

# *Counting the cost of carbon*

## Low carbon economy index 2011

November 2011



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## Foreword

*This is the third edition of PwC's Low Carbon Economy Index, but may be the first where the data point unambiguously towards one conclusion.*

The results of the 2009 Index gave grounds for cautious optimism. We had got off to a slow start, no question. Since 2000, globally, we had improved carbon efficiency only 0.8% a year on average, against the 2% a year that was needed to reduce carbon by 80% by 2050 and so limit global warming to 2 degrees. So there was a low carbon challenge. We needed to step up our improvements in carbon efficiency. But the annual improvement needed at that stage was still only 3.4% per year, a figure that a number of nations had achieved over sustained periods. On top of that was the regulatory and investment stimulus expected from Copenhagen. It was all to play for.

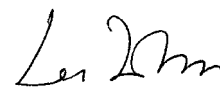
In year two, the case for optimism was less clear. Despite Copenhagen, against the 3.4% improvement needed, globally, we had only managed to achieve a 0.7% reduction in carbon intensity over the year, less than the 0.8% achieved in the previous year. Our rate of decarbonisation had slowed.

This year, 2011, the results are the starkest yet.

For the first time we have made no improvement in our rate of decarbonisation. We have in fact increased the carbon intensity of growth. The economic recovery, where it has occurred, has been dirty. Even where there has been growth in OECD countries during the global financial crisis, it has not been decoupled from carbon. The rapid growth of high carbon intensive emerging economies in this period, has also pushed up the average carbon intensity of the global economy.

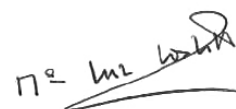
In sum, the 2011 PwC Low Carbon Economy Index shows that the G20 economies have moved from travelling too slowly in the right direction, to travelling in the wrong direction. The annual percentage reduction now required is 4.8% per year, a figure in excess of what has been proven to be historically sustainable. The results call into question the current likelihood of our global decarbonisation ever happening rapidly enough to avoid 2 degrees of global warming. But 2011 has thrown up a second challenge as well. The events of the Arab Spring have shown the social, economic and political necessity of delivering not just low carbon growth, but growth that delivers on the basic needs, including power, of the billions at the bottom of the pyramid.

It's around this emerging and complex challenge, delivering inclusive green growth at scale, that this year's Low Carbon Economy Index aims to give some context.



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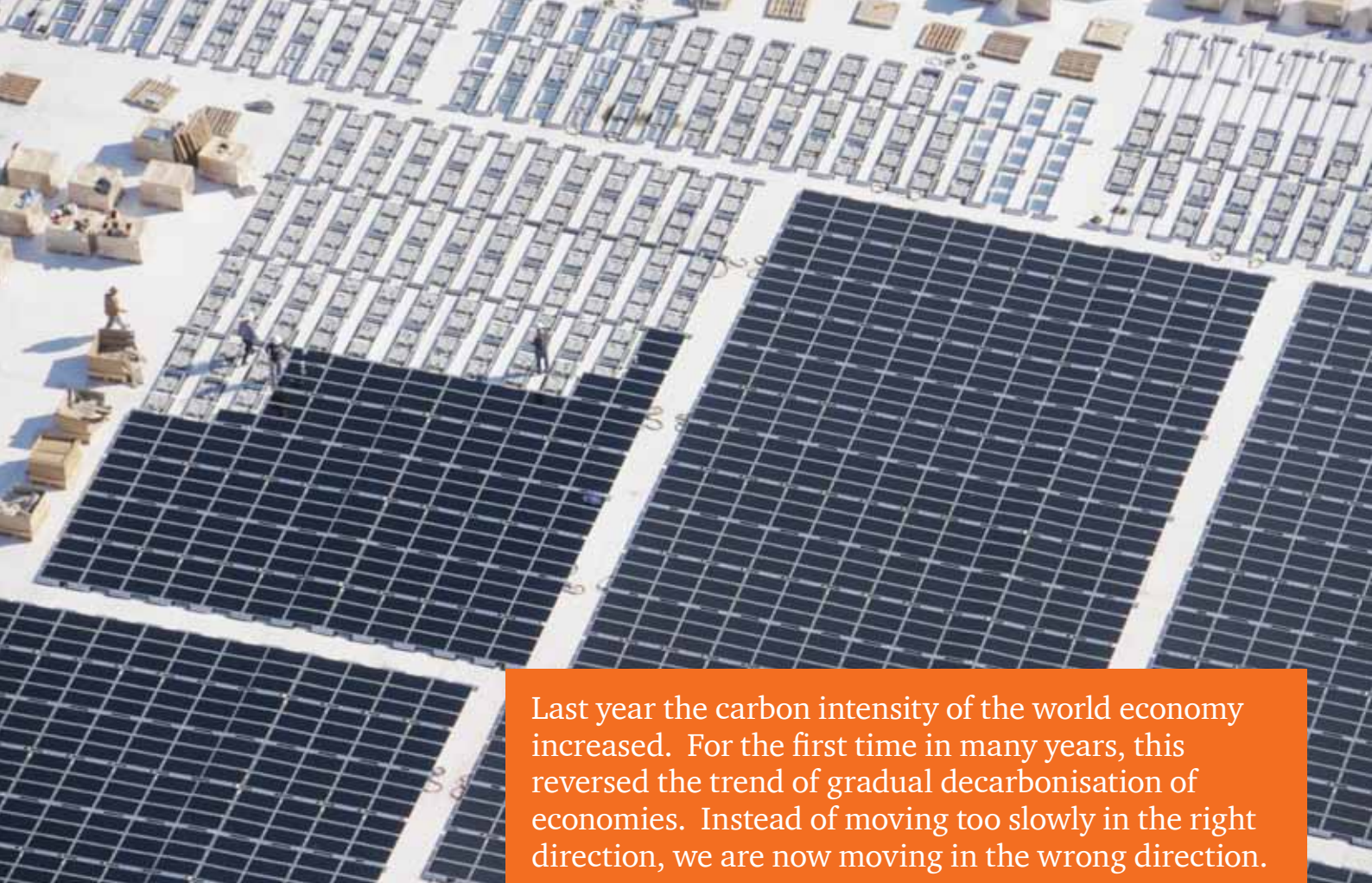
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## *Key Messages*

Last year the carbon intensity of the world economy increased. For the first time in many years, this reversed the trend of gradual decarbonisation of economies. Instead of moving too slowly in the right direction, we are now moving in the wrong direction.

Achieving the 2 degrees Celsius goal will now require reductions in carbon intensity of at least 4.8% every year until 2050. This compares with a 2% per year reduction in carbon intensity, to meet this goal, had we started in 2000.

It is only in exceptional circumstances that this rate of decarbonisation has been achieved in the past.

Many countries are trying to scale up the deployment of renewable generation. But their high cost and the financing challenge are significant barriers to the transition to a low carbon economy.

New approaches to financing and targeted support for renewable generation are needed to get back onto a low carbon pathway.

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# Low Carbon Economy Index

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## Introduction

Achieving the rates of decarbonisation needed to stay within the 2 degrees target agreed by governments in Cancun in 2010<sup>1</sup> requires a revolution in the way the world produces and uses energy. A transformation in financing will also be necessary to achieve the transition at the scale and speed needed.

PwC published the first Low Carbon Economy Index ahead of the COP15<sup>2</sup> in Copenhagen, 2009. This looked at the progress of the G20 economies against a 2000-based carbon budget estimated by PwC<sup>3</sup>.

Carbon intensity is our preferred metric for analysing countries' movements towards a low carbon economy, as it accounts for expected economic growth, and can generate comparable targets. The carbon intensity of an economy is the emissions per unit of GDP and is affected by a country's fuel mix, energy efficiency and the proportion of industrial versus service sectors.

Since COP 16 in Cancun, there has been an increasing focus on the cost of meeting the low carbon challenge and raising the capital required to finance it. This year's Low Carbon Economy Index focuses on this global financing gap and the reforms that might help to fill it.

In section one we present our analysis of economic and emissions growth and ask whether we are decarbonising fast enough. The second section asks are how much it will cost and can we afford it. We highlight the global financing gap, and focus on efforts to increase low carbon generation in the UK and South Africa. Our report concludes by outlining some steps that could be taken to help meet the low carbon challenge.

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1. Included in a COP16 decision for the first time  
2. United Nations Framework Convention on Climate Change (UNFCCC) Fifteenth Conference of the Parties  
3. See Appendix for details

## 1. LCEI results and analysis

In Cancun last year, governments agreed to limit global warming to 2 degrees Celsius. Achieving this will require deep reductions in GHG emissions as well as the decoupling of emissions growth from economic growth. In the last 10 years, most countries have reduced the carbon intensity of their economies – albeit too slowly (at on average 0.7% per year). In 2010, however, this decarbonisation trend went into reverse.

