

Energy beyond Paris

Future energy systems, investment flows and greenhouse gases

Looking beyond the Paris climate change conference in December, we expect countries to decarbonise energy in order to meet climate goals. This report demonstrates cost optimal pathways to achieve this

Fossil fuels to remain in the system, even if the 2°C target is achieved, as low carbon alternatives in power mean that coal, oil and gas can be used in sectors where substitution is difficult

Total investment in power generation to rise by up to USD870bn pa, as renewables take share and power demand increases by up to 47% during 2010-30

HSBC Climate Change Centre commissioned University College London's Energy Institute to use its TIAM-UCL global energy system model to generate data and analysis, which forms the basis of the analysis in this report

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Play Interview with
Zoe Knight and Ashim Paun



Disclosures and Disclaimer This report must be read with the disclosures and analyst certifications in the Disclosure appendix, and with the Disclaimer, which forms part of it

Did You Know?

- ▶ **Even though the world will keep using more energy**, total greenhouse gas emissions can be reduced
- ▶ **China and India can double their oil consumption** but still allow global climate-change targets to be met
- ▶ **Demand for power will increase** with rising global GDP and population, requiring substantial investment. A **shift from oil to electricity in cars** furthers this trend
- ▶ **Temperatures have risen by 0.85°C since 1880: the scientific consensus is to limit the increase to 2°C**
- ▶ The analysis completed for this report suggests that the **estimated temperature rise resulting from pledges made for the Paris climate conference** is likely to be 3.4°C in 2100

Context

In [*Keeping it cool – Oil, CO₂ and the carbon budget*](#), 2 March 2015, HSBC mapped out the energy system from supply to demand through to Greenhouse Gas (GHG) emissions. In this report we have built on that analysis by identifying how future climate goals and disruptive technologies could impact energy systems. To do this, we commissioned University College London to model the results of four scenarios, determined by HSBC, by using the TIMES Integrated Assessment Model in UCL (TIAM-UCL). TIMES stands for The Integrated MARKAL-EFOM System. TIAM-UCL is an energy system model which allows users to develop a framework of future energy supply and demand in a cost optimal way. TIAM-UCL was developed by UCL with funding from the UK Energy Research Centre (UKERC), and has been used for a number of research papers commissioned by the UK Department of Energy and Climate Change.

Summary

- ▶ Most countries have made pledges ahead of the Paris climate conference but these are not enough to achieve the 2°C target
- ▶ However, some fossil fuels will still be burned, even in a 2°C world, used in sectors where substitution is more difficult
- ▶ We estimate substantial investment in power generation, driven by low carbon technologies and economy-wide increases in demand

More energy but less carbon

In December, country delegations will gather in Paris to sign a universal climate agreement that sets out a framework to slow temperature rises and respond to the consequences of existing warmer temperatures. The aim is to keep temperature rises below 2°C compared with 1880. Around 0.85°C of warming has been recorded since then. Simply put, the way to solve climate change is twofold; make energy use more efficient so that more GDP is produced for each unit of energy, and decarbonise the energy supply so that countries use cleaner energy to grow and prosper.

As part of the process of negotiating the deal, countries have put forward their own plans, known as Intended Nationally Determined Contributions (INDCs), outlining how they will reduce emissions and adapt where necessary. These pledges provide blueprints for future energy systems and investment flows from 2020 to 2030. As at 27 October 2015, 154 countries covering 86.5% of global GHGs – greenhouse gases – had submitted an INDC to the UN Framework Convention on Climate Change (UNFCCC).

A low-carbon energy transition, irrespective of the outcome in Paris

Our central view is that an agreement will be delivered in Paris. But we expect investment in future energy systems to lean towards low-carbon instead of high-carbon in any case. The reasons for this are twofold. Firstly, the financial sector as a whole is under greater scrutiny to provide transparency of capital allocation. For instance, asset owners are being asked to at least disclose a climate strategy, or, even more forcefully, to divest from fossil fuels: so they thus are coming up with policies to do this. In turn they are asking investment managers for more clarity on fund processes in relation to climate, as well as other social and governance issues. In some countries, including France, regulation is pushing investors to disclose the carbon footprint of portfolios. In addition, central banks are asking lenders and insurers to provide more disclosure on climate positioning in relation to financial stability. This raises questions around high carbon lending and asset exposure.

Secondly, corporates and other entities, such as cities, are making their own climate pledges, which also contribute to moving energy investment flows away from high carbon. For instance, 10 Chinese cities and 17 US cities stated emission reduction goals in a joint US-China climate leaders' summit announcement in Los Angeles in September 2015 (see our report ['China-US climate cooperation'](#), 17 September 2015). These factors are advanced enough to drive change outside the negotiation process in our view. According to our analysis, implementing an energy system that delivers the emission reduction aims set out by INDCs would result in a 12% increase in coal use, a 19% increase in oil use and a 37% increase in gas from 2010 to 2030.

Four scenarios to simulate future energy systems

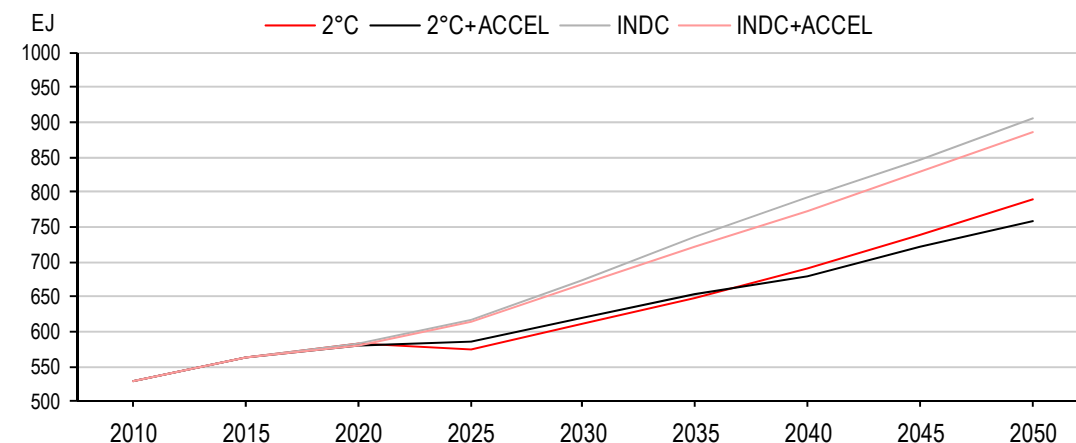
There are many combinations of global energy-system development. They will depend on various factors, such as the economic competitiveness of different energy sources by region, age of existing energy-system assets, level of public finances available for spending on energy infrastructure, population levels and stage of development. We have distilled the modelling possibilities into four scenarios that we believe capture the aims of this analysis, namely to demonstrate how the supply and use of fossil fuels will change in response to climate regulation and faster than anticipated technological change.

The two climate regulation based scenarios are **2°C** and **INDC**. The basis of the 2°C scenario is that the world collectively acts by raising ambition on emission reduction to limit temperature rises to 2°C compared with 1880 levels. The TIAM-UCL model outputs demonstrate how a 2°C energy infrastructure and uses can be achieved in the most cost-efficient manner. The second regulatory-driven scenario, INDC, is based on existing and publically-available country policy and emission-reduction goals and shows the cost-optimal way to deliver these through the energy system, with types of energy use, global emission levels and resulting temperature rises the key outputs in this case.

In addition, we expect disruptive technologies to accelerate the reduction in carbon emissions. These are technologies that can materially and quickly change existing structures as costs come down and technical advancements are made. They will have an impact on the future development of energy systems because they change the economics in favour of low-carbon instead of high-carbon, as we set this out in our report ['Keeping it Cool – Oil, CO₂ and the carbon budget'](#), 2 March 2015. The technologies for which we have used faster cost reductions are renewables, battery storage and electric vehicles – three areas we consider to be most disruptive to a high-carbon energy infrastructure. These would result in lower-cost pathways for decarbonising the power and transport sectors, in particular, as well as higher levels of power generation.

We have modelled for this acceleration, creating two scenarios, one in conjunction with the INDCs – the **INDC+ACCEL** scenario – and the other in conjunction with emissions reductions consistent with a 2°C outcome – the **2°C+ACCEL** scenario.

Chart 1: Total primary energy demand under various scenarios



Source: UCL, HSBC

A common feature of all the scenarios is that total energy consumption across the global economy will increase, as GDP and population growth increase energy demand in all sectors. (This is illustrated in Chart 1.) This is the case through until at least 2050, the period which our modelling covers for energy supply and demand (*temperature predictions are as at 2100, in line with global climate policy*).

2°C scenario requires USD870bn a year investment; INDC up to USD785bn

Power demand grows markedly within this overall growth in demand for energy. Delivering the power aims of INDCs and country policy on a cost-optimal basis would require USD385bn of investment in 2015 rising to USD785bn in 2030; investment flows in renewables would total about USD160bn, split 47%:53% between wind and solar. To achieve a 2°C power system on a cost optimal basis would require USD870bn of investment annually in 2030 and investment flows in renewables would total around USD200bn, split 45%:55% between wind and solar.

Transitioning to a lower carbon economy

In our report [Keeping it Cool – Moving towards global carbon pricing](#), 9 September 2015, we stated our belief that it is in everyone's best interests (investors, policymakers, corporates, and civil society) that decarbonisation – the transition to a low-carbon economy – is delivered as smoothly and as quickly as possible. We expect the economics of cheaper clean-technology, as well as policy, to move in favour of a low-carbon world. This analysis shows that even stringent climate pathways and advances in clean tech can be delivered alongside the use of fossil fuels in some sectors of the economy where substitutability is costly or technically difficult. Table 1 shows the key metrics in 2030 (vs a 2010 base), including what happens to consumption of fossil fuels and investment in power in three key regions for the future global emissions trajectory – China, the US and India. It also shows what happens to emissions to 2030.

Fossil fuels still have a role to play

In the section titled 'Enabling 2°C', on page 47 we consider how the implications of the 2°C scenarios differ from the INDC-based outputs. A key finding, and one that will surprise many, is the material position which fossil fuels maintain in the energy system overall, under all scenarios, with only the combination of 2°C climate policy and rapid cost-deceleration in power – the 2°C+ACCEL scenario – causing a net decrease in fossil consumption at 2050. Fossil fuels remain part of the primary energy mix

in all modelled scenarios because of limited substitutability in parts of industry and transport. In the 2°C energy system, continued use of coal, oil and gas is achieved by almost completely decarbonising the power sector to 6.0gCO₂/kWh. Implementing a 2°C power system on a cost-optimal basis would result in a 35% decrease in coal use, a 16% increase in oil use and a 52% increase in gas from 2010 to 2030.

Table 1: Summary results for HSBC's four energy transition scenarios

2010-2030	2°C	2°C+ACCEL	INDC	INDC+ACCEL
Global fossil fuel use				
	2030			
Coal consumption (PJ)	↓ -35%	↓ -29%	↑ 12%	↑ 4%
Oil consumption (PJ)	↑ 16%	↑ 16%	↑ 19%	↑ 17%
Gas consumption (PJ)	↑ 52%	↑ 49%	↑ 37%	↑ 44%
Global electricity				
Total capacity (GW)	↑ 34%	↑ 46%	↑ 27%	↑ 44%
Power investment p.a. (USD bn)	870.7	879.6	784.9	820.7bn
Renewables capacity (GW)	↑ 323%	↑ 568%	↑ 235%	↑ 554%
Renewables investment (USD bn)	200.7	254.2	158.7	241.5
Global energy use by sector				
Power fuel consumption (PJ)	↓ -17%	↓ -10%	↑ 7%	↑ 7%
Transport fuel consumption (PJ)	↑ 32%	↑ 31%	↑ 37%	↑ 36%
Buildings fuel consumption (PJ)	↑ 12%	↑ 15%	↑ 15%	↑ 18%
Industry fuel consumption (PJ)	↑ 34%	↑ 36%	↑ 41%	↑ 42%
GHG emissions per annum (GtCO ₂ e)	↓ -14%	↓ -10%	↑ 7%	↑ 5%
China				
Coal consumption (PJ)	↓ -24%	↓ -19%	↑ 23%	↑ 22%
Oil consumption (PJ)	↑ 107%	↑ 101%	↑ 93%	↑ 86%
Gas consumption (PJ)	↑ 279%	↑ 248%	↑ 99%	↑ 101%
Power investment p.a. (USD bn)	287.0	268.5	269.0	273.1
Renewables investment p.a. (USD bn)	89.0	71.4	70.6	78.2
US				
Coal consumption (PJ)	↓ -74%	↓ -72%	↓ -46%	↓ -67%
Oil consumption (PJ)	↓ -26%	↓ -24%	↓ -27%	↓ -25%
Gas consumption (PJ)	↑ 19%	↑ 19%	↑ 4%	↑ 34%
Power investment p.a. (USD bn)	131.5	129.4	124.1	98.1
Renewables investment p.a. (USD bn)	39.2	57.8	39.2	40.6
India				
Coal consumption (PJ)	↓ -23%	↓ -10%	↑ 80%	↑ 65%
Oil consumption (PJ)	↑ 99%	↑ 91%	↑ 108%	↑ 103%
Gas consumption (PJ)	↑ 372%	↑ 302%	↑ 233%	↑ 235%
Power investment p.a. (USD bn)	62.7	66.4	48.9	55.2
Renewables investment p.a. (USD bn)	21.4	28.0	13.9	26.2

Source: TIAM-UCL Model

Variance between 2°C energy systems in the big future emitters – China, India and the US

We look forward to 2050 in the final chapter – solving climate change is a long game – and ask what will be the key differences in fossil fuels, power generation and efficiency and use of renewables by this point to keep to the 2°C temperature target. We look at the big emitters of the future – China, India and the US – and consider how they can cost-optimally contribute to a 2°C energy system. (Some key findings in relation to these three countries are seen in table 1 for 2030.)

