operate under different scenarios and how prices in commodity markets would react to falling demand under a transition.
  - These supply models are based on aggregations of cash costs and investment costs from the same data sources, adjusted to account for the impact of sunk costs, transport costs, investment returns and in the case of gas, the interrelationship between oil and gas supplies.
  - The oil demand model is based on International Monetary Fund forecasts for country-by-country GDP growth, and historical multipliers for the relationship between GDP and oil

consumption in the absence of price changes. How demand would change for any given future price expectations is then forecast, based on a number of studies of oil sensitivity to price changes.

- Demand for coal oil, gas and power under the low-carbon scenarios is based directly on the IEA low-carbon scenarios..
- By comparing these demand estimates against the supply curves generated by the supply models, market price and which production assets will be needed in a given year can be estimated.

With this in hand, price minus cost is the value achieved per unit of production which can then be multiplied by quantity or output to define yearly profit. This profit is split between royalties and taxes and corporate profits, and then assigned the specific assets to companies and countries. Annual profits from 2015 to 2035 are then discounted to estimate value for any given asset. A discount rate of 8% is used to represent the return in the general market that the re-invested revenues from these assets could support were they not to be stranded. Higher or lower discount rates affect the headline number, but do not materially alter the relative impact and insight that this analysis brings. Finally, asset values are compared by owner between the business-as-usual and low-carbon scenarios to estimate the asset stranding impact on various players.

particularly small, since we assume that the market expects that carbon prices will return, over time, to 25 euros per tonne. As a result, some US\$28 billion of the US\$32 billion of stranding risk occurs in the US.

- Some of the plants that remain will be converted to low load factor, more highly flexible plants, and not therefore written off entirely. There are significant limits to the ultimate flexibility that can be achieved, depending on market design. The modelling

*Here, asset stranding costs to meet the IEA low-carbon scenarios are comparatively even smaller, at just over US\$32 billion*

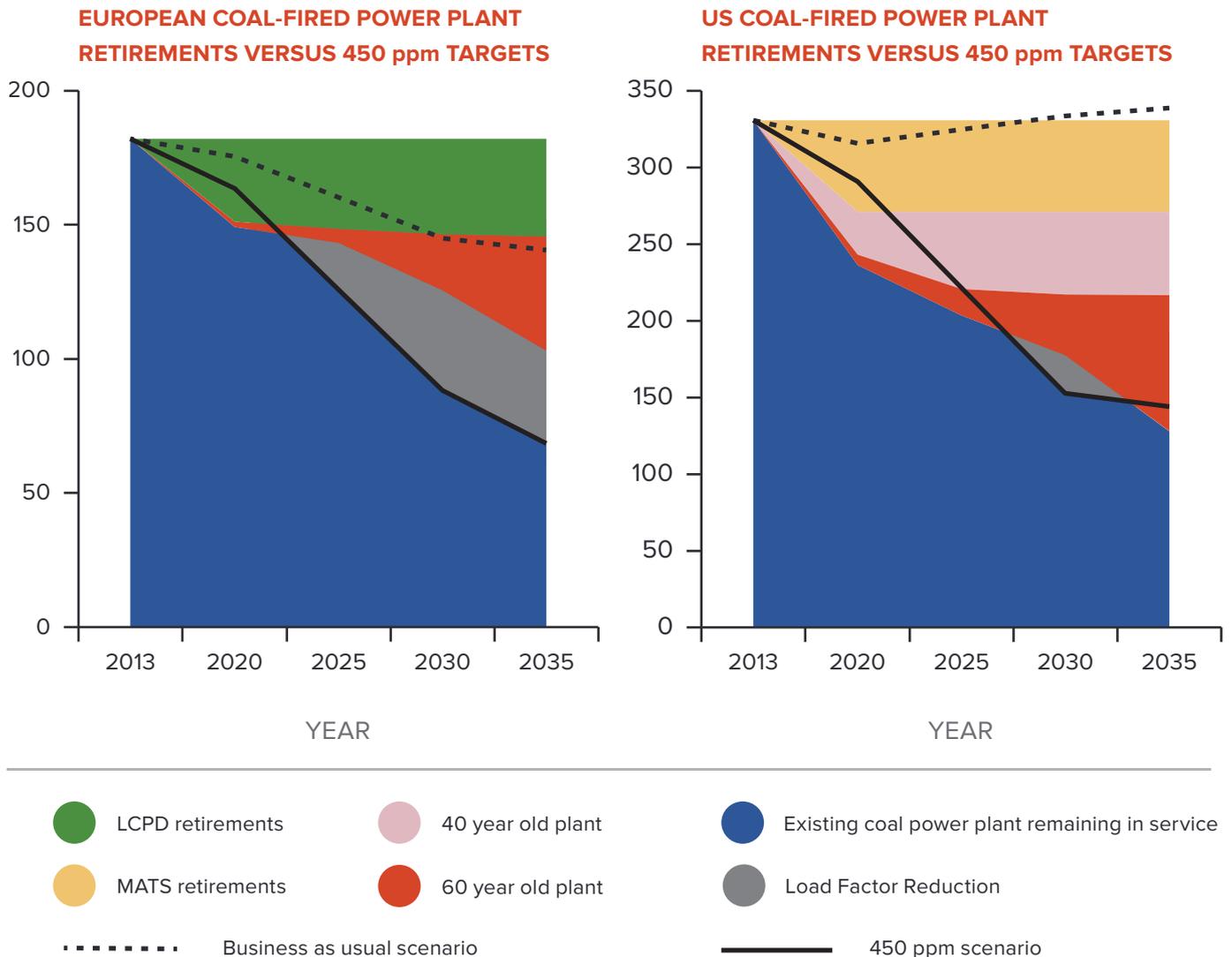
conducted suggests that some power plants may be able to maintain profitability in a renewable-heavy generation system by offering flexibility services in support of the renewable energy build-out.