In 2010, in addition to global emissions reaching their highest level in absolute terms, the carbon intensity of the global economy increased by 0.6%; emissions rose faster than GDP growth coming out of the 2008-09 recession (5.8% versus 5.1%). Last year our modelling showed that a 4.7% reduction in carbon intensity globally was necessary to stay on the path to a low carbon economy in 2050<sup>4</sup>. This year, only a decarbonisation rate of at least 4.8% every year will meet the 2 degrees target. The longer the delay in significant action to tackle emissions growth, the steeper the path becomes to stay on track with a 2 degrees target.

There are two reasons for this dirty recovery. First, there was the rapid growth of developing economies with typically higher carbon intensities. Given their income levels, higher levels of carbon intensity are to be expected, and so their increasing prominence in the global carbon intensity index will increase the overall average.

More significantly, many of the G20 countries (both developed and developing) saw an increase in the carbon intensity of their economies in 2010: a dirty recovery for those economies that had been in recession in 2009. This trend towards higher carbon intensity may have several explanations including, the cold winters in the northern hemisphere at the beginning and end of 2010, the fall in the price of coal relative to gas, and a drop in renewable energy deployment.

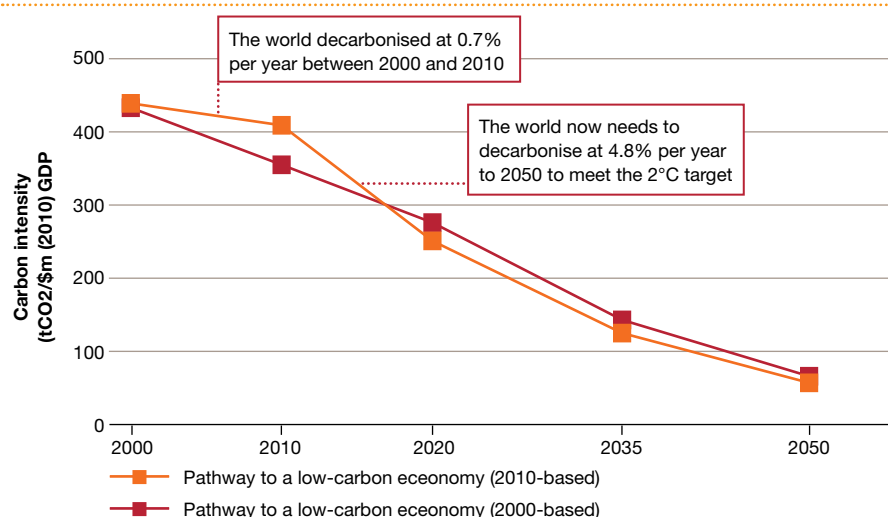
Table 1: Results of the Low Carbon Economy Index 2011 (G20 and Spain)

	Country	Growth in emissions	Real GDP growth (PPP)	Rate of decarbonisation	Low Carbon Challenge: decarbonisation rate to 2050
Reducing carbon intensity	Australia	-8.2%	3.0%	10.9%	4.9%
	Mexico	0.1%	5.5%	5.1%	4.5%
	Argentina	4.0%	9.2%	4.8%	4.7%
	Spain	-3.7%	-0.1%	3.6%	3.8%
	Turkey	6.2%	8.9%	2.6%	5.1%
	South Africa	1.6%	2.8%	1.2%	5.1%
	India	9.1%	9.7%	0.5%	4.0%
	Canada	2.6%	3.1%	0.4%	5.2%
Increasing carbon intensity	Italy	1.3%	1.3%	0%	4.7%
	France	1.5%	1.5%	0%	5.0%
	Germany	3.7%	3.6%	-0.1%	6.0%
	China	10.4%	10.3%	-0.1%	5.5%
	EU	1.9%	1.8%	-0.1%	5.2%
	Indonesia	6.6%	6.1%	-0.5%	4.5%
	World	5.8%	5.1%	-0.6%	4.8%
	US	4.1%	2.9%	-1.2%	5.7%
	Japan	6.8%	5.1%	-1.6%	5.3%
	Russia	6.1%	4.0%	-2.0%	6.5%
	Korea	8.4%	6.2%	-2.1%	7.0%
	UK	3.5%	1.3%	-2.2%	5.6%
	Saudi Arabia	7.0%	3.8%	-3.2%	6.3%
	Brazil	11.3%	7.5%	-3.5%	3.9%

Source: PwC analysis, BP Statistical Review of World Energy 2011, World Bank

4. This differs from the published figure last year (5%) due to revisions of historical data by BP and the World Bank

**Figure 1: Global Low Carbon Challenge (2010)**



Source: PwC analysis, BP Statistical Review of World Energy 2011, World Bank

Table 1 outlines these results, showing that only seven countries in the G20 reduced their carbon intensity in 2010.

The last column of Table 1 presents indicative targets for major economies as compared with a low carbon development trajectory modelled appropriately for each country (see appendix for our modelling methodology). This trajectory provides the baseline for our Low Carbon Challenge (LCC) index, which assesses the annual reduction in carbon intensity required by 2050. This low carbon pathway, at the global level, is illustrated in Figure 1.

In our model, different economic growth paths are set out for developed and developing economies. High-income countries are generally expected to have slower economic growth (around 2.1% for the G7), and reduce emissions in absolute terms. Developing countries are expected to have faster economic growth (around 5.5%) with economic growth progressively being decoupled from carbon emissions; total emissions are projected to rise at first and then slowly fall.

This year's results do not fit with this picture of economic and carbon growth. Not only did six of the G7 countries increase their carbon intensity, but the one that did reduce its carbon intensity – Canada – still increased its total emissions by a significant amount (2.6%). There were more encouraging signs in the E7. India made some progress with decoupling carbon from economic growth (achieving a 0.5% reduction in carbon intensity). But in China, emissions roughly kept pace with economic growth.

In Spain, it is similarly likely an unprecedented effort will be required to decarbonise its economy over the decades to come. Spain decreased its carbon intensity last year by 3.6%: one of the highest rates in Europe. With this rate of decarbonisation, Spain finds itself broadly aligned towards the 2050 target for not exceeding a 2 degree temperature rise (3.8%). However, this rate needs to be sustained every year to 2050. Further, the long-run emissions of Spain remain above its Kyoto target of a maximum emissions increase of 15% from 1990 levels in the period 2008 – 2012. In 2010 the level was 25%, down from 30% in 2009, but still significantly above the target.

There were some exceptions:

- Australia showed remarkable progress, with solid growth (3%) accompanied by a record fall in tonnes of carbon emitted (8.2%).
- Mexico showed evidence of decoupling in 2011, attaining high economic growth (5.5%) with near-zero emissions increases (0.1%).
- Argentina may also be starting to decouple, with breakneck growth (9.2%) matched by only a moderate increase in emissions (4%).

The results from these countries do show that an annual rate of decarbonisation of 4.8% is possible, but it will be extremely challenging to sustain this every year in every country till 2050.

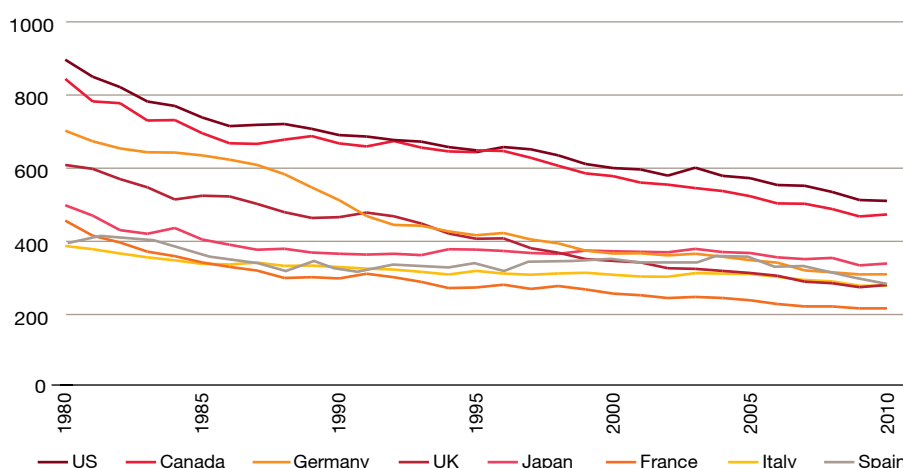
We can also put the 4.8% target in the context of the past thirty years. Over the period 1980-2010 the carbon intensity of economies globally declined on average at 1.3% a year (in purchasing power parity terms). This figure masks much variation between decades and countries. Figures 2 and 3 show changes in carbon intensity over the past 30 years, for individual countries in the G7 and E7 respectively. Of the G20 countries, there are six that have decarbonised their economies by an average of at least 3% per year in at least one decade: China, Russia, Germany, France, Japan and the United Kingdom (see Table 2). China is the only country to have reduced the carbon intensity of its economy by over 4.8% per year over a decade.