By 2050, China's power generation will see a 167% rise in a cost-optimal 2°C world, with coal virtually exiting the mix and being replaced by solar, nuclear and hydro power. Gas consumption in power also takes share in 2050. Annualised investment costs in Chinese power reach USD584bn in 2050. Chinese oil consumption also bucks the global trend, rising by 2.7-times as car use increases with a growing population and increasing GDP per capita. Gas use also soars, up 10 times by 2050, with significant consumption growth across all major sectors.

In the US, use of fossil fuels drops economy-wide by 2050, as coal use declines close to zero in all sectors, driven by cheaper low-carbon energy alternatives and decline in domestic manufacture of remaining high-carbon goods, and nuclear, wind and solar come to dominate the power mix. Overall, TIAM-UCL's findings show that in the cost-optimal global 2°C energy system, US emissions will come down by 75%, a significant reduction when compared with the US INDC pledge of 26-28% vs 2005. However, this is pledged by 2025, giving time to bring emissions cuts down further in the period to 2050.

India's power sector will see significant growth through to 2050 as the country's economy grows, bringing substantial corresponding power needs. We expect use of oil in transport and industry to soar, which can be accommodated in the cost-optimal 2°C energy system when coupled with decarbonisation of the Indian power system.

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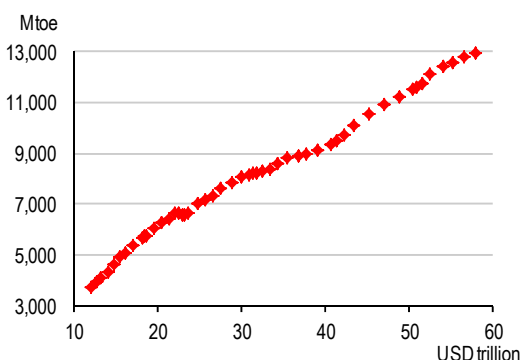
Future energy systems

- ▶ Decarbonising the economy requires a transition in the global energy system
- ▶ UCL's model shows how energy systems can cost-optimally meet climate goals and the impact of cheaper solar, storage and EVs
- ▶ Four scenarios paint a picture of changing future energy demand and supply, investments in power and temperature outcomes

Energy systems and climate goals

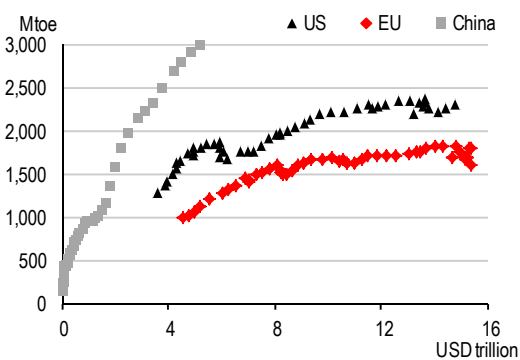
In short, solving climate change means reducing GHGs. This can be achieved by implementing regulation by sector to encourage energy efficiency (see our report [Green Buildings and climate](#), 21 July 2015), and to decarbonise the energy supply by changing the economics of high carbon versus low carbon power (see our report '[Keeping it cool – Moving towards global carbon pricing](#)', 9 September 2015). We argue that energy efficiency regulation can result in energy savings, as shown by the lower use of primary energy for the same level of GDP output for the EU versus the USA in chart 3. However, decarbonising the primary energy supply – i.e. removing GHGs from the supply of fuels to power, buildings, transport and industry, leading to less emissions from use of fossil fuels – remains a big challenge.

Chart 2: World primary energy demand and GDP



Source: BP Statistical Review 2014, World Bank. Note: GDP at constant 2005 USD

Chart 3: Top 3 emitters – Primary energy demand vs GDP



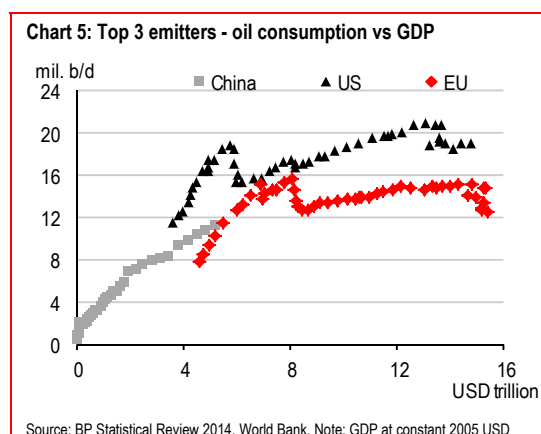
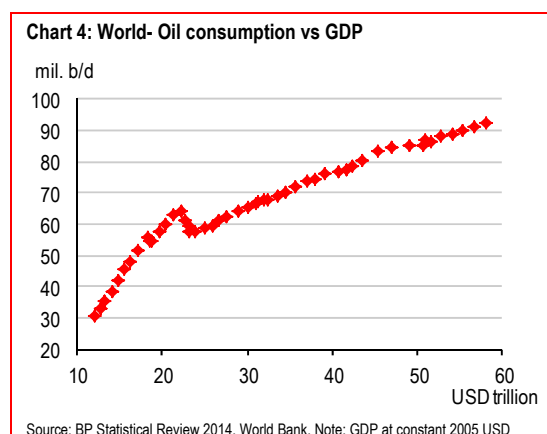
Source: BP Statistical Review 2014, World Bank. Note: GDP at constant 2005 USD

2015 is an important year for international climate change policy. It is the first time that a comprehensive selection of countries, from all income brackets, have publically stated *forward looking* plans (from 2020 to 2030) on what they will do to manage climate change, based on their economic status and their historical contribution to the stock of greenhouse gases. This is a remarkable achievement in itself in our view.

The 21st conference of the Parties (COP21) that will take place in Paris from 30 November to 11 December, aims to sign a Universal Climate Agreement (UCA). The agreement is currently being ironed out by a UNFCCC workstream – the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP). We believe a UCA will be signed, although the Paris negotiations will not be easy – given there are so many stakeholders, such as vulnerable nations, business, governments and environmentalists, it will be very difficult to ensure everyone is happy with the outcome. The final round of pre-Paris talks, which concluded in Bonn on 23 October, suggested that climate finance remains an area where there are conflicting viewpoints.

INDC pledges are genuine regulatory drivers as they catalyse national policy which will impose new restraints on the amount of greenhouse gases which countries can emit and therefore where and how countries can use fossil fuels. How we generate and use energy – and therefore create greenhouse gas emissions – in the future is fundamental to economic and social development as it may change the cost of energy. It also has manifold implications for governments and companies in allocating capital and in understanding the future cost of energy.

It will not be straightforward to deliver energy systems consistent with the global consensus to mitigate emissions to levels commensurate with a global temperature rise of no more than 2°C compared with pre-industrial times because, in some regions, high carbon energy sources remain the cost-optimal feedstock for certain industries. Nevertheless we expect future energy supply and demand trends to be different from the past because of a climate driver. The extent to which these trends will differ is a key uncertainty which we seek to unravel in this analysis. Our central view is that climate drivers will break down some of the historical energy growth and GDP correlations. Global oil use and GDP is shown in chart 4 and differences in existing country relationships between oil and GDP for China, the US and EU are shown in chart 5.



A multitude of factors will determine how the energy system will develop in the future including the age of existing energy infrastructure, regional economics of energy sources and technology shifts, economic output, population growth and regulatory drivers. To identify potential future changes to the existing energy framework that can combine climate and growth needs we commissioned the energy modelling capabilities of the UCL energy institute at University College London.

In allocating capital for future energy systems, investors and governments will need to incorporate new analysis around the implications of climate regulation, and how that changes the demand profile for different fossil fuel inputs across power generation, industry, buildings and transport. An energy system developed to a strict 2°C framework entails different capital allocation decisions than a looser framework built from the INDC pledges that countries have put forward as part of the Paris negotiations. In addition the resulting temperature rises from less stringent climate policy will have ramifications that governments and investors need to be aware of. In addition, there could be positive surprises that mean emerging clean technologies deliver emissions reductions beyond what policy can achieve. We have incorporated these issues into the scenario analysis from UCL using the TIAM-UCL Energy model, as described in box 1.

The TIAM-UCL Energy Model

The TIMES Integrated Assessment Model in UCL (TIAM-UCL) is an energy system model which allows users to build a picture of future supply and demand for energy. It also gives data on future greenhouse gas emissions and resultant global warming outcomes. Users are able to apply constraints in certain areas of the model, including technology costs, emissions and GDP, in order to gain an understanding of how the other variables will respond.

TIAM-UCL builds on previous energy system models developed by academic and research institutions over several years. It was built with modules covering input assumptions surrounding GDP, GDP per capita, number of households, energy service demand elasticities to price changes as well as detailed data for pricing of technologies within sectors. We include more detailed notes on the workings of TIAM-UCL, including its defining characteristics, main inputs and sector data inputs in Appendix 1.

For our analysis, variations were made within the climate and technology modules of TIAM-UCL. The climate module incorporates CO₂ concentration, temperature changes and radiative forces. It is calibrated using the climate model, MAGICC ('Model for the Assessment of Greenhouse Gas Induced Climate Change'), which takes emissions scenarios for greenhouse gases, reactive gases, and sulphur dioxide as input and gives global-mean temperature, sea level rise, and regional climate as output. MAGICC was initially developed by universities in the 1980s and has evolved as climate science and data have improved. MAGICC has been used in all Intergovernmental Panel on Climate Change assessment reports to produce projections of future global-mean temperature and sea level change. The temperature rise outputs found in this work are calculated using MAGICC according to 60% likelihood of staying below the reported temperature.

The technology learning module captures the rate at which the cost of specific energy technologies reduces over time, or the 'learning rate'. The base case learning rates are taken from the conclusions of several research and industry organisations such as the International Energy Agency but these can be varied. In addition, there are maximum penetration rates assumed for certain technologies; for example, given loading matching requirements, there is a maximum level of electricity generation that can come from intermittent renewable technologies.

The model provides results from 2010 to 2050, and was run on 31 August 2015.

UCL provided the modelling for four scenarios; 2°C, 2°C + ACCEL, INDC and INDC + ACCEL. The ACCEL or accelerated scenario incorporates faster cost reductions in key technologies (see table 2).

Table 2: Historical price trend and forecasts for Solar PV, Battery Storage and electric vehicles

Technology	Units	Average					Input assumption to model				
		2005	2006	2007	2008	2009	2010	2020	2030	2040	2050
PV installation	Historic \$/kW			6700	6695	6697.5					
	Standard \$/kW						3000	2115	1568	1366	1164
	Accelerated \$/kW						2700	1406	997	805	613
Battery storage	Historic \$/kWh	2005	1300	1100	950	840					
	Standard \$/kWh						720	432	378	334	300
	Accelerated \$/kWh						720	238	189	167	150
Battery electric vehicles	Standard \$/veh.							58,100	53,200	48,700	37,400
	Accelerated \$/veh.							32,100	28,900	26,600	25,200

Source: UCL, Averages for solar taken from five papers, average for historical battery storage costs taken from two papers

Outputs from the modelling include data on the geographies and sectors in which fossil fuels will be used in the future. We factor this into the scenarios by making assumptions on faster cost reductions in the technologies we believe are key to speed up the low-carbon transition, namely renewables, battery storage and electric vehicles.

Renewables: If this trend continues or were to accelerate dramatically, more widespread deployment could, in our view, trigger an economically-driven decarbonisation of the power sector, the section of the energy economy which contributes most towards carbon emissions.

Table 2 shows historical data for PV installation costs, and the input assumptions for future cost reductions, broken down as ‘standard’, i.e. predictions under the TIAM-UCL model for technology learning, and with the added constraint of faster cost decreases per kW in ‘accelerated’, which is the data points applied under the INDC+ ACCEL scenario.

In an HSBC report, *The rise of renewables*, 26 April 2015, HSBC analysts highlighted the accelerating rate at which wind and solar capacity has been installed in recent years. We stated our view that this trend is supported by advances in renewables technology, advances in battery storage, subsidies for low carbon energy, a carbon price on high-carbon power generation and, in our view, by the growth of auction-based systems for developers of wind and solar installations to gain the right to build projects. Competitive auctions, commonplace for other power generation technologies and highly cost efficient, have become an increasingly popular policy for renewable energy in favour of feed-in tariffs.