While there need be no risk of stranding to existing assets in the developing world, building of additional, new coal-fired plants will pose a dilemma. These additional power plants would either lead to stranding of existing assets, or the world would miss its low-carbon targets. In other words, the largest risk facing coal plant owners is that additional plants, once built, will reduce the value of their plant. Within the context of the IEA 450 ppm scenario, Figure 8 demonstrates the dilemma facing rapidly growing countries, particularly China and India. The figure shows coal-fired power plants that are under construction or planned, based on the Platts power plant database and the IEA. In India and China, the plants under construction alone, if completed, would push these countries past the targets outlined in the IEA 450 ppm scenario. (Russia includes 3 GW of early retirement.)

Beyond the stranded asset risk, this analysis highlights the urgent need to develop low-cost, low-carbon alternatives, including energy efficiency and renewables, to avoid the need to build more coal-fired power plant to support economic growth. CCS technology would also allow for more build-out of fossil fuel generation without stranding assets.

Figure 7

## Current pollution regulation, retirements and load factor reductions are enough to meet IEA low-carbon scenarios for coal-fired power plant



Source: Climate Policy Initiative analysis, using data from the European Commission (LCPD retirement projections), IEA, and Platts

### 5.6 How policy can turn oil industry stranded asset risk into a net economic benefit

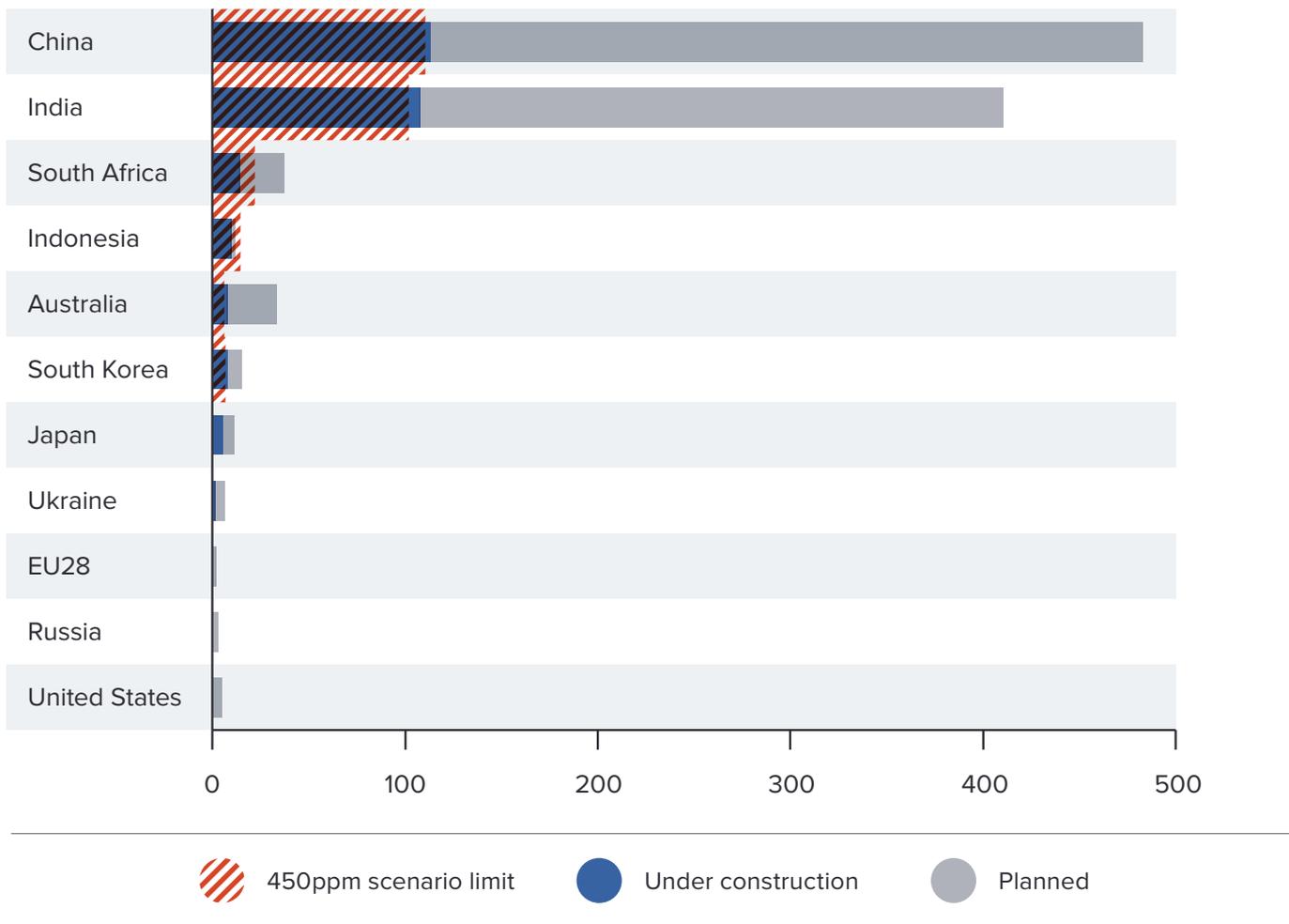
Nearly three-quarters of stranding risk lies in the oil industry. The risk is high partly because oil reserves are relatively large and continue to grow. The most important reason, however, lies in the global supply curve for oil and the relative sensitivity of oil prices to demand. As described in Box 6, we have modelled supply and demand for oil through 2035 as a function of the oil price. When oil demand falls, the most expensive new production is no longer needed and the remaining producers compete to sell oil into an oversupplied market. Prices are likely to fall as a result, notwithstanding the unusual structural characteristics of the global oil market.

To assess the stranding risk, the producer price for oil that would be consistent with output at the IEA 450 ppm

scenario levels was forecast. This was then compared with the forecast of oil demand and supply based on the analysis set out in Box 6. Additionally, the impact that the Organization of the Petroleum Exporting Countries (OPEC) members could have was modelled. It was found that given recent changes to non-OPEC supply and at these levels of demand, OPEC would be unlikely to be able to maintain, or benefit from, higher oil prices as the lost profit from production they would need to remove from the market would exceed the benefits of the higher prices.