There are two key messages from this analysis. First, over the whole period, no country has sustained decarbonisation rates even approaching the 4.8% that is now required. With the exception of China in the 1990s, none of the G20 countries has achieved the 4.8% reduction in any decade since 1980.

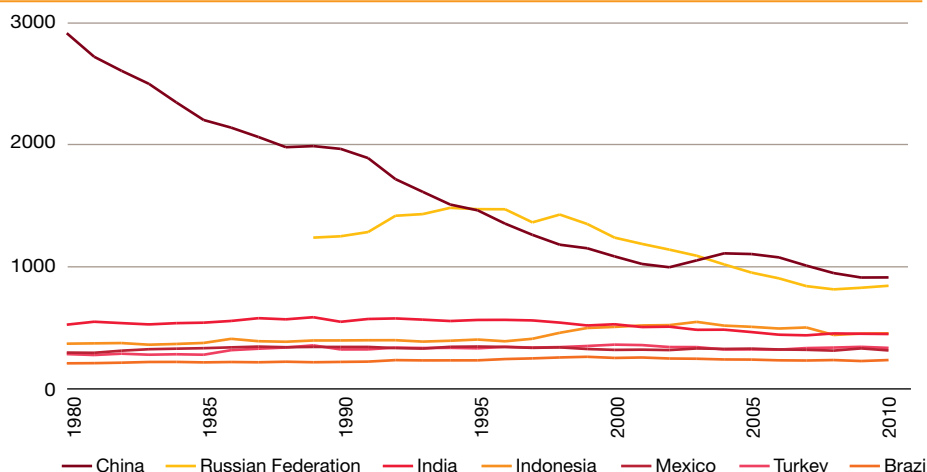
Secondly, the six countries that did reduce carbon intensity by more than 3% during individual decades have done so in unique circumstances only. For example, among the developed countries, France decarbonised at 4.2% during the 1980s by increasing the share of nuclear in the energy mix from 7% to 33%<sup>6</sup>(see Figure 4). It is debateable whether this can be replicated by other countries, especially following the nuclear disaster at Fukushima earlier this year (see Box 1). The UK decarbonised at 3.0% in the 1990s during a ‘dash’ for gas power generation that replaced coal generation (see Figure 5).

**Figure 2: Carbon Intensity of the G7 and Spain 1980-2010 (tCO<sub>2</sub>/\$m (2005 PPP))**



Source: PwC analysis, BP Statistical Review of World Energy 2011, World Bank

**Figure 3: Carbon Intensity of E7 1980-2010 (tCO<sub>2</sub>/\$m (2005 PPP))**



Source: PwC analysis, BP Statistical Review of World Energy 2011, World Bank

**Table 2: Highest decarbonising economies in the G20 1980-2010**

Country	Annual decarbonisation			
	1980-2010	1980-1990	1990-2000	2000-2010
China	3.8%	3.9%	5.8%	1.6%
Germany	2.7%	3.1%	3.3%	1.6%
United Kingdom	2.6%	2.7%	3.0%	1.9%
France	2.5%	4.2%	1.5%	1.6%
Russia <sup>5</sup>	1.5%	n.a.	0.1%	3.4%
Japan	1.3%	3.1%	-0.2%	0.9%

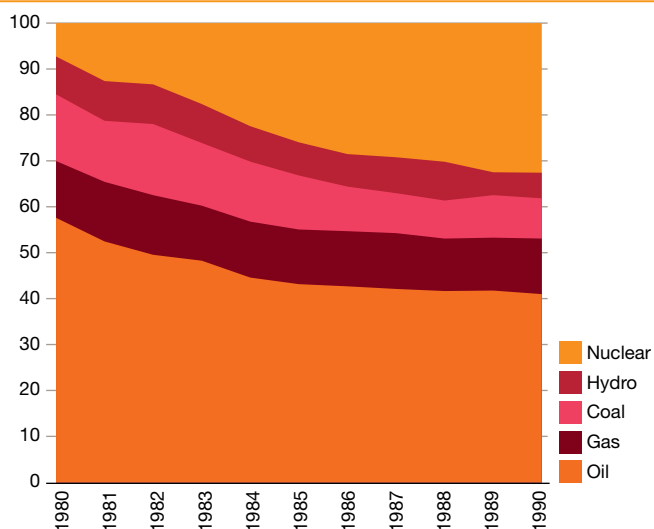
Source: PwC analysis, BP Statistical Review of World Energy 2011, World Bank

5. Data for Russia cover 1989-2010

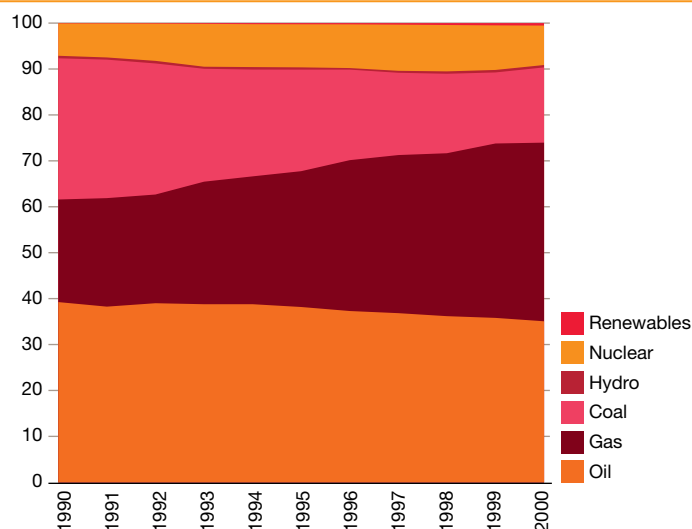
6. Source : PwC analysis, BP Statistical Review of World Energy 2011



**Figure 4: Decarbonising at 4.2%: France's changing energy mix in the 1980s**



**Figure 5: Decarbonising at 3%: The UK's dash for gas in the 1990s**



Source: PwC analysis, BP Statistical Review of World Energy 2011

### Box 1: *Decarbonising after Fukushima*

On 11th March 2011, an earthquake measuring 9.0 on the Richter scale struck off the Eastern coast of Japan. The damage to Japan's nuclear infrastructure from the resultant tsunami was significant, with the Fukushima plant still down eight months later and concerns about the long-term safety of nuclear power lingering. National policy decisions regarding nuclear energy made in response to the earthquake and damage at the Fukushima Daiichi power plant have been mixed. In the short term, a number of countries, including Japan, Italy and Venezuela, have delayed plans for nuclear power generation; at least until safety lessons from the event can be learned. Germany has closed seven of its oldest plants with immediate effect and has stated that nuclear power generation in the country will cease by the end of 2022. While Switzerland announced that the country's five ageing plants will not be replaced and therefore nuclear generation will cease in 2034.

Although current reports suggest that the incident will slow, rather than stop nuclear energy growth, the immediate closure of nuclear plants and impact on future decisions will have a knock on impact on reducing global carbon emissions. In the short term, the loss of 7GW of German capacity would require nearly doubling the country's renewable energy generation to avoid increases in carbon emissions. Japan has already increased global demand for Liquefied Natural Gas, with Japanese LNG imports up 20.9% year-on-year in April<sup>7</sup>. The knock-on, short-term effects of these developments on the global fuel mix and emissions are highly uncertain at this stage, but likely to be substantial.

In the longer-term though, some commentators are downplaying the impact, with Germany considered in a minority in terms of policy response. The International Atomic Energy Agency only reduced its baseline estimate for nuclear capacity in 2030 by 45GW. Only an additional 4% of global renewable generation would be required to fill this gap, which is equivalent to Italy roughly doubling its renewable generation<sup>8</sup>.

7. IHS Global Insight (October 2011) "Japanese utilities prepare to step up LNG imports to meet summer electricity demand"

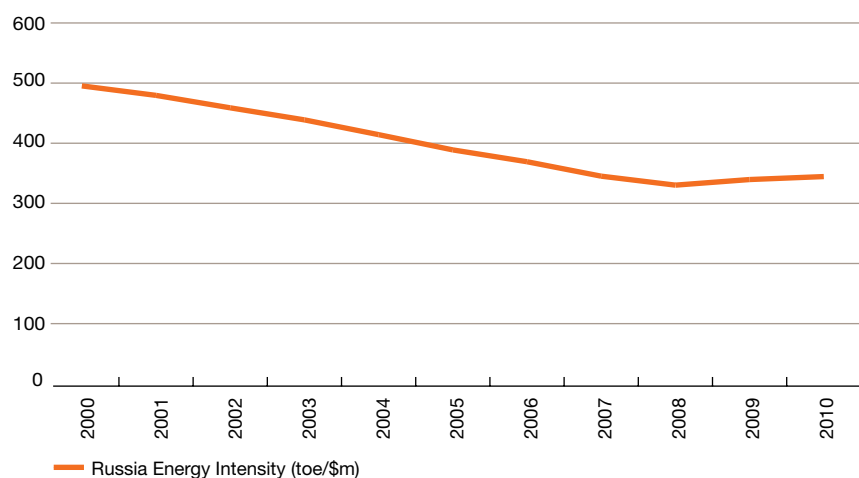
8. Source: PwC Analysis, BP Statistical Review of World Energy, New Europe Energy online : "IAEA lowers nuclear growth forecast after Fukushima". Assumes 80% nuclear capacity factor.