Battery storage: A sharp advancement in battery technology, for instance via more efficient use of lithium or advances in aluminium battery technology, would transform the energy economy in our view. It would further catalyse the growth of renewables in the energy mix as the energy produced from intermittent renewables could be stored until needed. There are also important implications for the transport sector, as batteries are a major component cost of electric vehicles. Table 2 gives the historical trend data for battery storage costs, taken as the average of a number of papers which have studied the trends.

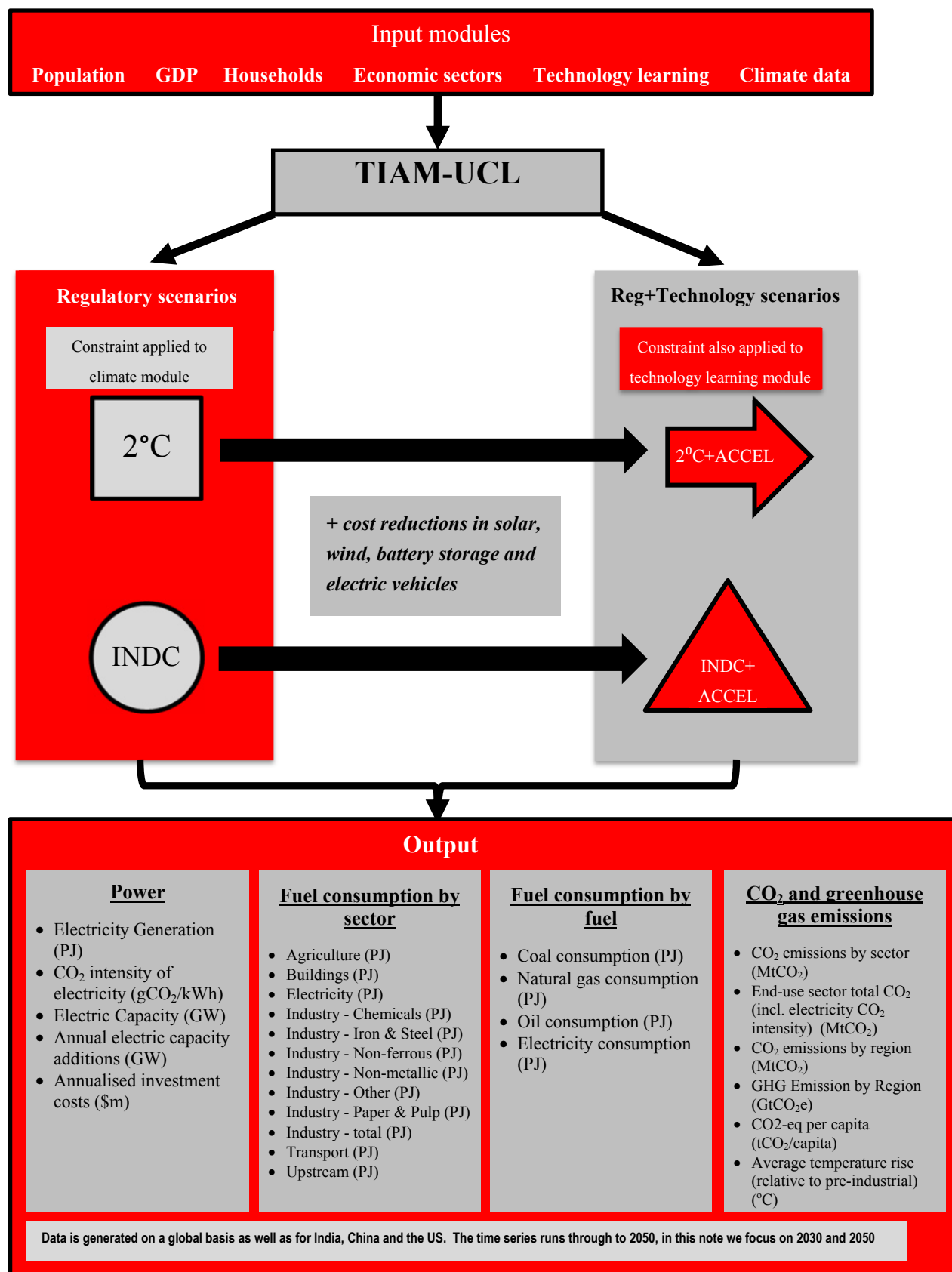
As with the solar data, Table 2 shows data for battery storage costs, broken down as ‘standard’, i.e. predictions under the TIAM-UCL model for technology learning, and with the added constraint of faster cost decreases per kW in ‘accelerated’, which is the data points applied under the INDC+ACCEL scenario.

Electric vehicles: Currently, batteries are an expensive and bulky component in electric vehicles (EVs). In our report [Stranded Assets: what next?](#), 16 April 2015, we identified electric vehicles as a beneficiary technology of the advancements in battery storage, i.e. that as battery technology advances so do EVs. A step-change or continued incremental improvements would clear an important hurdle in their ability to take significant market share from traditional petroleum-burning engines, and change the demand profile for oil – the transport sector currently uses oil for 95% of its energy and accounts for 60% of oil use. Under the INDC+ACCEL Scenario, EVs are considered as a third, separate clean technology, given the technological advancements which can be made beyond batteries and specifically in relation to electric car technology and associated infrastructure. Table 2 shows data for the retail price of electric vehicles, broken down as ‘standard’, i.e. predictions under the TIAM-UCL model for technology learning, and with the added constraint of faster price decreases in ‘accelerated’, which is the data points applied under the INDC+ACCEL scenario.

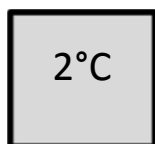
For the purposes of this study, the energy system is mapped forward to 2050, the date at which the IPCC stated a 40-70% emissions reduction vs 2010 levels is needed in order to maintain warming to 2°C. In this report, outputs from the model are analysed at 2050 and also at 2030, the period when a Universal Climate Agreement comes to an end.

TIAM-UCL includes 16 geographies with different assumptions for climate policy, technological development, and commodity markets. We discuss outputs in terms of the global energy system but also focus in more detail on the US as the world’s largest economy and on China and India, arguably the biggest growth economies over coming decades and predicted by the IEA to be the largest sources of emissions growth.

Figure 1: HSBC's future energy system scenarios



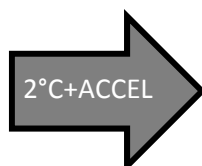
Four scenarios modelled



2°C Scenario

This scenario delivers a maximum temperature rise of 2°C higher than pre-industrial levels, which is the globally agreed temperature goal. This is achieved by restricting emissions to levels consistent with a 2°C world within the climate module of TIAM-UCL (see box 1).

Technology transfers between regions are facilitated and trading of CO₂ emissions are fully permitted to allow the world to keep within the carbon budget and achieve this in the most cost-optimal manner.



2°C + ACCEL Scenario

This scenario builds on the 2°C above by adding faster than expected reductions in the future cost of specific clean technologies – renewables, energy storage and electric vehicles. In this case we alter the rates of technology learning so that intermittent renewables (solar PV & wind), battery storage and electric vehicles (EVs) – become cheaper and therefore more widely deployed.



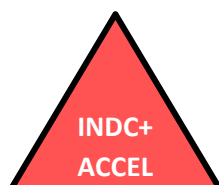
INDC Scenario

Most of the INDCs that countries have put forward towards a UCA contain mitigation targets. These goals are used as the basis for the INDC scenario. In this case the TIAM-UCL model restricts emissions in a way that is consistent with the INDC aims. The model cut-off date for this analysis was 31 August 2015. At this point not all country INDCs were published (detailed in Appendix 2) including several large emitters, including India, Indonesia and Brazil.

For larger emitters that had not released their INDCs at the time the model was run, the model instead includes the emissions reduction pledges made at the Copenhagen Conference of Parties (CoP15) in 2009 which formed part of the Copenhagen Accord, which are generally-emission reduction goals for 2020.

Since the model results map the energy system to 2050, it is also necessary to estimate what might occur to emissions after the end of the INDC period. The model was set to assume that GHG emissions per capita remain constant for all regions after the end of their INDC period, or are fixed at their 2030 level if no pledged contribution exists. Emissions after 2030 therefore grow or shrink depending on changes in regional population. Although other countries have nominally made pledges post-INDC, these are either not included within legislation or were adjudged by UCL to be unlikely to become firm targets, given current political and social environments. The only exceptions to this are the European Union (EU) and Mexico, both of which have made firm commitments to GHG emissions in 2050 (the EU built on its INDC pledge of a 40% emissions reduction on 1990 levels by 2030 with an 80% target for 2050. Mexico

pledged a 25% reduction on its BAU scenario by 2030 vs 1990 levels with a 2050 target of a 50% reduction on 2000 levels.) The INDC scenario hereby seeks to understand how the energy system can generate emissions in compliance with a UCA in the most cost-optimal manner.



INDC+ACCEL Scenario

Under this scenario, again only the INDCs are followed, but these are combined with the ACCEL technology improvements, in order to understand the impact these constraints would have on the energy system, i.e. what the system would look like given both strong climate regulation and rapid technological advance.

Box 2: Global Apollo Program – a clean technology catalyst?

Advances in technology can and will likely continue to be delivered organically through research and development at universities and innovative companies in our view. However, some are taking steps to expedite progress. An example is an initiative founded by Sir David King, the UK's Chief Scientific Advisor, Lord Browne, former CEO of BP plc and a number of senior academics; the Global Apollo Program's aim is to accelerate the decarbonisation of the world economy through more rapid technical progress, achieved through an internationally-coordinated program of shared research and development. The Program is focussing on certain key technologies, including the three modelled for in our INDC+ACCEL scenario - renewables, battery storage and electric vehicles (the others are grid management and use of hydrogen).

In our report [*Stranded Assets: what next?*](#), 16 April 2015, we considered technology drivers which catalysed the supply and demand sides of the energy economy and which pose stranding risks to fossil fuels, making them economically non- or less viable. We believe such risks to be material and entirely plausible. In the past, advancements in technology have catalysed supply and demand in the energy economy rapidly. An example is the rapid switch from steam to diesel and electric trains in the 1950s and 1960s. A second is the rise of nuclear in France's power mix in the mid-1970s, as the imported oil used in the majority of electricity generation became more costly following what is known as the first oil crisis, when OPEC ceased exports and oil prices rose by around four times in under a year. Nuclear's share in the French power mix went from under 4% in 1970 to almost 60% in 1984 and 78% in 1993. We believe these examples demonstrate that transitions in parts of the energy system can happen quickly, when exogenously catalysed, in these cases by technological advance and market prices driving relative economics.

Risks to HSBC's energy transition scenarios

A number of factors in the model may not be fully captured. We think these could be expected to alter energy system flows and give different output data, although overall, we think the model is robust in its range of inputs. Risk factors to the output include:

- ▶ Factors susceptible to inertia in the real world (e.g. consumer behaviour) – i.e. where demand may not adjust in an entirely cost-rational manner and instead display entrenchment – may not be fully captured by the model.
- ▶ Rapid progress may be experienced in further technologies which have not been modelled. This could occur in cleantech, including less widely deployed forms of renewable energy such as tidal, wave and different types of solar power generation. It could also happen in relation to fossil fuels, including types of unconventional gas and oil, rapid cost reductions in relation to use of compressed and liquefied natural gas, and in relation to enhanced oil recovery.
- ▶ The TIAM-UCL model output, in relation to additions of specific technologies to the energy mix, may vary from that used by HSBC analysts because of input differences. Specifically, the use of 2010's actual figures for additions of power generation technologies as a base year means capacity additions from that point forward are calculated by TIAM-UCL with certain roll-out constraints. It should be noted that, in some instances, capacity additions may break through this roll-out 'ceiling'. Shorter term projections for intermittent renewable technologies through to 2015 and to 2020 (based on 2010), for instance, have been surpassed by some distance by the actual numbers seen to date. HSBC analysts are utilising more up-to-date actual data from which to base future trajectories for capacity additions.
- ▶ Global data outputs from TIAM-UCL may mask regional data which is conflicting or moving in opposing directions, and regional data points may contain components which are similarly non-symmetrical for nation states or sub-national areas or markets. To illustrate, much of the data described in this report was generated at the global level and then broken down for China, India and the US. In relation to demand for power, the model suggested a rising trend in the long term. This may not be consistent with what HSBC analysts have predicted for Europe, where efficiency gains are predicted for the next 10 years leading to gradually falling demand, as described in HSBC's report, *European Energy Utilities*, 10 April 2013. However, such a prediction for European efficiency gains is masked by the global data and to an extent by the discussion of timeframes in *this* report which focus on 2030 and 2050.
- ▶ There are large uncertainties around the evolution of the industry sector structure. This is particularly the case in emerging and developing economies, many of which could choose to bypass heavy industrial activity in favour of a service-based economy, which means that the role of fossil fuels across different sectors, and in different regions, remains a challenge to assess accurately. Economic re-structuring was built into the industry drivers, allowing some manufacturing-to-service restructuring to occur in some countries/regions included in the model, explained in more detail in Appendix 1.
- ▶ Fundamental underlying socio-economic input building-blocks such as GDP and even population may not be accurate. Certainly, forecasts show a range rather than a narrow consensus. Divergence from predicted numbers could substantially alter energy and emissions trajectories.