This modelling demonstrates an important dilemma in the oil transition. If demand falls to the 450 ppm level, oil prices are likely to fall. By 2035, the 450 ppm price for oil could be less than half of our forecast for the business-as-usual scenario. This decline in price is the most important

Figure 8  
**Coal-fired power plant under construction and planned versus IEA 450 ppm scenario**



Source: Climate Policy Initiative analysis, using data from IEA, Platts

contributor to oil asset stranding risk. Indeed, our natural gas market modelling suggests that by 2030, low oil prices would also begin to suppress the price of liquefied natural gas and cause further risks there.

Yet, if prices were to stay low, and no other action was taken, demand would grow. The demand modelling suggests that prices would need to be almost 40% higher than the business-as-usual case to suppress demand to the 450 ppm levels. With higher prices, over time consumers would buy more efficient cars or electric vehicles and move closer to work, logistics chains would shift to reduce transport costs, and prices would spark innovation in new energy saving.

The question for the transition is how to bridge the gap between producer prices and consumer prices consistent with the lower demand. Two solutions emerge:

- Impose energy taxes (or in the case of many countries, remove subsidies) to give consumers price signals equivalent to that of higher commodity prices, while the resulting decline in demand leads to lower prices for producers; or,

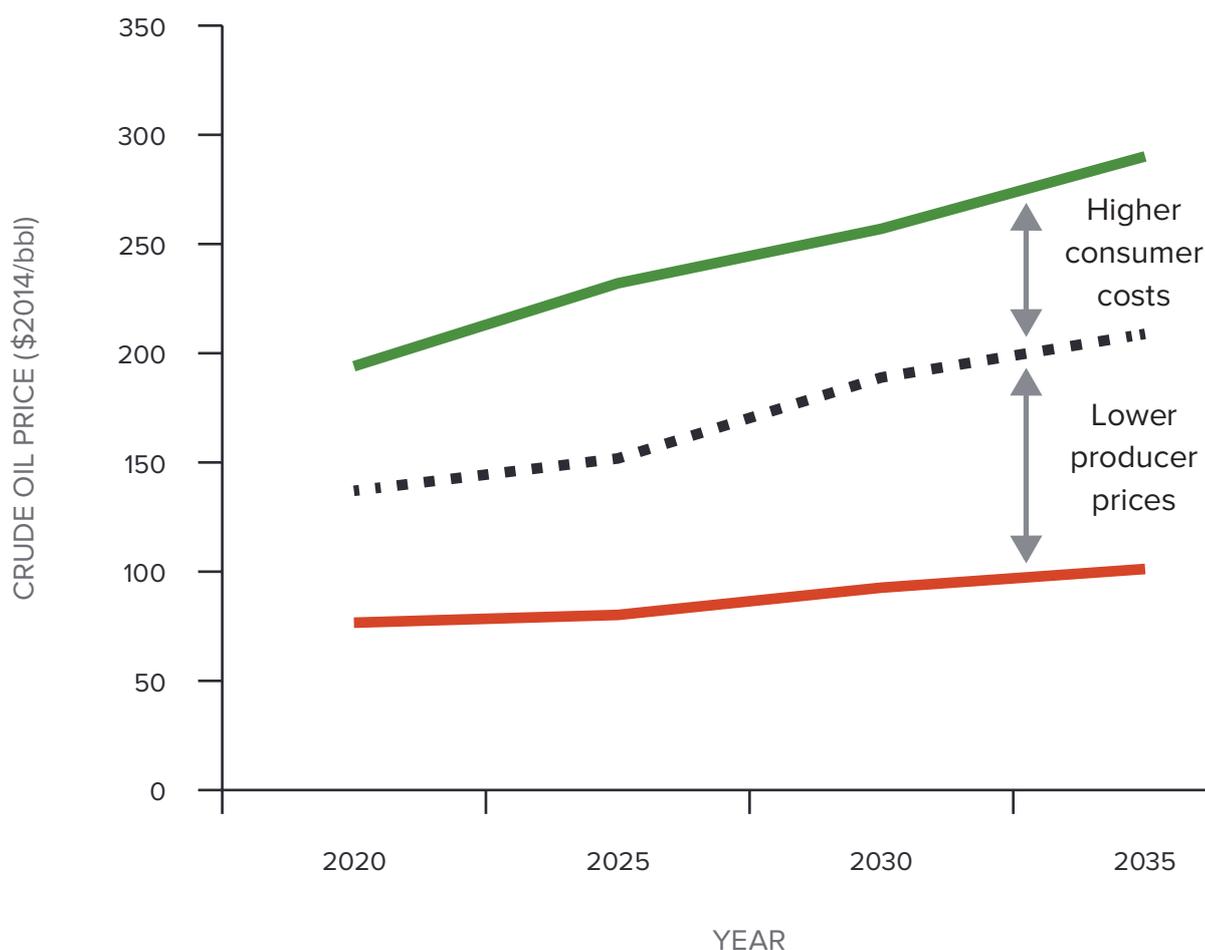
- Innovate to shift demand by creating low-cost or more attractive alternatives. Governments can induce innovation through several channels, including implementing financial incentives, imposing fuel economy standards, and sponsoring research.