In the developing countries, China decarbonised the most quickly, notably attaining an average decarbonisation rate of 5.8% per year during the 1990s. This was driven by significant improvements in energy efficiency and a shift towards services rather than changes in the fuel mix (see Figure 7). Yet China had a very high starting point: in the 1980s China's carbon intensity was five times higher than the other E7 countries (with the exception of Mexico). The adoption of good energy management practices, alongside rapid economic growth (as high as 14.2%) and the development of the service sector, simply helped bring this closer to the international average. Even after this period of decarbonisation, China's carbon intensity still remains more than double most other G20 countries.

Similarly, there are particular circumstances which explain Russia's economic and emissions trajectories – especially in the 2000s. Russia benefitted from very rapid economic growth in the 2000s of 4.5% per year, but this was, in part, driven by the increasing value of Russia's oil exports, which results in emissions in other countries.

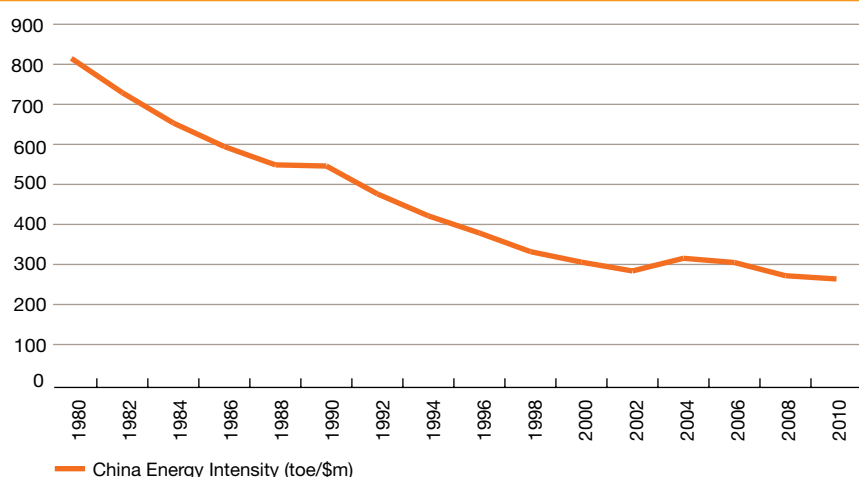
In summary, the results of the Low Carbon Economy Index this year suggest that the move to a low carbon economy will be a huge challenge, albeit one that has been achieved in exceptional circumstances in some countries in the past. Historically, rates of over 4.8%

**Figure 6: Russia's energy intensity 2000-2010 (toe/\$m GDP)**



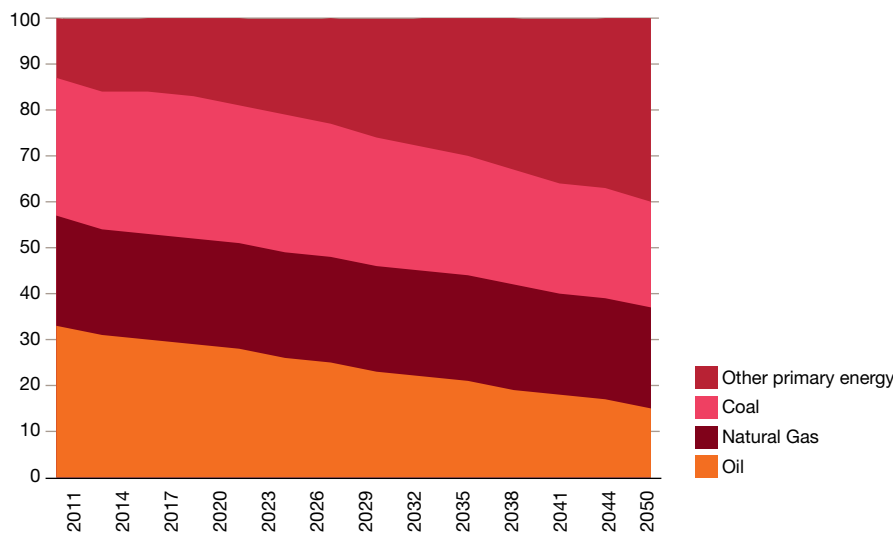
Source: PwC analysis, BP Statistical Review of World Energy 2011

**Figure 7: China's energy intensity 1980-2010 (toe/\$m GDP)**



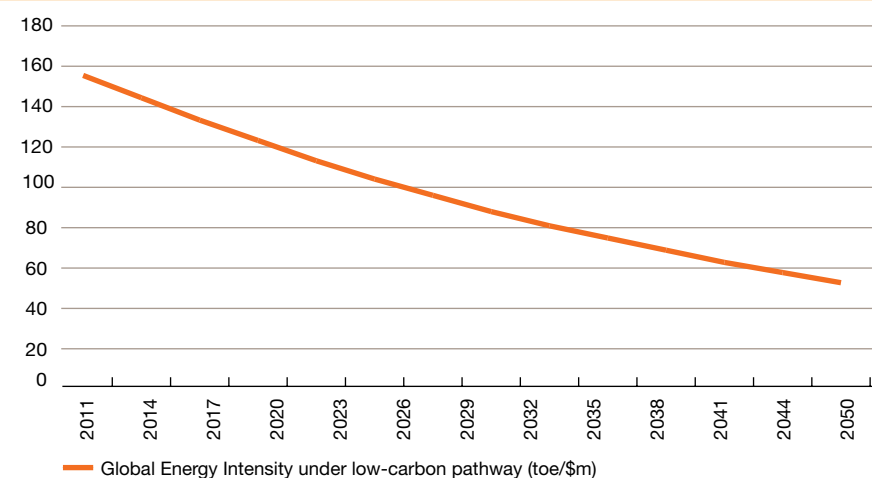
Source: PwC analysis, BP Statistical Review of World Energy 2011

**Figure 8: Low carbon pathway; required changes in the fuel mix (consumption)**



Source: PwC analysis

**Figure 9: Low carbon pathway; required changes in energy intensity**



Source: PwC analysis

have been attained, and this year several countries exceeded the decarbonisation goal required to limit warming to 2 degrees. However, to consistently achieve 4.8% per year to 2050 will require a revolution in energy supply and use.

To stay within the carbon budget, our model suggests how the fuel mix may have to change and how much energy intensity has to fall over that period (see Figure 8 and Figure 9). Nuclear and renewable generation will need to account for around 40% of the energy mix by 2050, and carbon capture and storage will be required for much of the remaining 60%.

In Spain, PwC expects private companies and public authorities will generate both carbon intensity targets and absolute emissions targets. Absolute targets are necessary because the atmosphere's capacity is ultimately limited. Likewise, carbon intensity targets and reporting are essential to offer clarity regardless the influence of economic cycles, turnover and acquisitions. Companies and countries that introduce carbon intensity targets will no longer feel constrained in growing at the expense of less carbon-intensive competitors even though this hurts their absolute emissions targets.

The remainder of this report discusses how much this might cost, and how this transition might be financed.

## 2. The financing gap

The results of this year's Low Carbon Economy Index suggest that the world as a whole is following a business-as-usual path, with growth still coupled to carbon emissions. Clearly, a critical factor is the high cost of low carbon energy, and the difficulty of raising finance for innovative low carbon business models.

The World Economic Forum and Bloomberg New Energy Finance put this incremental low-carbon funding requirement at \$500 billion per year by 2020<sup>9</sup>. In comparison, actual clean investment last year was estimated at \$243 billion<sup>10</sup>, less than half the amount required. Hitting the 4.8% per year decarbonisation target will require a substantial scaling-up of low carbon finance.

There are promising signs of new sources of finance. Following the Copenhagen Accord, developed country governments have pledged to increase funding to tackle climate change in developing countries, from around \$10 billion each year today to \$100bn per year by 2020.

Private investors are also increasingly aware of the investment opportunity; last year's \$243 billion investment in clean technology was a historical record<sup>11</sup>, and the number of global renewables deals rose by two-thirds year-on-year<sup>12</sup>.