Conclusions

HSBC commissioned UCL Energy institute to model future energy systems in order to demonstrate how the supply and use of fossil fuels could change in response to climate regulation and faster than anticipated technological change. The four scenarios analysed which were identified by HSBC consist of delivering a cost optimal energy system that meets a 2°C climate goal, a cost optimal energy system that builds on country pledges according to the INDCs. In addition we have added accelerated technology deployment rates driven by faster cost reductions than in a standard case. In the next chapters we look at the results from each scenario.

2°C

The 2°C energy transition

- ▶ Coal demand declines 35% during 2010-30 and further thereafter, as use in power is down 92%. Renewables grow 5 times by 2030
- ▶ Gas demand grows 52% during 2010-30, driven by all major sectors, oil rises 16% with more vehicles in developing countries
- ▶ Investment costs in power generation increase 4 times during 2010-30, to USD 870bn pa

16% more energy consumed in 2030 under the 2°C scenario

Fossil fuels remain part of a cost optimal energy system to meet a 2°C world

The 2°C scenario, delivers a maximum temperature rise of 2°C higher than pre-industrial levels, which is the globally agreed temperature goal. This is achieved by varying the climate module to achieve a maximum 2°C and allowing other variables to adjust in a cost-optimal manner, against the backdrop of higher energy consumption across the economy, 16% higher in 2030 than 2010 and 50% higher in 2050.

In this section, we consider key findings from data generated by the TIAM-UCL model, under the emissions constraints of the 2°C Scenario, which suggest what the cost-optimal energy system could look like in 2030 and 2050 if 2°C indeed becomes the policy target.

The first section looks at fuel consumption per fossil fuel. Subsequent sections look at fuel consumption per sector with a focus on the future for power generation, including investment costs. We have focused on this sector because power is the sector most commonly prioritised for emissions reductions as technological substitutes for fossil fuels are most viable here, from a capacity and cost point of view.

Fossil fuels remain in a cost optimal 2°C energy system

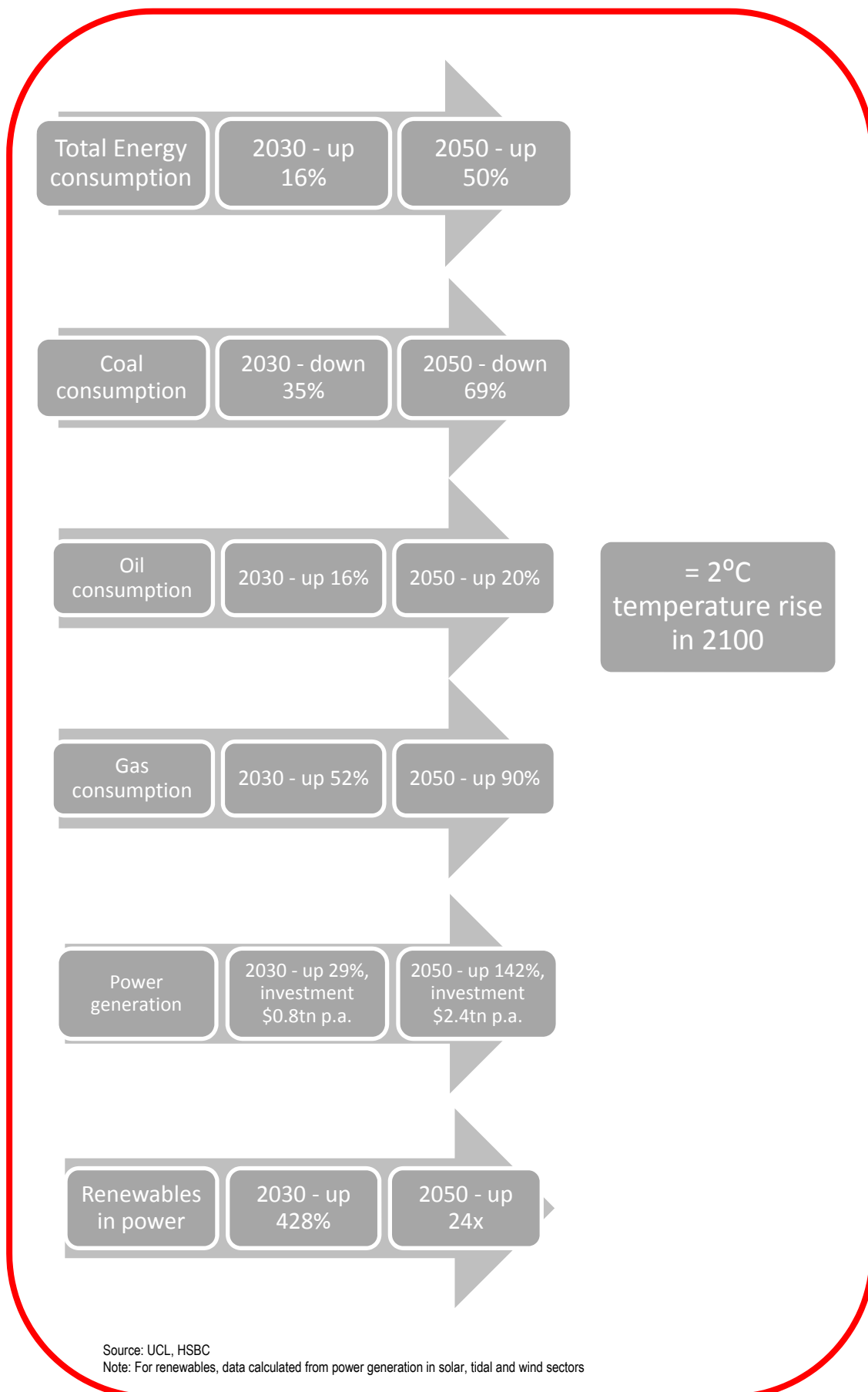
Coal use declines 35% during 2010-2030 and by 69% to 2050

The majority of the decline (92%) in global coal consumption is from power sector decarbonisation under the 2°C scenario. The challenge of removing coal from the industry sector, where technology allows less substitution, is evident however and coal increases by 6% by 2030 and reduces by only 15% by 2050.

Around 30 exajoules (or about one and a half billion tonnes) of annual coal consumption remains in 2050, a much more modest 15% reduction on levels in 2010 (compared to the fall seen in the power sector). By 2050 a large proportion (around 66%) is also used for non-energy uses.

Figure 2: Key tenets of the energy system under the 2°C Scenario

2°C



2°C

Oil use increases by 16% during 2010-2030, and by 20% to 2050

Current and future use of oil reflects the use of this commodity in both transport and industry sectors, which accounted for 60% and 23% of consumption in 2010 respectively. The 2°C scenario has a lower level of car stock decarbonisation than in INDC+ACCEL but much stronger action in other transport sub-sectors. Nevertheless, despite the complete switching to LNG in the shipping sector and significant passenger and freight vehicle efficiency gains, under the 2°C scenario oil use in transport is also still 20% higher in 2050 than in 2010.

Gas use increases by 52% during 2010-2030, and by 90% by 2050

Consumption of natural gas increases substantially, reflecting the importance of this commodity under even stringent climate objectives. Low growth is observed in the buildings sector, where emissions cannot be captured using CCS. More gas is used in industry, reflecting the need to displace coal. More gas is also used in transport, as LNG takes share as the feedstock in ship engines.

Power generation under 2°C – exit fossil fuels from the mix

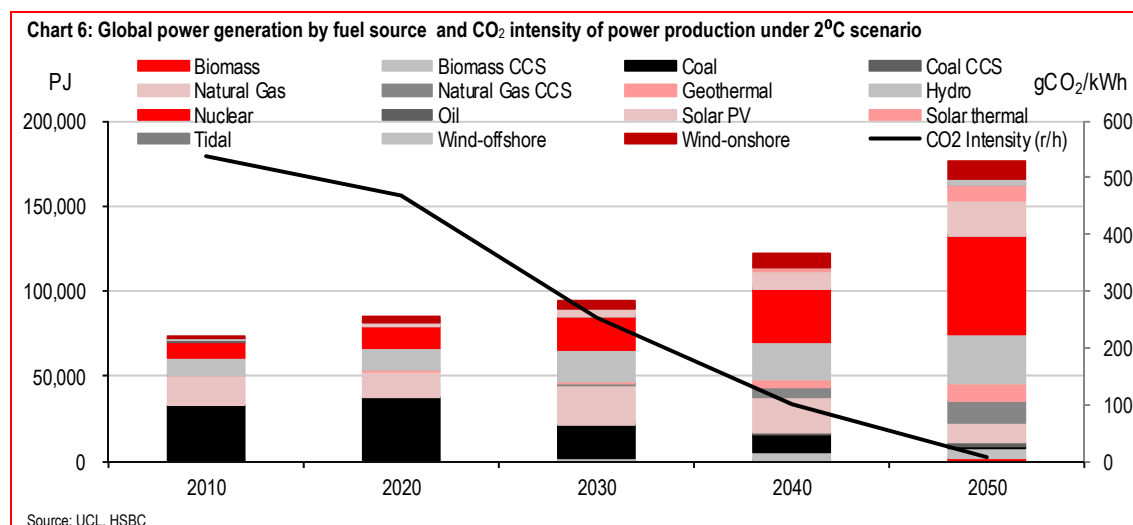
The power sector accounted for 31% of emissions in 2010 and is key to achieving climate goals. A key finding from the TIAM-UCL model, in our view, is substantial growth in demand for power. This highlights the increasing use of power in some sectors – transport to power electric vehicles, heating in buildings where it is a cost-optimal way of replacing fossil fuels in the overall mix and increased use in several industrial processes. It is also reflective of overall population and GDP growth over the period. Total global power generation under the 2°C scenario increases from 73,153 PJ in 2010 to 94,432 PJ in 2030, a 29% increase. By 2050, this reaches 176,724 PJ, a 142% increase.

Fossil fuels – mostly coal and gas – are dominant in the power sector fuel consumption mix in 2010, accounting for 64% and 25% shares, respectively. Under the 2°C scenario, the main difference from other scenarios lies in the removal over coming decades of coal from the list of power generation feedstock, and in the use of gas largely with CCS technologies. By 2030, coal use in the power sector is down to 46,600PJ from 95,795 PJ, a 51% drop from 2010 and now representing 37% of the total fuel consumption mix in the sector. By 2050, coal represents only 6% of the total fuel consumption mix, dropping 92% relative to 2010.

Much of the increase in total power capacity is met by low carbon sources of generation, in particular nuclear, solar and hydro. Chart 6 illustrates the changes in the mix. The stringency of the target also results in a role for biomass CCS (BECCs), generating so-called negative emissions (i.e. whereby carbon is sequestered from the atmosphere through photosynthesis in plants to be used for fuel – typically, but not restricted to, wood products – and then the carbon emitted through combustion for fuel is in turn captured and stored away).

The CO₂ intensity of electricity falls to 253 gCO₂/kWh in 2030, representing a 53% drop from 2010, as seen in chart 6. By 2050, this figure is down to 6 gCO₂/kWh, representing almost a 99% drop – a virtually decarbonised power mix (when CCS is included). This reflects the importance of power in cost-effective decarbonisation of the economy in line with the 2°C target – power is the low-hanging fruit sector in terms of emissions mitigation.

2°C



Investment in new power capacity highest in nuclear and renewables by 2050

Sharply rising investments in power capacity additions are required to meet demand for electricity. Table 3 breaks this down per fuel source, showing how much capacity in gigawatt (GW) is coming on line each year. In descending order, natural gas, nuclear, solar PV and offshore wind are the generation categories driving the largest capacity additions in 2030. By 2050, solar PV is the largest.

The new capacity translates to substantial annual investment costs rising dramatically over time. (Investment costs include costs incurred by new capacity added to the system in earlier years and still operating, discounted over the expected lifespan.) Annualised investments in **solar photovoltaic** installations increase from USD20.8bn per annum in 2010 to USD106.1bn in 2030 (an increase of over 5x) and USD332.2bn in 2050 (15x). **Solar thermal** investments increase from USD1.1bn in 2010 to USD5.0bn in 2030 (an increase of 3.4x) and USD223.5bn in 2050 (an increase of c.200x). Annualised investments in **wind** power also soar: **offshore** installations increase to USD2.2bn in 2030 (up 638%) and to USD82.9bn in 2050 (up 280x), **onshore** increases to USD87.5bn in 2030 (an increase of 144%) and USD204.7bn in 2050 (an increase of 471%). For **nuclear**, annualised investments in installations to USD203.2bn in 2030 and USD723.5bn in 2050, the largest area of power investment at both these dates.