For either of these solutions, the impact on the economy and investment extends beyond just the stranding loss faced by producers. With taxes, governments will benefit from tax receipts, while consumers will suffer from higher prices; although governments could, presumably, lower other taxes to compensate them for their higher costs. In the case of innovation, consumers will benefit from lower fuel prices, as even in the 450 ppm case oil demand continues at around 80% of today's level.

When taxes are the primary mechanism for consumption reduction, the net stranding impact – broadly defined to include governments, producers and consumers – amounts to US\$3 trillion of lost value.<sup>61</sup> This figure accounts for all of the investment required to make the transition happen on the consumer

Figure 9

### Consumer prices required to suppress demand to 450 ppm targets versus implied producer prices



- Consumer prices required to suppress demand to 450 ppm targets
- Producer prices if demand falls to 450 ppm targets
- Business as usual forecast

Source: Climate Policy Initiative analysis, using data from IEA, IMF and Rystad.

side as well as the producer side, as the consumer response inherent in our demand curves effectively value the trade-off that a consumer would see, for instance, in moving a warehouse closer to consumers to reduce transportation costs.

Alternatively, if innovation could spark a transition without the need for consumer trade-offs, taxes would not be needed and the benefits of lower fuel expenses to consumers would outweigh the stranding of producer assets by US\$7 trillion. Clearly, innovation is unlikely to be costless and some consumer trade-offs could be useful. This suggests that the eventual answer lies somewhere in

between. A mix of tax incentives and investments in innovation will lead the net stranding costs to lie somewhere between these two extremes.

#### 5.7 Investors face risks, but it is policy action that matters

While governments bear the majority of risk, the threat of asset stranding is real and could have a significant impact on overall investment performance. As in Box 8, many financial investors may choose to ignore the dilemma by maintaining equal weight positions – that is investments that reflect the share of fossil fuel in the overall market –

## Box 8

### Institutional investors manage their portfolios in ways that minimise stranding risk

Many institutional investors and sovereign wealth funds seek to maintain or grow their relative share of the global or regional economy. These investors diversify across the entire economy, owning shares of industries in correspondence to their weight in the market. They continually rebalance to maintain an equal weighted portfolio. For these investors, taking a position different from the benchmark constitutes a risk. Thus, owning less than the market share of the fossil fuel sectors constitutes a risk as much as having too much exposure.

If these investors are convinced that the market is underestimating the risk that policy will change, and therefore the oil and gas sector is overvalued, they might reduce their investments in the oil and gas sector, seeking to outperform the market based on this insight. If enough investors take this stance, the relative share prices of oil companies would fall and markets would rebalance. In this respect, current valuations reflect average market perceptions as to whether policies like taxation or innovation will be implemented, and how strongly.