However, the gap between the \$243 billion and the required \$500 billion will be hard to fill. Although the number of global renewables deals was up two-thirds between 2009 and 2010, their total value fell from \$49 billion to \$33 billion. It seems questionable whether the world will be able to more than double clean energy investment by 2020.

In this section, we present case studies of two countries, South Africa and the UK. Both are reforming their energy markets in order to meet the low carbon challenge. We outline the challenges they face in doing this, and in section three, make recommendations for financing a low carbon economy.

### 2.1 The UK

The UK government has estimated that the low-carbon investment required in the power sector by 2020 is in the order of £89 billion (see Figure 10). This amount is additional to the £110bn required to simply meet energy needs with coal and gas. Costs will largely be recouped through consumer bills: average energy bills under the green transition were forecast by Ofgem to increase from 2009-2020 by around £360, to £1450 (although bills were

forecast to rise by a similar amount anyway due to rising wholesale prices and reduced energy efficiency)<sup>13</sup>. Rising bills alone though, will not guarantee that enough capital will be invested in time to meet the government's 2020 climate targets; there remains the possibility of a financing gap.

Current annual capital expenditure by the Big 6 utilities in the UK (E.ON, RWE npower, SSE, Scottish Power, Centrica, and EDF) and National Grid would need to triple to reach the government's target. Given that the sector is by its own account, highly 'leveraged'<sup>14</sup>, it is unlikely to be able to significantly ramp up investment. And the UK is also not the only European country with a high funding requirement. The German Government, for example, has estimated that EUR200billion is required annually to meet its *Energiekonzept* 2050 targets<sup>15</sup>.

Alternative forms of funding have the potential to fill this finance gap. It has been suggested to the Electricity Market Reform committee that pension and insurance funds will contribute significant chunk of the finance<sup>16</sup>. But, for these players to invest in UK PLC, green technologies must provide a stable return with limited downside risk. We examine how this challenge will be met in section three.

9. World Economic Forum and Bloomberg New Energy Finance (2011) Green Investing 2011: Reducing the Cost of Financing

10. Bloomberg New Energy Finance, excludes M&A activity

11. Bloomberg New Energy Finance. Note that public sector finance played an "unprecedented" role in supporting this figure.

12. PwC Renewables Deals (2011)

13. Ofgem (2009) Project Discovery Energy Market Scenarios

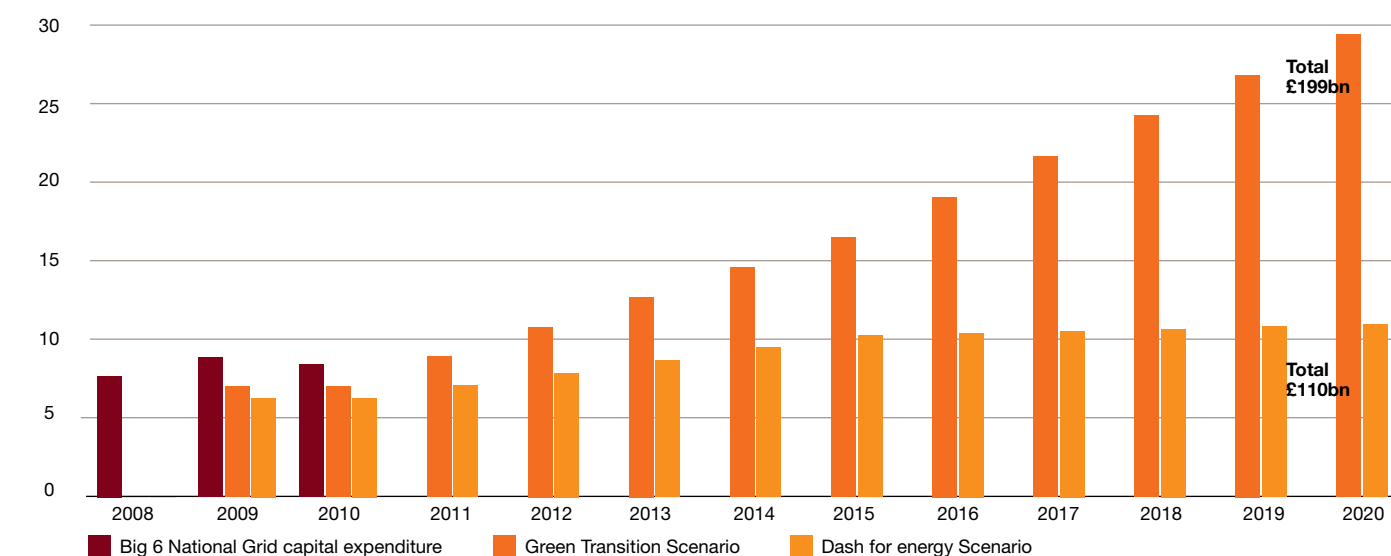
14. House of Commons Energy and Climate Change Committee : Electricity Market Reform : Fourth Report of Session 2010-12

15. BMU "Energy concept for an environmentally friendly, reliable and affordable energy supply" (2010)

16. House of Commons Energy and Climate Change Committee : Electricity Market Reform : Fourth Report of Session 2010-12



**Figure 10: Ofgem's investment forecasts under low-carbon and fossil-fuel based scenarios, as compared to historical UK capex by National Grid and the Big 6**



Source: PwC analysis, company financial statements. Capex defined as relevant additions to PPE, includes intangible assets for RWE npower and Scottish Power.

## 2.2 South Africa

In South Africa, the government has outlined its ambition to hit a target of 17.8GW of renewable capacity by 2025. This would represent 9% of total generation (its current share of renewables is 0.2%)<sup>17</sup>. Based on estimates of the levelised cost of generation of different renewable technologies, the government has introduced a subsidy regime of Feed-in Tariffs (ReFIT) to encourage renewable generation.

As is shown in Figure 11, the extra cost of generation is significant. The government will have to pay over five times the current electricity retail price to incentivise solar photovoltaic generation. Even the cheapest technology, biomass, will be subsidised at twice the current retail price.

While this has been successful in attracting renewable energy developers (a Request for Interest in 2010 attracted 384 responses<sup>18</sup>), it could cost up to \$324/MWh for the government compared to procuring electricity generated mainly from coal from the state-owned utility, Eskom (see Figure 11). The World Economic Forum stated that meeting the country's goals for

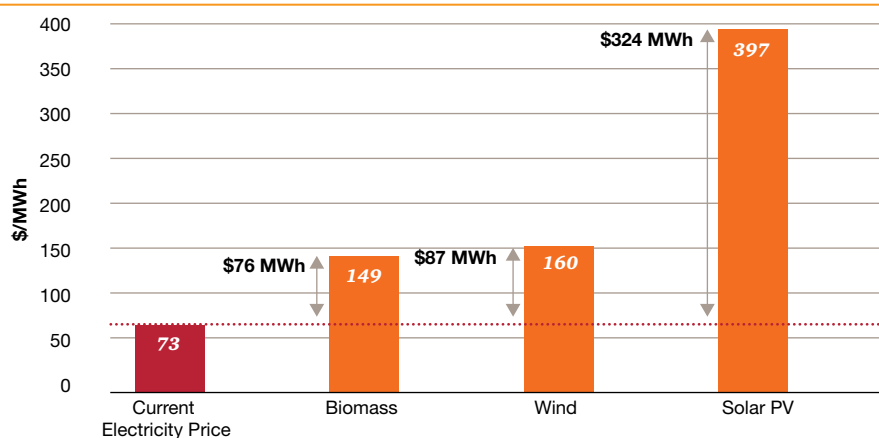
renewable capacity by 2025 will cost significantly more than the alternative of relying on coal-based generation. They suggest that this will be "in excess of what would be domestically affordable"<sup>19</sup>.

As both these case studies illustrate, in both the developed and developing world, low carbon energy can be expensive. Even where policy offloads this cost to the consumer or the taxpayer, attracting private investors is a challenge. In Section 3 we consider

ways of meeting both the cost and finance challenges.

As both these case studies illustrate, in both the developed and developing world, low carbon energy can be expensive. Even where policy offloads this cost to the consumer or the taxpayer, attracting private investors is a challenge. In Box 2 we outline similar challenges being faced in Spain. In Section 3 we consider ways of meeting both the cost and finance challenges internationally.

**Figure 11: South Africa's payments for renewable generation under the ReFIT programme (maximum), versus the current regulated electricity price (2010-11)**



Source : PwC Analysis, Norton Rose, NERSA, ZAR:USD FY2010/11 average .