In relation to **natural gas**, however, annualised investments in installations increase from USD38.3bn in 2010 to USD107bn in 2030 (up 179%) but then decrease to USD94.5bn in 2050. Annualised investments in **coal** increase from USD92.3bn in 2010 to USD208.2bn in 2030 (up 126%) but then decrease sharply to USD64.3bn in 2050 (down 30% vs 2010). Table 3 illustrates that carbon capture and storage features in a cost-optimal 2°C scenario for some biomass and natural gas and for all coal use as fuel stocks.

2°C

Table 3: Global annualised capacity additions and investment costs in power sector under the 2°C scenario

	2010		2030		2050	
	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)
Biomass	1	1,007	1	10,095	3	14,469
Biomass CCS	0	0	5	6,996	16	61,812
Coal	101	92,299	20	208,212	0	64,325
Coal CCS	0	0	1	1,478	12	20,488
Natural Gas	90	38,331	44	106,971	16	94,451
Natural Gas CCS	0	0	7	3,690	88	75,479
Geothermal	0	0	6	23,483	22	126,554
Hydro	23	19,134	23	105,370	79	410,301
Nuclear	0	518	41	203,162	107	723,470
Oil	0	24	0	546	0	0
Solar PV	10	20,814	34	106,123	156	332,192
Solar thermal	0	1,130	2	4,956	84	223,515
Tidal	0	0	0	0	0	278
Wind-offshore	0	294	1	2,172	30	82,918
Wind-onshore	37	35,879	36	87,462	91	204,740
Total	263	209,431	222	870,715	703	2,434,993

Source: UCL, HSBC. Note: Forward looking capacity additions for 2030 and 2050 are cost-optimal projections. There is some recognition of 2010's actual figures as a base year, however, and capacity additions from that point forwards are calculated by TIAM-UCL with certain roll-out constraints. It should be noted that, in some instances, capacity additions may break through this roll-out 'ceiling'. Shorter term projections for intermittent renewable technologies through to 2015 and to 2020 (based on 2010), for instance, have been surpassed by some distance by the actual numbers seen to date.

Primary energy demand increases across all sectors under 2°C

Primary energy consumption increases in most sectors of the economy (except for power), with the highest overall proportional increases by 2050 in agriculture (90%), upstream (322%), and transport (79%). However, while power, the biggest consumer of primary energy, sees a significant shift from coal to low carbon technologies, in other sectors, fossil fuels retain share. Here we look at how energy is used in the other three major demand sectors of the energy system.

Industry uses more power, and more fossil fuels, though coal use declines

Industry accounted for 27% of total energy use and 22% of emissions in 2010. Use of low-carbon energy and efficiency improvements in this sector would therefore be meaningful in terms of overall mitigation targets. However, the high level of fossil energy use in industry in 2030 and 2050, even under the 2°C scenario, is largely due to limited fuel switching potential and large feedstock use across the different industrial processes, particularly the chemical sector, in which naphtha (derived from oil) is relied upon heavily. Chart 7 shows this as well as that industry accounts for a material share of the increased demand for power generation, described in the previous section.

In the 2°C scenario, coal consumption in industry increases by 6% between 2010 and 2030 and drops by just -15% by 2050, illustrating the feasibility challenge of removing all coal from the industry sector, even under stringent climate constraints. This reflects both the cost-effectiveness of using coal to generate high temperature heat, its usefulness in combined heat and power as many sub-sectors can utilise both the heat and electricity generated, and the lack of technological alternatives for many specific processes, in particular steel making.

Currently, steel is typically made using coking coal, which is combined with iron ore and limestone to achieve high temperatures and remove water, tar and coal gas. However, a process called direct reduced iron uses natural gas to concentrate iron ore into pellets within a furnace that requires less or no coking coal. Iron

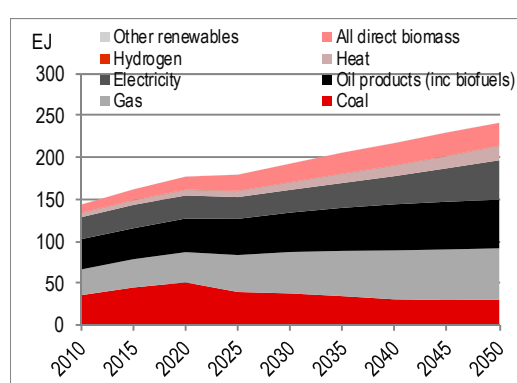
2°C

and steel is the largest industrial sector in terms of energy use, accounting for 37% of the total in 2010. Use of gas in this subsector increases by 247% by 2050 and by a similar amount for other metals processes.

The analysis shows that gas is a vital alternative when trying to reduce emissions across the industrial sector, given the need to reduce coal consumption to the maximum extent possible, across all subsectors, as coal is the most carbon intensive of fossil fuels. Chart 8 illustrates the ranges of relative CO₂ intensity of producing power with different fossil fuels. In industry as a whole, gas use increases more in the 2°C scenario than in INDC, increasing by almost 99% in 2050 relative to 2010. Similar to gas, oil use increases materially, by 30% by 2030 and over 61% by 2050.

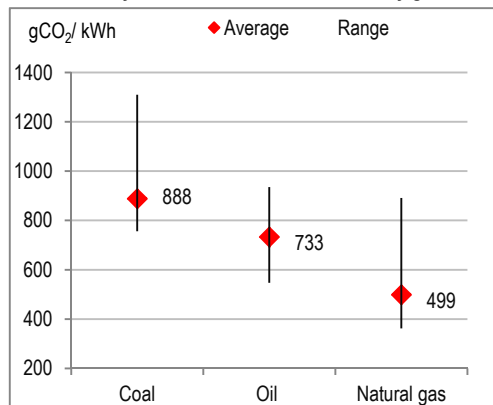
Overall, the direct fossil fuel share as feedstock to industry falls from 71% in 2010 to 62% in the 2°C scenario. Biomass, electricity and heat (mainly produced by combined heat and power) account for the non-fossil share, in aggregate doubling relative to 2010 levels across all scenarios. Combined with greater energy efficiency gains, a larger increase in these types of energy in 2°C allows for the lower share of fossil fuels. Overall, however, and despite the drop in coal use, absolute fossil fuel consumption increases by 31% between 2010 and 2030 and 46% by 2050.

Chart 7: Industry fuel consumption under the 2°C scenario



Source: UCL, HSBC

Chart 8: Lifecycle GHG emissions for electricity generation



Sources: Comparison of lifecycle greenhouse gas emissions of various electricity generation sources, World Nuclear Association

Oil still dominates transport, gas and electricity the new entrants

Transport accounted for 18% of total energy use and 19% of emissions in 2010. Total primary energy consumption by the transport sector increases under 2°C by 32% by 2030 and 79% by 2050, versus 2010 levels. Within this, as shown by chart 9, oil consumption broadly maintains its share (down to 64% in 2050) and grows 16% in absolute terms. The largest growth in demand from this sector is for electricity (up from 1% to 7% in 2050), used to power EVs and for gas (up from 1% to 21% in 2050), which will be increasingly competitive for use as liquefied natural gas (LNG) in shipping. Hydrogen use also becomes competitive under the 2°C scenario and shows an increase in market share from 0% to 8%.

2°C

Chart 9: Transport fuel consumption under the 2°C scenario

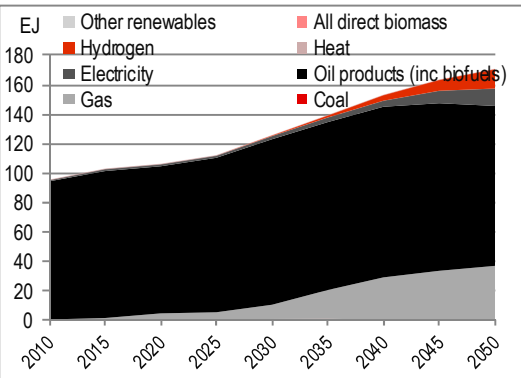
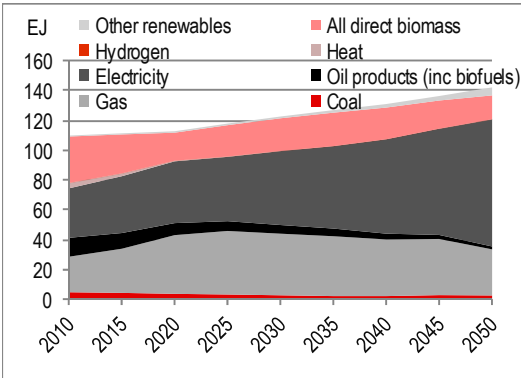


Chart 10: Buildings fuel consumption under the 2°C scenario



Buildings will consume more power as fossil consumption slides

The buildings sector sees growth in total energy consumption of 122,426PJ in 2030 (up 12% on 2010) and an increase up to 141,982PJ in 2050 (up 29%). Power use fulfils the majority of energy demand in buildings in 2050 as a cost-optimal means of achieving economy-wide decarbonisation. Chart 10 illustrates growth of 49% by 2030 and 157% by 2050. Meanwhile, overall fossil fuel use in buildings is down to 35,475PJ in 2050 from 41,219PJ in 2010 (a drop of 14%).

2050 GHG emissions down to 24.8 GtCO₂e p.a., down 47% vs 2010, giving 2°C warming in 2100

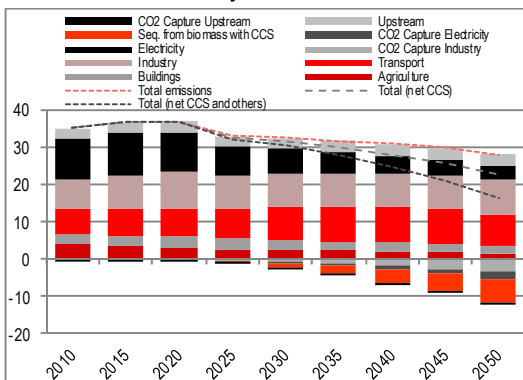
The principal constraint put on TIAM-UCL model for this scenario was to limit warming to 2°C. Annual GHG emissions in 2050 are constrained down to 24.8GtCO₂e to give a 60% probability of the temperature change at 2100 being 2°C, vs pre-industrial times. TIAM-UCL has suggested the cost-optimal changes to the energy system which will get to this number from 46.9GtCO₂e in 2010. It is this which has governed major changes in the energy system, including the dramatic switch away from coal in power.

CO₂ emissions are up most from the transportation and industry sectors, by 31% and 33% in 2050 (excluding CO₂ capture). However, the share of emissions from power is down from 31% in 2010 to 20% in 2030 and 13% (excluding CO₂ capture) in 2050. Chart 11 captures this and also illustrates the growing importance of sequestration – via CCS at the point of fossil fuel combustion and via use of biomass, seen as the part of the column below zero on the vertical axis – in bringing emissions down towards the level commensurate with the 2°C target.

By 2050, emissions are down in India by 12%, US by 75% and China by 50%, illustrated by Chart 12. On a per capita basis, India is down 34%, China by 52% and the US by 80%.

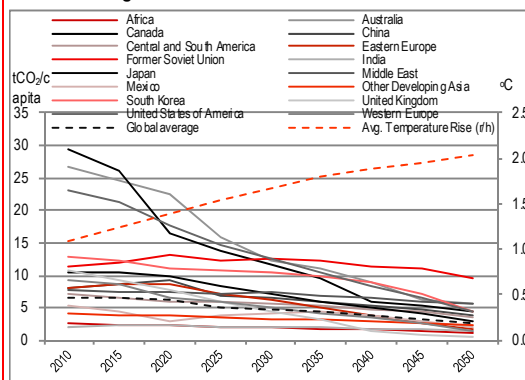
2°C

Chart 11: CO₂ emissions by sector under the 2°C scenario



Source: UCL, HSBC

Chart 12: Regional emissions under the 2°C scenario



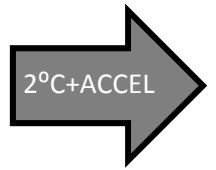
Source: UCL, HSBC

Conclusion

In a 2°C world, the cost-optimal energy system will see less coal used across the economy but upticks in consumption of gas and oil. Meanwhile, there will be soaring investment in renewables, as regional per capita emissions come down in most regions, seen in Chart 12.

In the buildings sector, there is considerable scope for emissions reductions, both by building green new buildings and through retrofitting. We explored this theme in [Green Buildings and climate](#), 21 July 2015, looking at how energy efficiency measures implemented to optimise energy use during the occupancy phase offer a significant emission reduction potential. Ambitious retrofitting through glass, insulation and efficient building products can mean emissions per capita and per building are much reduced. Furthermore, advances in renewable power generation and battery storage increasingly mean buildings can act as mini-power stations at cost-effective levels of investment. Indeed, under the 2°C scenario, the prediction is that on-site renewables will be used much more, increasing by 93% by 2030. However, this is from a very small base and even at this point, they will only account for 3.8% of total generation, globally.