The risk to investors is that they have over- or underestimated the impact and timing of the potential new policies, technology changes, or public opinion. Many investors avoid this risk by maintaining equal weight positions and then rebalancing their portfolios each time relative valuations change. An investor pursuing such a strategy would maintain their market-like performance. Only those investors who are overweight in sectors, especially those locked into illiquid, or difficult to sell, positions, would bear risk that policy change might accelerate. We note that many sovereign wealth funds in hydrocarbon-rich countries are already overly exposed to fossil fuels and derive new cash flows from their fossil fuel revenues; they would benefit from diversifying their investment portfolios away from hydrocarbons, and many are already doing so.

in the fossil fuel industry and avoiding illiquid assets that could trap them as policy changes.

Yet others may choose to bet that the market is not pricing all of the risk of the sector into asset values, and thus maintain little or zero exposure to the sector. Others may view the risk as being overstated by the market and thus increase their exposure to the sector. At the end of the day, it is policy that will drive the transition, and it is investors' views on policy development that will lead them to take a position on investing in the sector. Uncertainty around policy will lead to a wider range of investor views, which will, in turn, facilitate a divergence of views

amongst corporate investors in actual projects. Where there is a divergence of views, there will be a greater risk that corporate investors may invest in assets that could eventually be stranded.

The short and simple lesson is that policy ambiguity not only increases the medium- to long-term risk of significant asset stranding. It also affects short-term economic performance by reducing investment activity, including the creation of associated jobs; and it also adversely affects medium-term economic performance by limiting the productivity benefits that better energy infrastructure could have generated. Sending clear policy signals – possibly including an effective carbon pricing or energy tax regime and investments in innovation together with appropriate sectoral policies – is the most direct way to limit stranded asset risk and at the same time, to reduce investor uncertainty.

## 6. Recommendations

Investment in low-carbon energy can both strengthen economic growth and cut carbon emissions. Mobilising capital presents a challenge, however, because a low-carbon transition requires new and sometimes unfamiliar assets and policies. Low-carbon policies will also impact the value of existing assets.

The Commission makes recommendations to governments, financial regulators, and national and multilateral development banks along these two themes: how to stimulate low-carbon investment, and reduce the cost impact of stranded assets.

### 6.1 Stimulating investment in low-carbon assets

- **Provide long-term policy signals possibly including carbon pricing, resource pricing and regulation.** These will ensure that there is a robust business case to invest in a low-carbon economy. Further details of policies to reform asset pricing are provided in Chapter 5: Economics of Change.
- **Develop financing arrangements, industry structures and market designs that reflect the infrastructure characteristics of many of the assets underpinning the low-carbon transition.** These assets particularly include renewable energy and the electricity sector:
  - Develop commercial investment vehicles that provide investors direct access to low-carbon infrastructure including renewable energy. This contrast with the present model of investing as shareholders in renewable energy developers including utilities. These alternative investment vehicles, including YieldCos, municipal finance,

and crowd-funding, may reduce the annual investment return requirement by 1-2% and in so doing reduce the cost of renewable energy by up to 20%.

- Explore expanding direct financing of low-carbon infrastructure by regional, municipal and national governments, potentially using national infrastructure banks, infrastructure bonds, and green bonds to reduce capital costs. Such direct infrastructure finance also reduces renewable energy costs by as much as 20%.
- In middle-income countries facing high interest rate environments, replace all or a portion of support for low-carbon infrastructure, such as feed-in tariffs, with low-cost debt. This could reduce the total subsidy (including debt concession) by as much as 30% or more; reduce the cost of energy; and harness other benefits from renewable energy such as reducing foreign currency needs to buy imported fossil fuel.
- Develop or strengthen the capabilities of national development banks to perform this new role of providing low-cost debt to low-carbon infrastructure projects, while enhancing systems to ensure the efficiency of project selection and development. These banks may be an appropriate conduit for international financial flows into the industry.
- For low-income countries, continue multilateral and bilateral development bank assistance as a major source of investment and aid for energy system and infrastructure development. Enhance development cooperation to support country-led domestic policy and regulatory reforms that can strengthen enabling conditions for investment in energy infrastructure. These institutions should review their policies to ensure that development is consistent with a low-carbon transition, including the phase out of high carbon projects. Where needed, development finance institutions should be strengthened or created to support low-carbon financing.
- In both developed and developing countries, consider restructuring the electricity industry, market design, and regulation in accordance with the financial and operating characteristics of low-carbon infrastructure, and in so doing lower the cost of capital for low-carbon energy.