17. South Africa Integrated Resource Plan

18. Dewey and LeBoeuf (March 2011) "South Africa's Refit Programme to Launch Imminently Following Finalisation of 20-Year Electricity Plan"

19. WEF (2011) Scaling up low carbon infrastructure investments in developing countries – The Critical Mass Initiative. This calculation is based on an updated target of 20GW by 2020 set by the Ministry of Trade under the South Africa rather than DoE capacity targets for 2030

### Box 2: **Renewable Energy in Spain**

In 2010, the decarbonisation in Spain was driven mainly due to a shift in the fuel mix away from coal and towards renewable and assisted by the limited economic activity. In Spain the share of renewable energy in total primary energy use in 2010 was more than 11% (up over 20%) – notably assisted by an especially productive year in hydropower.

Spain follows the overall EU's 20-20-20 targets for emissions reduction, use of renewable energy and reduction in energy consumption. To achieve these targets Spain has established a number of new initiatives including:

- The Climate Change and Clean Energy Strategy for Spain 2007-2012-2020: incorporating 198 measures and 75 indicators relating to energy use and emissions as well as climate adaptation.
- The Indicative Energy Plan 2012-2020: a forecast of future demand and the resources to meet the changing market conditions to ensure supply and achievement of environmental objectives.
- The Renewable Energies Plan 2011-2020: designed to increase the contribution of renewables to 20.8% in 2020.

The new Renewable Energy Plan details the expected growth by renewable source. Three sources: geothermal, wave/tidal energy and offshore wind are new areas to be developed. Of the other sources solar thermoelectric is expected to see the largest rate of growth.

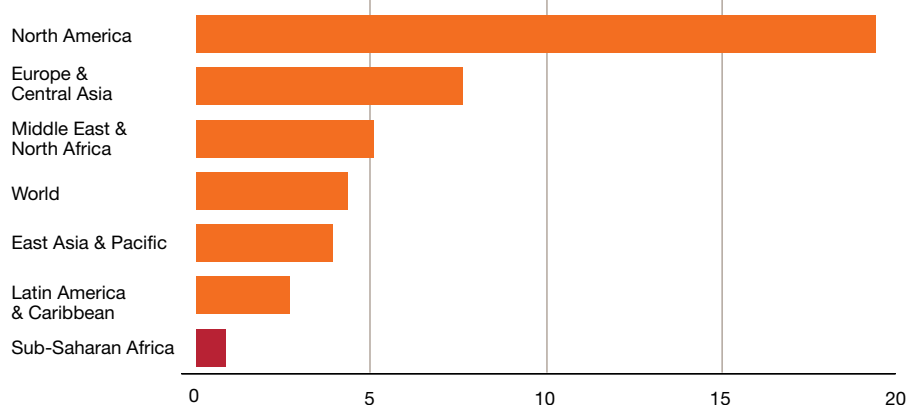
The real challenge for Spain will be maintaining current levels of decarbonisation when the economy recovers. The new renewable plan and Spain's potential for renewable generation and leadership can help achieve both goals of decarbonization and growth.

### 3. Moving towards the low carbon economy

The two main challenges in increasing low carbon generation are the high cost and getting the capital to flow to low carbon options instead of towards conventional technology. There are three areas where countries can focus their attention to address these challenges:

1. 'Win-win' opportunities, typically in off-grid situations where the conventional generation is higher cost.
2. Removing regulatory and infrastructure barriers to profitable low carbon business.
3. Using innovative models of finance to attract capital to low carbon business.

Figure 12: Average carbon emissions per capita, 2000-2007 (tCO<sub>2</sub>)



Source: World Bank (2010)

#### 3.1 Win-win opportunities

The trade-off between cost and carbon is not inevitable. In the developing world, where countries do not have an existing high carbon infrastructure, there are opportunities for 'win-win' investment: cost competitive and low carbon energy.

This opportunity for renewables is particularly evident in Sub-Saharan African countries that do not have large scale grid infrastructure and coal or gas fired power stations. Current emissions per head that region are extremely low, less than one-quarter of the global average, and a twentieth of the average in North America (see Figure 12). Ensuring that future demand for energy in Africa does not result in higher future emissions is a key part of ensuring the global Low Carbon Challenge of 4.8% per year is met.

This lack of incumbent high carbon infrastructure now provides an opportunity for cost competitive low carbon generation in these developing

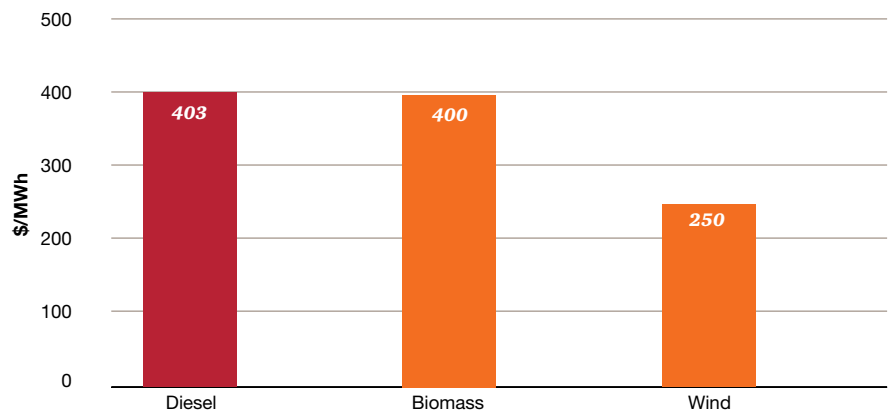
countries. For example, based on a study of Kenya, Ghana and Ethiopia, The World Bank (2010) has estimated that wind and biomass have similar, or lower, levelised costs than the alternative, small scale diesel generation. This finding applies both to stand-alone generation and mini-grids (see Figure 13). The World Bank's conclusion is that "the economics of decentralised renewable power may be compelling for large regions of rural Africa"<sup>20</sup>.

Clearly, such opportunities are only present in some circumstances; and in the long-term full grid-based electrification is desirable. However, in rural and remote areas across the developing world, where renewables are low cost relative to fossil fuel alternatives, donors and governments should seize these medium-term 'win-win' opportunities for low carbon development. This is particularly the case in the Asia Pacific, which is expected to account for 42% of global middle-class spending by 2020, and nearly 60% by 2030<sup>21</sup>.

20. World Bank Development Research Group, Environment and Energy Team (2010) "The Economics of Renewable Energy Expansion in Rural Sub-Saharan Africa"

21. Kharas (2010) "The emerging middle class in developing countries" OECD development centre

**Figure 13: Levelised costs of stand-alone renewable generation, compared to equivalent diesel generation**



Source: World Bank (2010) The Economics of Renewable Energy Expansion in Rural Sub-Saharan Africa

### 3.2 Addressing key regulatory and infrastructure barriers

The high cost of low carbon energy has been highlighted in Section 2. This cost is not entirely due to the inherent technological cost of low carbon energy, which will come down over time anyway with economies of scale and learning effects. There are also institutional and physical barriers that artificially drive up costs for businesses trying to generate low carbon energy. One study by the World Economic Forum (WEF)<sup>22</sup> identified a series of regulatory and infrastructure barriers, largely revolving around the capacity and coverage of national grids, and limited coordination, experience and integrated planning on the part of national regulators.

WEF concluded that bringing down the costs of doing low carbon business in emerging markets would require the following actions:

- Appropriate assessment of the country's renewable resource potential
- Transparent, clear, consistent policy
- Provision of strategic long term implementation plans with clear capacity targets for different technologies

- Continued reform of electricity market structure e.g. appointment of an independent regulator
- Grid infrastructure development
- Robust commercial frameworks

In South Africa, the government has made a number of steps towards the costs of doing low carbon business including introducing a competitive tender process for Independent Power Producers (IPPs), creating an independent regulator, NERSA (National Energy Regulator of South Africa), and prohibiting the state electricity utility, Eskom, from generating the target capacity (Eskom must instead enter into a power purchase agreement with the successful bidder).

### 3.3 Innovative finance

Making the business case for low carbon technology is a prerequisite for attracting finance to the sector. However, it will not ensure it. Government should also focus on financial and risk-based barriers that currently deter investment. The most challenging of these barriers, identified in a recent WEF report<sup>23</sup>, include a lack of confidence in the bankability of Power Purchase Agreements, the small scale of renewable projects, uncertainty around long-term policy support, and the absence of credit and risk guarantees.

Further, governments should recognise that finance will be increasingly likely to come from unconventional sources such as pension funds or sovereign wealth funds. Currently, less than 1% of the assets pension and insurance funds manage are apportioned to green investment. This has been attributed to a range of barriers, including a lack of appropriate investment vehicles, scale issues, regulatory disincentives and limited expertise in this area<sup>24</sup>.

The OECD<sup>25</sup> has suggested that encouraging pension and sovereign funding will require the following actions:

- take subordinated equity or debt positions in low carbon investments,
- provide risk mitigation and issue green bonds,
- review inadvertent barriers to pension fund involvement around investment and solvency regulations, and
- support pension trustee education initiatives.