The most dramatic shift away from fossil fuels is in the power sector, as we have already seen, where a material transition results from cost-optimal decarbonisation of the overall economy, as coal declines materially and use of CCS becomes competitive. Asset allocation in long-term investment portfolios which are positioned for a 2°C world should consider this change in the balance and scale of use of fossil fuels, the fact that the power sector will see huge investment in coming decades and gauge whether assets are resilient to 2°C warming.



The 2°C+ACCEL energy transition

- ▶ Coal demand declines by 66% from 2010-50, with use in power down 88%, as renewables grow 8x to 65% feedstock share
- ▶ Gas demand grows 49% from 2010-30 and 80% to 2050, driven by growth in all major sectors, with oil demand down 8%
- ▶ Investment costs in power generation increase by 321% from 2010-30, to USD1.12trn p.a. By 2050, they reach USD2.34trn p.a.

17% more energy consumed in 2030 under 2°C+ACCEL

The 2°C+ACCEL Scenario, described on page 14, delivers a maximum temperature rise of 2°C higher than pre-industrial levels, which is the globally agreed temperature goal. This is achieved by varying both the climate module to achieve a maximum 2°C and by varying the technology module to increase the speeds of cost reduction for key clean technologies, then allowing other variables to adjust in a cost-optimal manner, against the backdrop of higher energy consumption across the economy, 17% higher in 2030 than 2010 and 44% higher in 2050. In this section, we consider key findings from data generated by the TIAM-UCL model, under the emissions and technology constraints of the 2°C+ACCEL Scenario, which suggest what the cost-optimal energy system will look like in 2030 and 2050. The first section looks at fuel consumption per fossil fuel. Subsequent sections look at fuel consumption per sector with a focus on the future for power generation, including investment costs.

Overall fossil fuel consumption – coal and oil down long term

Coal use declines 29% during 2010-2030 and by 66% to 2050

Under the 2°C+ACCEL scenario global coal consumption declines over both time periods is mostly driven by power sector decarbonisation. The challenge of removing coal from the industry sector, where technology allows much less substitution, is evident however and coal increases by 11% by 2030 and reduces by only 10% by 2050. By 2050, around 31 exajoules (or about 1.5 billion tonnes) of annual coal consumption remains in the industry sector. By 2050 around 63% is also used for non-energy uses.

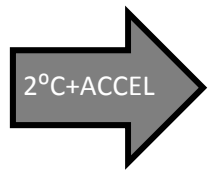
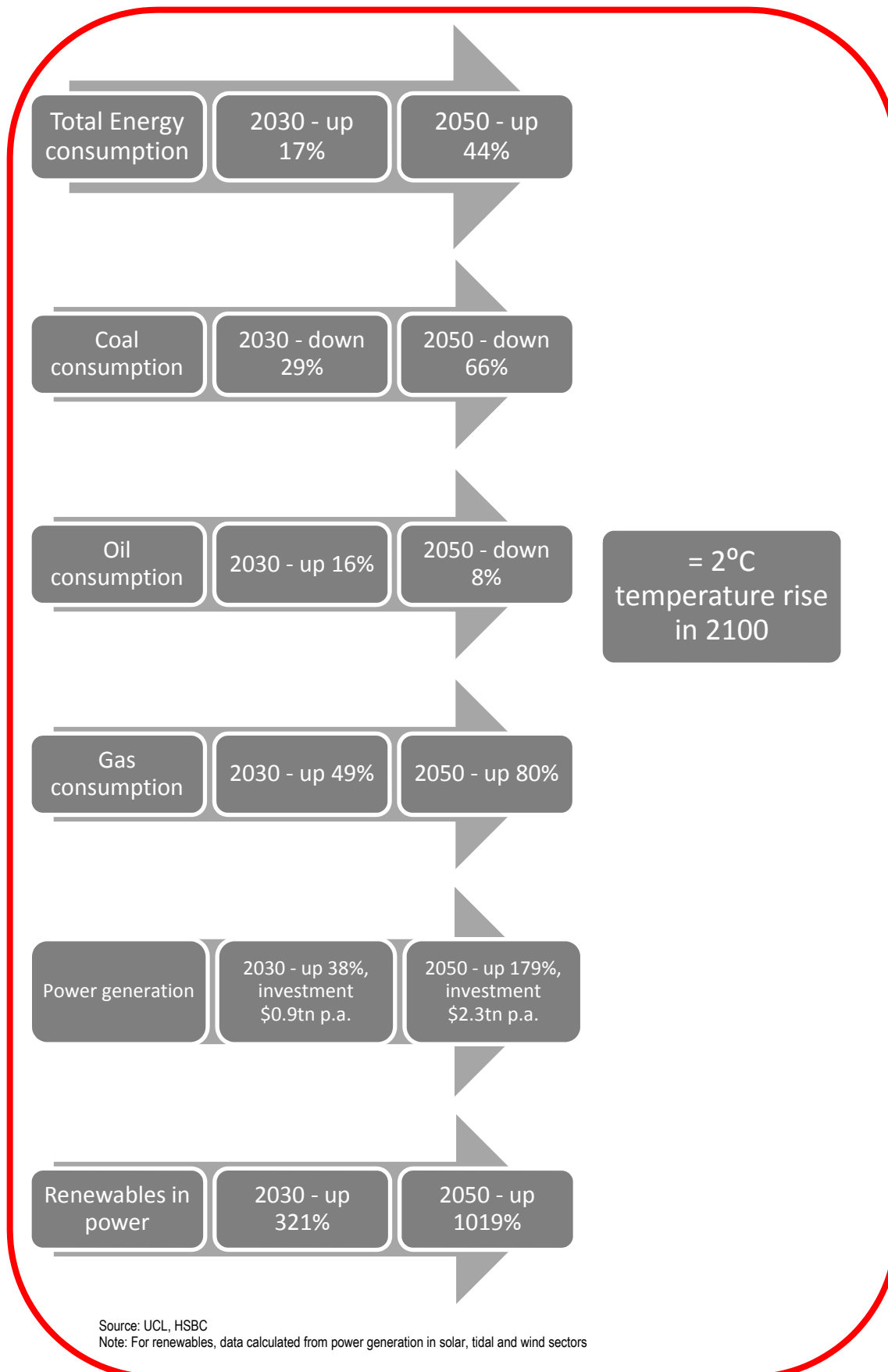
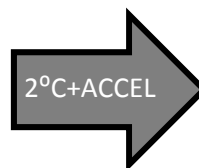


Figure 3: Key tenets of the energy system under the 2°C+ACCEL Scenario





Oil use increases by 16% during 2010-2030, but decreases by 8% to 2050

Current and future use of oil reflects the use of this commodity in both transport and industry sectors. The decrease of 8% in 2050, reflects continued cost reductions for EVs seeing them taking more transport share under the 2°C+ACCEL scenario. With the complete switching to LNG in the shipping sector, significant passenger and freight vehicle efficiency gains, and cheaper EVs, under the 2°C+ACCEL scenario oil use in transport is 31% lower in 2050 than in 2010.

Gas use increases by 49% during 2010-2030, and by 80% by 2050

Consumption of natural gas over both time periods reflects the importance of this commodity under even stringent climate objectives. Low growth is observed in the buildings sector, where emissions cannot be captured using CCS. More gas is used in industry, reflecting the need to displace coal. More gas is also used in transport, as LNG takes share as the feedstock in ship engines.

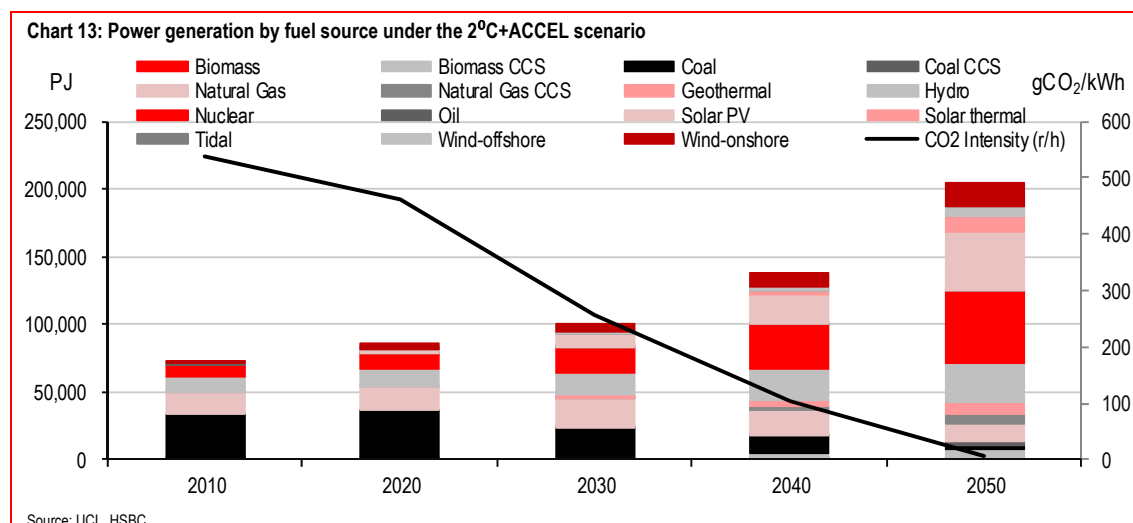
Power generation under 2°C+ACCEL – nuclear, solar and hydro replace coal and gas

Total global power generation under the 2°C+ACCEL scenario increases by 38% from 2010-30. By 2050, there is a 179% increase.

Fossil fuels – mostly coal and gas – are dominant in the power sector fuel consumption mix in 2010, accounting for 64% and 25% shares, respectively. Under the 2°C+ACCEL scenario, the main difference from other scenarios lies in the removal over coming decades of coal from the list of power generation feedstock, and in the use of gas largely with CCS technologies. By 2030, coal use in the power sector is down 45% from 2010 and now represents 39% of the total fuel consumption mix in the sector. By 2050, coal represents only 7% of the total fuel consumption mix, dropping 88% relative to 2010.

Much of the increase in total power capacity is met by low carbon sources of generation, in particular nuclear, solar and hydro. Chart 13 illustrates the changes in the mix. Again, there is a role for biomass CCS (BECCs).

The CO₂ intensity of electricity falls to 255 gCO₂/kWh in 2030, representing a 52% drop from 2010, as seen in chart 13. By 2050, this figure is down to 6gCO₂/kWh, representing almost a 99% drop – as per the 2°C scenario, a virtually decarbonised power mix.



Investment in new power capacity led by renewables

More capacity additions are required for 2°C+ACCEL than under 2°C, driven by the additional demand from electric vehicles. Cheaper **solar photovoltaic** under the variations made to the technology learning module in this scenario factor through into the power generation mix, taking a greater share of new capacity additions, where annualised investments are up to USD165.3bn in 2030 and USD426.6bn in 2050. **Solar thermal** increases from USD3.5bn in 2030 and then soars to USD214.7bn in 2050.

Offshore wind sees annualised investments up 20x to USD8bn in 2030 and then to USD91.6bn in 2050.

Some low-carbon technologies do not rise as much as under 2°C, displaced by cheaper solar despite the higher overall demand for energy in 2°C+ACCEL. **Onshore wind** rises 116% from USD35.9bn in 2010 to USD77.4bn in 2030 and then higher to USD190.7bn in 2050. Investments in **nuclear** are up to USD178bn in 2030 and USD654.1bn in 2050.

New fossil fuels generation: i.e. using natural gas and coal, follows a similar pathway under both the 2°C scenarios, although there is less short-term growth in coal-powered generation, displaced more quickly by solar. Table 4 illustrates that carbon capture and storage features in a cost-optimal 2°C+ACCEL scenario for some new biomass and natural gas capacity additions and for all new coal use as a fuel.

Primary energy demand increases across all sectors under 2°C+ACCEL

Primary energy consumption increases in most sectors of the economy (except for power), with the highest overall proportional increases by 2050 in agriculture (90%), industry (71%) and upstream (204%). However, while power, the biggest consumer of primary energy, sees a significant shift from coal to low carbon technologies, in other sectors, fossil fuels retain share. Here we look at how energy is used in the other three major demand sectors of the energy system.