## 6.2 Reducing the cost impact of stranded fossil fuel assets

- **Develop transition arrangements that account for and minimise the impact of asset stranding:**
  - In all countries, focus on opportunities to reduce consumption of coal. Commission modelling suggests that coal represents an opportunity to achieve 80% of the emissions reductions under IEA's low-carbon scenarios with only 12% of total stranded asset value.
  - In high-income countries, avoid investment in coal-fired power plant, including new build and life extension. Retire existing plant at the end of their normal life or when major refurbishment would be required.
  - One exception to the no new investment rule would be investment designed to increase the flexibility of coal-fired power plant in ways that would support renewable energy and enable reduced operating hours of coal-fired power plant (and emissions) while maintaining profitability.
  - In emerging markets, slow down the construction and planning of new coal-fired power plant, as new-build plants could create a significant stranding risk to existing plants.
  - To maintain economic growth in rapidly developing countries while slowing growth in coal-fired power plant, there is an urgent need to develop and scale alternative technologies, low-carbon manufacturing capabilities, energy efficiency and low-cost financing arrangements to create viable and cost effective replacements for coal as an energy source.
  - In general, across all of the high-carbon investment sectors, the transition from the fossil fuel investment should be addressed by demand strategies. For example, oil use in transport should be gradually reduced through a combination of consumer taxes and innovation in alternatives and vehicle efficiency standards.
  - With oil-producing country governments facing the greatest asset stranding risk, there will be a need to address and manage the budgetary consequences of reduced demand and the falling oil prices that would result. This should include more rapid phasing out of current fossil fuel subsidies.

- For net consuming countries, policies used to reduce demand will need to be developed carefully, but the benefits to net consuming countries of lower fossil fuel prices and energy savings could create room for policies to smooth the transition and avoid significant distortions associated with asset stranding.

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53 Stranded asset values are discounted at an 8% return, reflecting typical average capital costs for fossil fuel companies invested in moderate to low risk assets.

54 IEA, 2012, Energy Technology Perspectives; IEA, 2014, World Energy Investment Outlook 2014; Platts World Electric Power Database, and Rystad UCube database.

55 This section summarises analysis presented in detail in: Nelson, D., Goggins, A., Hervé-Mignucci, M., Szambelan, S.J., Vladeck, T., and Zuckerman, J., 2014 (forthcoming). Moving to a Low Carbon Economy: The Impact of Different Transition Policy Pathways on the Owners of Fossil Fuel Resources and Assets. New Climate Economy contributing paper. Climate Policy Initiative, San Francisco, CA, US. To be available at: <http://newclimateeconomy.report>.

56 This term became particularly important in the restructuring of the electricity industry in the 1990s in the US and Europe, where changes to regulation were put in place to improve the efficiency of the industry, but the changes reduced the value of investments that had been made in reliance upon the previous regulatory regime. In this case, the stranded assets concept was often used to compensate investors for their losses and avoid what otherwise might be considered expropriation of assets.

57 IEA, 2012. Energy Technology Perspectives.

58 International Energy Agency (IEA), 2013. World Energy Outlook 2013. Paris. Available at: <http://www.worldenergyoutlook.org/publications/weo-2013/>.

59 IEA, 2014. World Energy Investment Outlook 2014.

60 Carbon Disclosure Project, 2013. Use of internal carbon price by companies as incentive and strategic planning tool: A review of findings from CDP 2013 disclosure. Available at: <https://www.cdp.net/CDPResults/companies-carbon-pricing-2013.pdf>.

61 The price to earnings ratio is the price of a company shares divided by earnings. Higher PEs generally reflect market expectations that a company's earnings will grow, making the company more valuable.

62 Note that the reduction in oil transport stranded asset value includes only that portion of oil consumption that is dedicated to transport; this figure includes all oil use.