22. Source: WEF (2011) Developing renewable energy capacity – Addressing regulatory and Infrastructure challenges in emerging markets

23. WEF (2011) Scaling up low carbon infrastructure investments in developing countries – The Critical Mass Initiative

24. Kaminker and Stewart (2011) “The Role of Pension Funds in Financing Green Growth Initiatives”

25. Kaminker and Stewart (2011) “The Role of Pension Funds in Financing Green Growth Initiatives”



Finally, governments must aim to maximise the leverage factor of their financial contributions, and get as much private finance from the public funds as possible. One example of an innovative financing model, which underpins the European Union's NER300 programme, is outlined in Box 2.

In the UK, Electricity Market Reform has made some progress towards meeting this goal, through introducing Contract for Difference Feed-in Tariffs, agreeing to make capacity as well as generation payments, establishing a Green Investment Bank (GIB), and a Carbon Price Floor (CPF)<sup>26</sup>. However, further details on implementation and specific price points are needed to further reduce investor uncertainty and close the finance gap. The £1bn pledged by the GIB only partially closes the finance gap visible in Figure 13.

In the context of offshore wind for example, Renewables Obligation Certificates (ROCs) and the CPF only go so far in providing the appropriate investment opportunities in the industry<sup>27</sup>. Policy must now address specific issues such as pre-construction financing risk that deter institutional investors from investing in offshore wind. Appropriate measures to reduce risk include underwriting technology and construction risks via a consumer levy, regulating offshore assets, and measures to increase returns include increasing the numbers of ROCs available in the first few years of a project and extending the tax-free allowance on Individual Savings Accounts on investments in offshore wind.

### Box 3: *An example of innovative financing: NER300* <sup>28</sup>

The NER300 programme in the EU is one of the innovative approaches taken to maximize private sector investment from limited public climate finance. Approximately €4.5 billion will be raised from the sale of 300 million EU carbon allowances held in the New Entrants Reserve of the EU Emissions Trading System and this will be used to fund carbon capture and storage projects and innovative renewable projects. NER300 is an innovative financial instrument as because first, it co-funds the cost of the innovation only, secondly, it leverages private sector investment, and finally, it ring fences public money from the sale of emissions credits to support low carbon projects.

NER300 supports the funding of only the innovative component of a project – known as the relevant costs. The calculation of the relevant costs accounts for the additional investment required as well as the operating benefits from a project (such as feed in tariffs or the carbon price). For CCS projects, the relevant costs would include costs associated with the capture, transport and storage of the CO<sub>2</sub>, not the power plant itself. For renewables projects, costs and benefits are compared to those of a conventional power plant with the same electricity generation capacity.

NER300 will fund half the relevant costs. The other half, as well as all the conventional costs of the project, will be funded by a combination of private investment and national government support. The NER300 is therefore leveraging public funds to incentivise only the innovative aspects of low-carbon energy technologies. By defining and funding the relevant costs only, NER300 maximises the value for money to the public, and increases the total number of projects that the EU can support.

The budget for NER300 is ring-fenced from the EU carbon market. Any funds will be raised from carbon intensive industries covered by the EU Emissions Trading Scheme. This not only reinforces the incentive to reduce carbon emissions, but also avoids imposing additional costs on taxpayers.

26. PwC Roadmap to reform of the UK Power Sector (2011)

27. PwC Meeting the 2020 renewable energy targets: Filling the offshore wind financing gap (2010)

28. For further information, please see : [http://ec.europa.eu/clima/funding/ner300/index\\_en.htm](http://ec.europa.eu/clima/funding/ner300/index_en.htm)

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## *Concluding remarks*

The economic downturn initially caused global emissions to fall. Now total emissions are increasing faster than economic growth – indicating that during the recovery in 2010, the long term trend of slow decarbonisation has gone into reverse. Unless economic growth is rapidly decoupled from emissions growth, the prospect of achieving the 2 degrees goal stated by governments in Cancun appears remote. Delaying action to decouple emissions from economic growth means that the reductions required in future are steeper and probably more costly.

The British Chancellor, George Osborne, said: “we will not save the world by putting the UK out of business”. Rapid low carbon economic growth is required to tackle climate change, but not at any cost. There is a risk that consumers will object to climate change action if the cost, passed on through fuel and electricity bills, is excessive. Currently, in many countries, low carbon generation requires substantial government subsidy or market reform to make them viable.

One exception to this could be in rural areas of developing countries which are off-grid. Rural electrification, particularly in sub-Saharan Africa, will be instrumental in achieving broader development goals. In these areas, conventional power generation may come from expensive and small scale diesel generation – so here, renewable technologies may be competitive with the fossil fuel alternative. In addition to green jobs and economic growth, the low carbon pathway, in this context, offers the potential to improve access to mobile phones, provide clean lighting and improve indoor air quality.

Addressing some of the institutional and risk-related barriers to these technologies is necessary, but not sufficient for large scale economy-wide deployment. Innovative financing mechanisms, such as NER300 which leverages private finance with public funding, and other targeted incentives are necessary to make the transition to a low carbon economy viable and affordable.

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## *Appendix*

# Methodology and additional modelling results

## PwC Macroeconomic Model

The study focuses on the G20 economies with grossed-up estimates for the world as a whole:

- G7 economies (US, Japan, Germany, UK, France, Italy, Canada)
- E7 economies which covers the BRICs (Brazil, Russia, India and China), and Indonesia, Mexico and Turkey
- Other G20 (Australia, Korea, EU, South Africa, Saudi Arabia, Argentina)

The study draws on long-term GDP projections from an updated version of PwC's "World in 2050" model, which is based on a long-term GDP growth model structure.

Each country is modelled individually but connected with linkages via US productivity growth (known as the global technological frontier). Each country is driven by a Cobb-Douglas production function with growth driven by:

- Investment in physical capital
- Working age population growth (UN projections)
- Investment in human capital (rising average education levels)
- Catch-up with US productivity levels (at varying rates)

Real exchange rates will also vary with relative productivity growth.

The results are not forecasts, but rather indicate growth potential assuming broadly growth-friendly policies are followed and no major disasters (e.g. nuclear war, radical climate change before 2050).

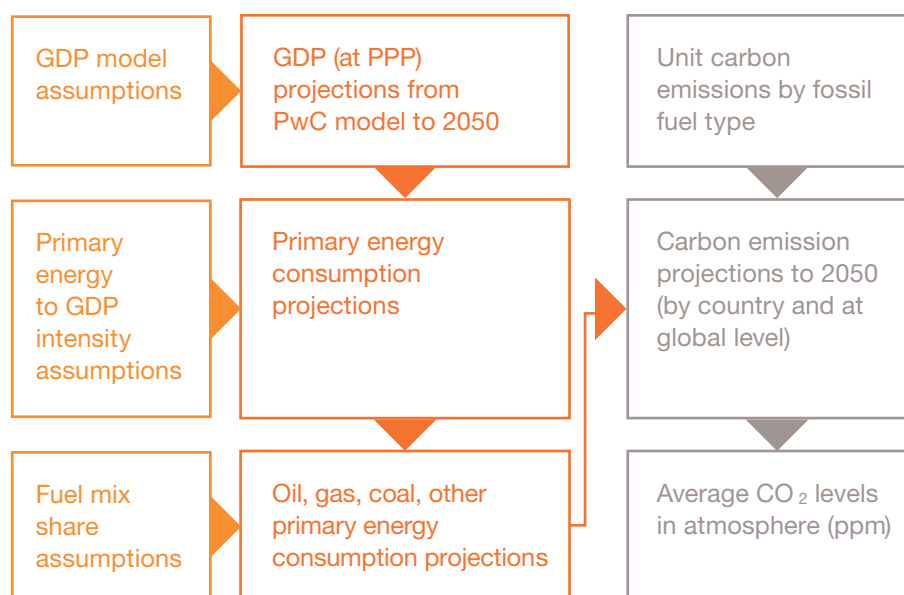
The study considers energy-related carbon emissions, driven by a series of assumptions including the primary energy intensity and fuel mix share.

## Business as Usual (BAU) scenario

A BAU scenario is constructed assuming

- Energy efficiency improvements in line with historic trends (around 1.5% per year with country variations)
- Stable fuel mix
- No carbon capture and storage (CCS)

This is NOT intended as being the most likely scenario, just a reasonable benchmark which serves as a starting point for constructing other scenarios.



Note: all projections done by country then aggregated to global level



## **Greener Growth plus CCS (GG+CCS) scenario**

This is intended to be a very challenging but technically feasible scenario on which the LCE index is based.