Industry uses more power, and more fossil fuels, though coal use declines

The high level of fossil fuel energy use in industry in 2030 and 2050, even under the 2°C+ACCEL scenario, is largely due to limited fuel switching potential and large feedstock use across the different

Table 4: Global annualised capacity additions and investment costs in the power sector, under the 2°C+ACCEL scenario

	2010		2030		2050	
	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)
Biomass	1	1,007	0	9,758	0	4,616
Biomass CCS	0	0	3	5,266	26	75,684
Coal	101	92,299	21	210,146	0	64,399
Coal CCS	0	0	2	2,275	11	19,683
Natural Gas	90	38,331	46	103,158	5	89,649
Natural Gas CCS	0	0	5	2,677	19	22,967
Geothermal	0	0	5	19,695	19	112,322
Hydro	23	19,134	20	93,229	55	367,131
Nuclear	0	518	46	178,014	93	654,050
Oil	0	24	3	1,198	0	904
Solar PV	10	20,126	101	165,248	300	426,634
Solar thermal	0	1,130	2	3,531	174	214,744
Tidal	0	0	0	0	0	278
Wind-offshore	0	294	4	8,015	40	91,630
Wind-onshore	37	35,879	40	77,393	123	190,645
Total	263	208,744	299	879,603	865	2,335,336

Source: UCL, HSBC. Note: Forward looking capacity additions for 2030 and 2050 are cost-optimal projections. There is some recognition of 2010's actual figures as a base year, however, and capacity additions from that point forwards are calculated by TIAM-UCL with certain roll-out constraints. It should be noted that, in some instances, capacity additions may break through this roll-out 'ceiling'. Shorter term projections for intermittent renewable technologies through to 2015 and to 2020 (based on 2010), for instance, have been surpassed by some distance by the actual numbers seen to date.

industrial processes, particularly the chemical sector. Chart 14 shows this as well as that industry accounts for a material share of the increased demand for power generation, described in the previous section. Coal consumption in industry increases by 11% between 2010 and 2030 and drops by just 10% by 2050, illustrating the feasibility challenge of removing all coal from the industry sector, even under stringent climate constraints. This is unsurprising as the variations made to the technology learning module under this scenario do not have extensive application to the industrial sector, particularly compared to uptake in power and transport.

In industry as a whole, gas use increases by almost 102% in 2050 relative to 2010. Similar to gas, oil use increases materially, by 31% by 2030 and over 68% by 2050.

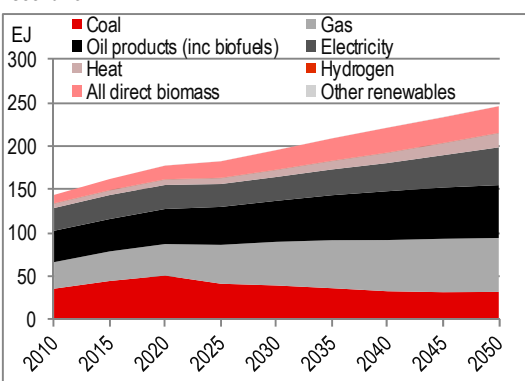
Overall, the direct fossil fuel share as feedstock to industry falls from 71% in 2010 to 63% in the 2°C+ACCEL scenario. Biomass, electricity and heat (mainly produced by combined heat and power) account for the non-fossil share, in aggregate doubling relative to 2010 levels across all scenarios. Combined with greater energy efficiency gains, a larger increase in these types of energy allows for the lower share of fossil fuels. Overall, however, and despite the drop in coal use, absolute fossil fuel consumption increases by 34% between 2010 and 2030 and 51% by 2050.

With stronger cost reductions in renewable technologies, an increase in overall generation is observed, for solar and wind technologies in the 2°C+ACCEL case.

Oil use in transport is down, as gas and electricity take share

Transport accounted for 18% of total energy use and 19% of emissions in 2010. Total primary energy consumption by the transport sector increases under 2°C+ACCEL by 31% by 2030 and 44% by 2050, versus 2010 levels. Within this, as shown in chart 15, oil consumption broadly maintains its share (down to 47% in 2050) and declines by 31% in absolute terms. The largest growth in demand from this sector is for electricity (up from 1% to 20% share in 2050), used to power EVs which under this scenario see costs

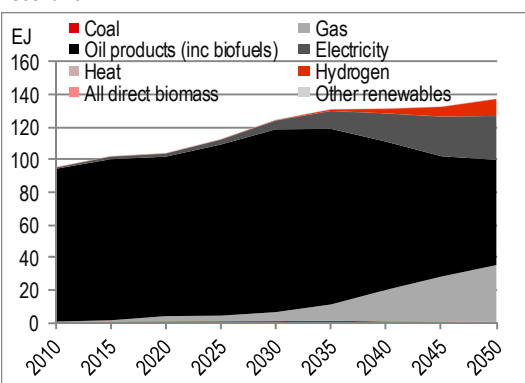
Chart 14: Industry fuel consumption under the 2°C+ACCEL scenario



Source: UCL, HSBC

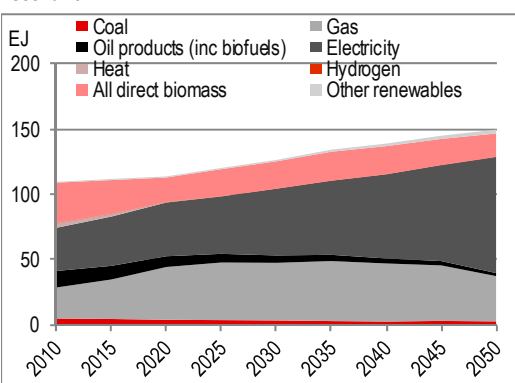
fall faster to USD31,200 per vehicle in 2050, vs USD54,200 under the standard case, and therefore also see greater adoption, and for gas (up from 1% to 25% share in 2050), which will be increasingly competitive for use as liquefied natural gas (LNG) in shipping. Hydrogen use also becomes competitive and shows an increase in market share from 0% to 8%. The reductions in oil use through innovation in alternative technologies, in 2°C+ACCEL, results in oil consumption below 2010 levels in 2050.

Chart 15: Transport fuel consumption under the 2°C+ACCEL scenario



Source: UCL, HSBC

Chart 16: Buildings fuel consumption under the 2°C+ACCEL scenario



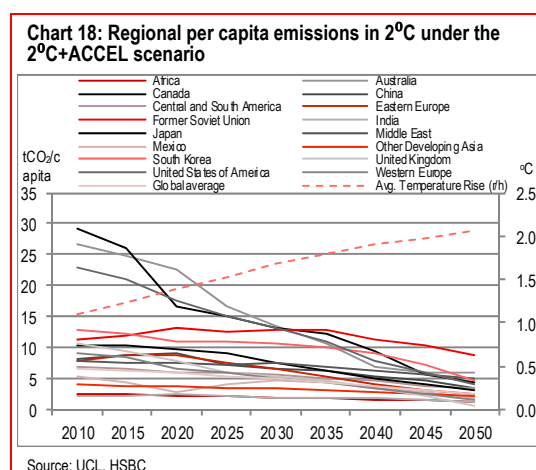
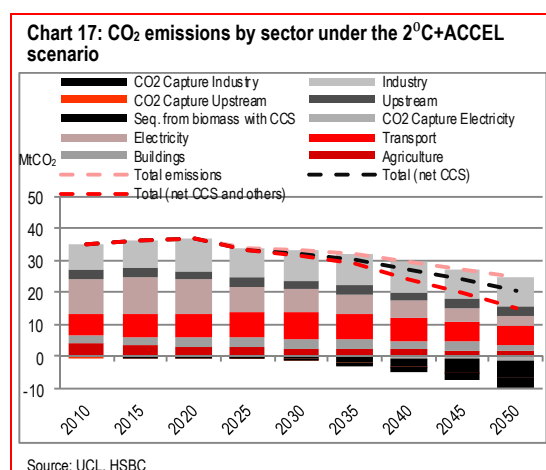
Source: UCL, HSBC

Buildings will consume more power, consumption of fossil fuels peaks in 2030

The buildings sector sees growth in total energy consumption rise 15% in 2030 (on 2010) and 37% in 2050. Power use fulfils the majority of energy demand in buildings in 2050 as a cost-optimal means of achieving economy-wide decarbonisation. Chart 16 illustrates growth of 54% by 2030 and 169% by 2050. Meanwhile, overall fossil fuel use in buildings is down to 39,631PJ in 2050 (a drop of 4% from 2010).

Annual GHG emissions fall to 23.6 GtCO₂e in 2050, giving 2°C warming in 2100

The principal constraint put on the TIAM-UCL model for this scenario was to limit warming to 2°C. As with the 2°C scenario, the temperature increase at 2100 is indeed 2°C at a 60% probability, constrained by bringing annual GHG emissions at that point down to 23.6GtCO₂e. TIAM-UCL has suggested the cost-optimal changes to the energy system which will get to this number from 46.9GtCO₂e in 2010. It is this which has governed major changes in the energy system, including the dramatic switch away from coal in power. The most notable difference from the 2°C Scenario is that emissions from transport are down dramatically in 2°C+ACCEL, driven by cheaper EVs, allowing lower emissions cuts from other sectors, notably buildings.



CO₂ emissions contribution is up most from the transportation and industry sectors, by 23% and 38% in 2050 (excluding CO₂ capture). However, the share of emissions from power is down from 31% in 2010 to 21% in 2030 and 13% (excluding CO₂ capture) in 2050. Chart 17 captures this and also illustrates the growing importance of sequestration in bringing emissions down towards the level commensurate with the 2°C target, as regional per capita emissions again come down in most regions, seen in Chart 18.

Conclusion

Investors and companies believing in strong climate regulation and accelerated cost reductions in clean technologies should position themselves for a global economy in which coal consumption is down substantially as oil drifts down too by 2050, while gas grows significantly. In the transport sector, the major difference is the growth in EVs, which require more electricity, and in ships using LNG instead of oil-based bunker fuel. Companies in a number of sectors stand to gain from this transition along the value chain: builders of cars and ships and components for these, infrastructure suppliers for recharging or refuelling as well as providers of power and natural gas. Buildings are also catalysed by cheaper technology as lower cost renewables and batteries under the 2°C+ACCEL scenario, mean that on-site renewables will be used much more, increasing by 84% by 2030. However, this is from a very small base and even at this point, they will only account for 2% of total generation, globally.

Meanwhile, the power sectors sees larger demand under this scenario and also benefits from the clean tech catalysts – investors should be aware of the growth of this sector and the cost-optimal mix within the more stringent climate restrictions applied, which includes CCS for gas turbines.

The INDC energy transition

- ▶ Coal demand increases 17% in 2010-50. Coal use in power is down 18%, as renewables grow 4x to 29% feedstock share
- ▶ Gas demand grows by 37% in 2010-30 and 97% to 2050, driven by growth in all sectors, with oil up 52% as car use soars
- ▶ Investment in power generation increases twofold in 2010-30, to USD785bn pa; by 2050, it reaches USD1.65trn pa

27% more energy consumed in 2030 under the INDC scenario

The INDC scenario makes the assumption that a Universal Climate Agreement is signed at the Conference of Parties in Paris later this year. It then assumes that the world ceases to pursue efforts to stay below 2°C in the long term and instead countries aim only to meet their Intended Nationally Determined Contributions (INDCs). TIAM-UCL is constrained to achieve targets via variations applied to the climate module.

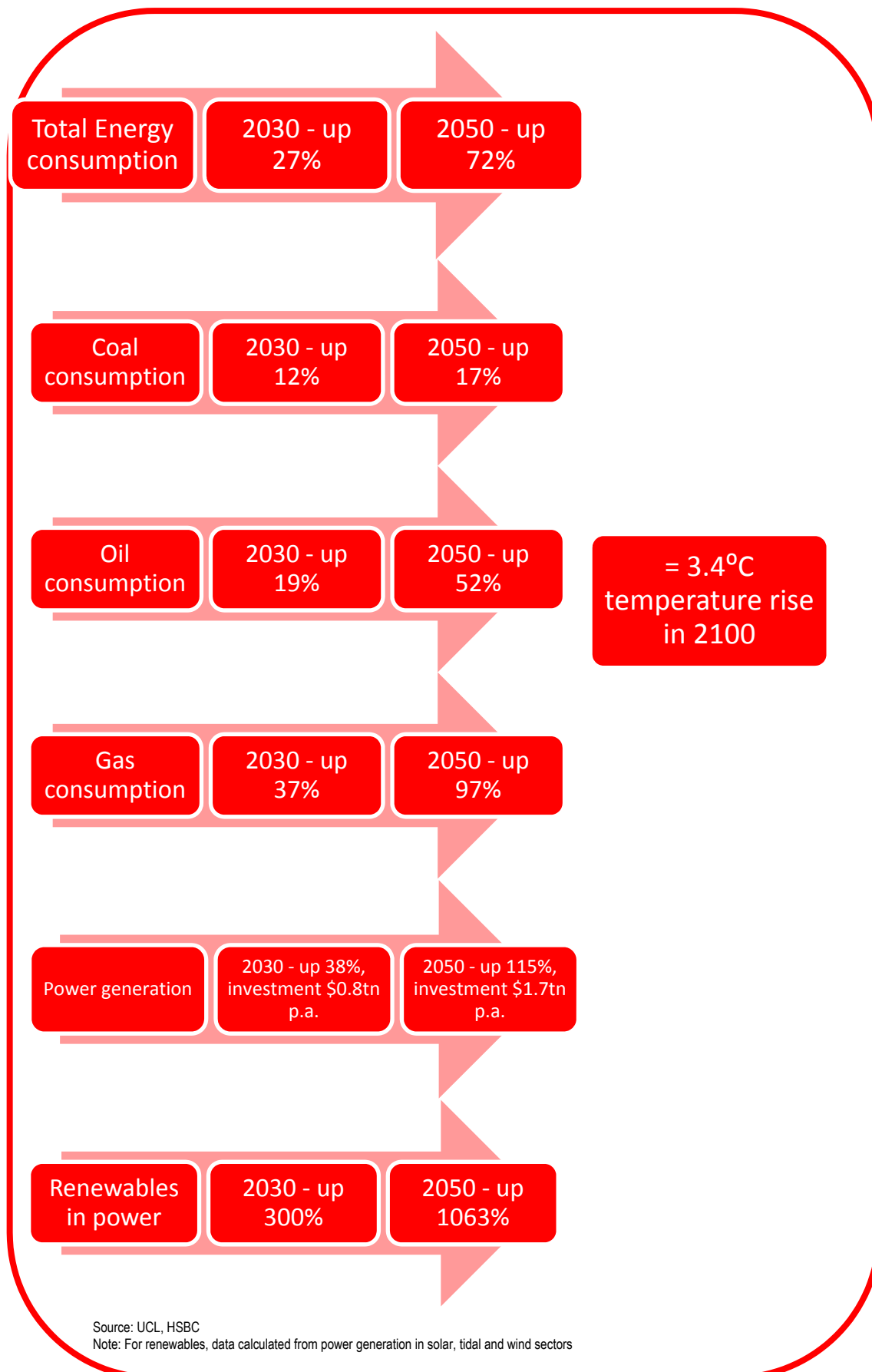
In this section, we consider key findings from data generated by the TIAM-UCL model suggesting what the cost-optimal energy system will look like in 2015 under the INDC Scenario, against the backdrop of higher energy consumption across the economy, 27% higher in 2030 than 2010 and 72% higher in 2050. This is broken down into sections for fuel consumption per fossil fuel, power generation (including investment costs), fuel consumption per sector and greenhouse gas emissions (including temperature rise). Regional variations are also explained throughout and the implications for the energy system are discussed as at 2030 and 2050.