In deriving the global carbon budget, we adopted the general consensus of aiming for global CO<sub>2</sub>e concentrations to stabilise around 450ppm by 2100. This broadly corresponds to a peaking of concentration by 2050 at around 515ppm and then declining towards 450 ppm by the end of the century. Climate scientists broadly agree that this level of greenhouse gas concentration stabilisation will provide a fair chance of limiting the increase in global average temperature to around 2°C.

The three key sets of assumptions which underpin this scenario in terms of energy-related carbon emissions at global and country level are discussed in turn below. Additional assumptions at global level for carbon emissions from land use change and forestry are then discussed later together with assumptions on natural carbon sink capacity at global level.

### **1. Energy intensity improvements significantly in excess of historic trends**

Declines in the ratio of primary energy consumption to GDP ('energy intensity') are assumed to average 3% per year at the global level between 2010 and 2050, which is almost twice the historic average since 1980 and seems to be the limit of what might reasonably be achievable in this area. All countries are assumed to converge on this 3% per year achievement trend from 2025 onwards, but with short term country variations up to 2025. For example for this earlier period from 2010-24, we assume that:

- China (4% pa) has one of the most ambitious scope for improvement, which reflects its higher initial level of energy intensity and the emphasis that the Chinese government has placed on improving energy efficiency since 2005, which is expected to remain a major focus of climate change policy in that country;

- the US (3.5%) is also assumed to have high rates of energy efficiency improvements, as it has one of the highest energy intensity of major advanced economies and so the most potential scope to reduce this intensity level, for example through much tougher standards on automotive fuel efficiency levels;
- the EU (2.7% pa) is assumed to have a somewhat lower, but still ambitious, potential to improve its energy intensity levels; nonetheless, this would still require a significantly better performance than the historic EU average trend improvement rate; and
- India (2% pa) is seen as having the least scope for energy intensity improvements in the next 15 years given that it is starting from a much lower level than China and has still got further to go on its industrialisation process, which will inevitably tend to create some headwind against very rapid energy intensity improvements; nonetheless, a 2% per year improvement by India would still be above the global average rate of improvement in 1980-2009, so it is still a challenging prospect.

We make individual assumptions here for all of the G20 countries based on the similar considerations as outlined above (which dominate the overall global picture as described earlier in the report).

### **2. Shift from fossil fuels to nuclear and renewables**

At the global level, we assume a progressive shift in fuel mix away from coal and oil towards nuclear and renewables for the period 2010 to 2050. Trends in the share of natural gas are more mixed: with falling trends for the advanced economies but to rise for China and India where they are starting from low levels.

Overall, the global share of primary energy accounted for by nuclear and renewables<sup>29</sup> is assumed to rise to around 40% by 2050 in this scenario, which is very challenging but aligned with levels projected by previous studies by the IEA and others. Key assumptions for the key economies for each fossil fuel are as follows:

- **Coal:** for the US, the share of coal in the fuel mix is assumed to decline by 0.3 percentage points per year between 2010 and 2025 and at a faster rate of 0.5 percentage points per year thereafter as renewable alternatives to coal for electricity generation become more economically attractive; for China, the same rate of decline is assumed as for the US up to 2025, but an even faster rate of decline of 0.8 percentage points per year is then assumed after 2025 to reflect the fact that China is starting from a very heavy dependence on coal and so has more potential to reduce this in the long run as its economy shifts from heavy industry to services; India, with lower initial level of development is assumed to have potential for less rapid reductions in its coal share of 0.1 percentage points per year up to 2025, but accelerating to 0.3 percentage points thereafter; assumptions for the EU countries, vary with Germany (as a relatively heavy coal user) being assumed to have scope for reductions at the same pace as the US, while France (with its focus on nuclear power and very little use of coal by comparison) seeing only a token further reduction at a rate of 0.1 percentage points per year throughout the period.
- **Oil:** assumptions here are less varied than for coal to reflect the fact that the oil share of the fuel mix is more uniform across the major economies than the degree of reliance on coal; we assume a trend rate of decline in the oil share of 0.3 percentage points up to 2025 and this is assumed to continue thereafter for China and India; for the US and the EU, we assume that the rate of decline in the oil share accelerates after 2025 to around 0.5-0.6 percentage points per year due to a more fundamental shift away from reliance on oil in the automotive and other sectors; this may take longer in China and India since car ownership there will continue to rise after 2025 whereas in the US and EU this may already have reached saturation point by then (particularly with oil prices potentially rising as supplies pass their peak levels at some point).

29. For simplicity the model assumes both nuclear and renewables to have zero carbon emissions, which is not strictly correct but is a reasonable approximation for our purposes. We therefore do not try to break down fuel mix between nuclear and different types of renewables.

- **Natural Gas:** as noted above, China and India currently make little use of natural gas compared to coal in particular, but this is expected to change with a particularly marked rise in China in the gas share of the overall fuel mix by around 0.3-0.4 percentage points per year over the period to 2050; for India the corresponding rate of shift to gas is assumed to be slower but still moving steadily in that direction at an average of around 0.1-0.2 percentage points per year. In contrast, natural gas fuel mix is assumed to remain relatively flat in the US and EU up to 2025 and then to decline thereafter at a rate of around 0.2 percentage points per year as these economies shift increasingly into renewables (and nuclear in some countries).

### 3. Carbon capture and storage (CCS)

The third key set of assumptions relates to CCS. It is beyond the scope of this study to attempt to do a country-by-country assessment in any depth here, bearing in mind that CCS is at most at an early pilot stage in a few countries at this time. We therefore make a much simpler assumption here that global CCS capacity builds up steadily to an emissions reduction of 1.5 GtC (around 5.5GtCO<sub>2</sub>) between 2015 and 2050. This CCS capacity is apportioned to each country based on the share of total carbon emissions excluding CCS, which therefore automatically takes account of the fact that more coal-intensive (and so carbon-intensive) economies will tend to have more scope to use CCS.

The actual scale and geographical distribution of CCS capacity remains highly uncertain at this very early stage in its history, so these estimates may be subject to particularly wide margins of uncertainty at this time.

#### Summary

In differentiating countries in the way described above, we aim to generate energy-related carbon emission pathways that are challenging but fair in terms of recognising the different starting points of each country in terms of energy intensity and fuel mix and their differing stages of economic development and, in particular, industrial structure. CCS is then factored in using a consistent proportional formula as described above.

We have also made assumptions on non energy-related emissions and carbon sinks:

- Net annual CO<sub>2</sub> emissions from land use changes and forestry (LUCF) around 5.8GtCO<sub>2</sub> in 2008 declining to around 1.4GtCO<sub>2</sub> by 2020, and then at a slower rate to around just over -4GtCO<sub>2</sub> by 2050. Current estimates on reducing emissions from deforestation and forest degradation (REDD) expect it to deliver around 5GtCO<sub>2</sub> emissions reduction by 2020.
- Global absorption capacity of the planet (oceans, forests etc) is around 15 GtCO<sub>2</sub> per year and broadly stable over time.

This scenario therefore has some common features across countries but also some variations to reflect differing starting points, stages of economic development and energy resource endowments. We have compared this with the IEA's 450 scenario for 2030 emissions, giving broadly similar results as the next chart shows. This gives some reassurance that our GG + CCS scenario, while clearly challenging, is reasonable both at global level and, broadly speaking, in terms of allocations to major countries/regions.

Further details on the construction of the low carbon achievement index

This index looks at the extent to which countries have consumed their carbon budget for the first half of the 21st century by 2009. Since it is cumulative global emissions that drive atmospheric CO<sub>2</sub> concentrations rather than emissions in any one year, there is an implied global carbon budget between 2000 and 2050, estimated here at just under 1,300 GtCO<sub>2</sub>.

Based on the same cumulative carbon budget, we constructed two GG + CCS scenario pathways beginning from 2000 and 2008. As GDP is also assumed the same in both variants, we can focus on carbon intensity rather than levels of carbon emissions in the analysis. Our assumptions include:

1. Same trend rates of decline for each particular country in the fossil fuel shares of primary energy consumption in 2001-2025 in the 2000-based model and in 2010-25 in the 2009-based model. In both variants, the 2026-50 trend rates of decline would be the same (but generally higher than the decline rates up to 2025 as the costs and feasibility of renewable fuels increases).
2. The rate of decline in energy intensity of GDP is set at 3% p.a. for all countries in 2026-50 in both GG + CCS variants.
3. Set country-specific rates of decline in energy intensity of GDP in 2001-25 to give the same cumulative 2000-50 carbon budgets in both variants (as in point 1 above). For reasons due to rounding, while in most cases, the levels of carbon emissions in 2050 are similar in the 2000-based and 2008-based scenarios, they are not necessarily identical.
4. By comparing the projected emissions pathway of 2000 – 2050 under the Greener Growth + CCS scenario against the actual emissions between 2000 and 2008, the low carbon achievement index compares how actual carbon intensity performs against a 2000-based low carbon pathway.

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