Overall fossil fuel consumption – more of everything

Coal increases to 12% by 2030 and 17% by 2050

Under the INDC scenario global coal consumption actually increases. Only in the power sector does coal use actually decline. Coal use shows a strong increase in the metals sectors in the INDC scenario, where substitution potential is less simple.

Figure 4: Key tenets of the energy system under the INDC Scenario



Gas doubles through 2050, with higher demand from transport and buildings

Consumption of natural gas doubles by 2050 vs 2010, reflecting the importance of this commodity in the future. Unlike in the 2°C scenario, more gas is used in buildings (up 76% in 2030 and 101% in 2050) and in transport (up 1,558% in 2030 and 8,157% in 2050).

Oil increases by over 50% by 2050, as road and industry consumption soar

Current and future use of oil reflects the use of this commodity in both transport and industry sectors, which accounted for 60% and 23% of consumption in 2010 respectively. In the INDC scenario, oil use increases by 19% in 2030 and by 52% in 2050. The largest demand growth comes from transport (up 60%) and industry (up 82%). Oil use can increase because the climate pledges focus cost-optimal emissions mitigation efforts in the power sector rather than the transport sector, except for international shipping, where oil is displaced by gas.

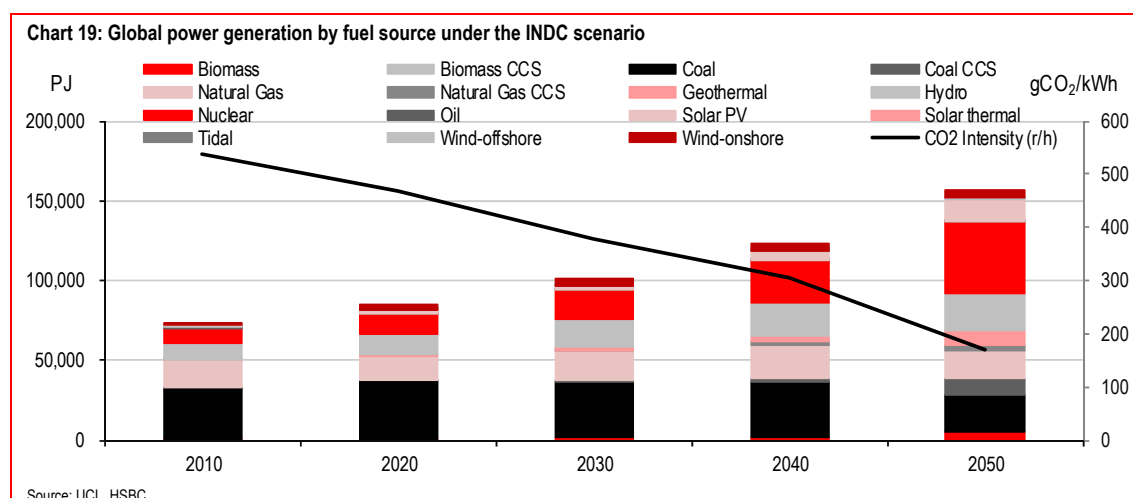
Power generation – coal down, gas flat in share of the mix

As stated in previous sections, the power sector is key to achieving climate goals and a key output of the TIAM-UCL model, in our view, is the substantial growth in demand for power. Total global power generation capacity under the INDC scenario increases by 38% from 2010 to 2030, the end of the INDC period. By 2050, this reaches 157,219PJ, a 115% increase. This is lower than in the 2°C scenario, to reflect the fact that there is less penetration of EVs in the transport sector meaning less demand for power.

However, while power, the biggest consumer of primary energy sees growth in the mix from low carbon technologies, fossil fuels retain share, albeit slightly with CCS applied to two fifths of coal production and a quarter of gas production in 2050. This suggests that the UCA in isolation could have a significant impact on the generation mix.

Fossil fuels – mostly coal and gas – are dominant in 2010. However, by 2030, coal fuels are 35% of total power generation. By 2050, coal represents 15% of the mix. Most of the increase in total power capacity is met by low carbon sources of generation, in particular nuclear, solar and hydro. Un-sequestered gas production is flat to 2050, although increases 20% through use with CCS.

The **CO₂ intensity of electricity** falls to 377gCO₂/kWh in 2030, the end of the INDC period, representing a 30% drop from 2010, as seen in chart 19. By 2050, this figure is down to 169gCO₂/kWh, representing almost a 69% drop. This reflects the importance of power in cost-effective decarbonisation of the economy in line with the targets agreed by countries in their INDCs – power is the low-hanging fruit sector in terms of emissions mitigation.



Investment in new power capacity – solar, nuclear, coal and gas fuel electricity

Electricity consumption roughly doubles from 2010 to 2050, requiring new capacity additions. Without the faster cost reductions seen in the INDC+ACCEL scenarios or the more stringent climate policy of the 2°C scenarios, there remains headroom for investment in new fossil fuel capacity through to 2020. Table 5 shows annualised **coal** investments increase from USD92.3bn in 2010 to USD221.4bn in 2030 (an increase of 140%) and are still at USD151.8bn in 2050. **Natural gas** investment increases from USD38.3bn in 2010 to USD106.8bn in 2030 (an increase of 179%) and USD134.1bn in 2050 (an increase of 250%). Substantial investment in new **nuclear** capacity is also a cost-optimal means of meeting demand, increasing to USD159.3bn in 2030 and USD509.7bn in 2050. Renewables also grow, with **Solar PV** investments up 290% to 2030 and reaching USD204.2bn in 2050 (an increase of 881%). **Onshore wind** investments double to USD73.4bn in 2030 and reach USD101.4bn in 2050.

Table 5: Global annualised capacity additions and investment costs in the power sector, under the INDC scenario

	2010		2030		2050	
	Capacity additions (GW)	Investment costs (\$m)	Capacity additions (GW)	Investment costs (\$m)	Capacity additions (GW)	Investment costs (\$m)
Biomass	1	1,007	3	11,721	18	55,176
Biomass CCS	0	0	0	0	0	0
Coal	101	92,299	24	221,407	16	151,819
Coal CCS	0	0	2	2,369	37	60,233
Natural Gas	90	38,331	61	106,774	51	134,129
Natural Gas CCS	0	0	4	1,635	43	33,445
Geothermal	0	0	5	21,573	21	113,647
Hydro	23	19,134	25	100,686	55	256,429
Nuclear	0	518	32	159,335	81	509,659
Oil	0	24	1	712	0	1,645
Solar PV	10	20,814	17	81,241	117	204,152
Solar thermal	0	1,130	0	2,205	2	13,779
Tidal	0	0	0	0	0	0
Wind-offshore	0	294	1	1,869	7	15,554
Wind-onshore	37	35,879	22	73,412	29	101,437
Total	263	209,431	197	784,940	477	1,651,103

Source: UCL, HSBC. Note: Forward looking capacity additions for 2030 and 2050 are cost-optimal projections. There is some recognition of 2010's actual figures as a base year, however, and capacity additions from that point forwards are calculated by TIAM-UCL with certain roll-out constraints. It should be noted that, in some instances, capacity additions may break through this roll-out 'ceiling'. Shorter term projections for intermittent renewable technologies through to 2015 and to 2020 (based on 2010), for instance, have been surpassed by some distance by the actual numbers seen to date.



Demand for energy increases across all sectors

Energy consumption increases in most sectors of the economy under the INDC scenario, with the highest overall proportional increases in transport and industry. However, while power, the biggest consumer of primary energy sees growth in the mix from low carbon technologies, fossil fuels retain share. Here we look at how energy is used in the other three sectors of the energy system (after power) with great demand for primary energy.

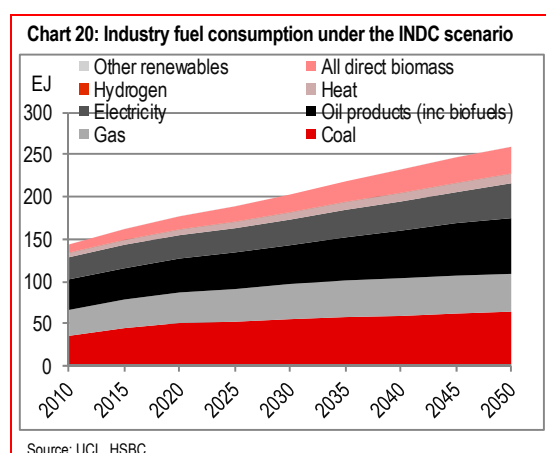
Industry – more of everything as emissions cuts focussed elsewhere

Industry accounted for 27% of total energy use and 22% of emissions in 2010. A high level of fossil fuel energy use in industry in 2030 and 2050 remains in place under the INDC scenario. This is largely due to limited fuel switching potential as described in the 2°C and 2°C+ACCEL scenarios. Chart 20 shows this as well as that industry accounts for a material share of the increased demand for power generation, described in the previous section.

In the INDC scenario, coal consumption increases by 55% between 2010 and 2030 and by 80% by 2050. Removing coal from many industry processes is technologically challenging or costly, and so increased need for products to meet demand from a growing economy and population mean growth in coal consumption, despite climate constraints attached to mitigation targets within country pledges.

The use of gas in industry increases by 35% by 2030 and 45% by 2050, less than half of the increase seen in the INDC scenario. Similar to gas, oil use increases materially, by 27% by 2030 and over 82% by 2050.

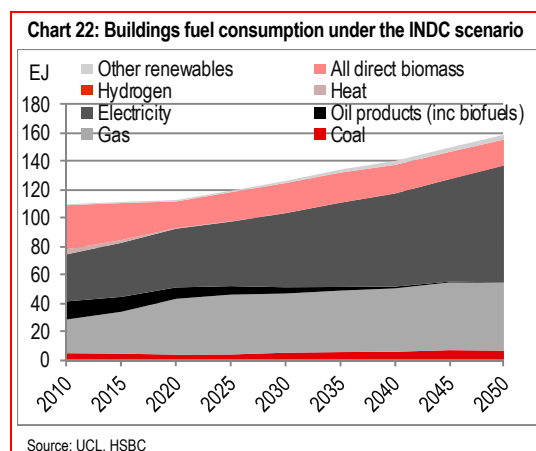
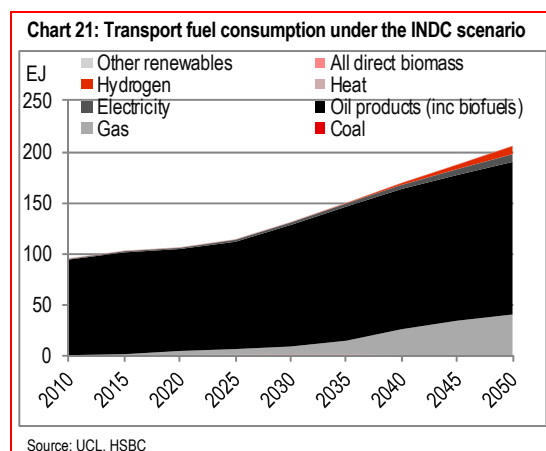
The direct fossil fuel share in industry falls from 71% in 2010 to 67% in the INDC scenario. Biomass, electricity and heat (mainly produced by combined heat and power) account for the non-fossil share, in aggregate increasing its share marginally to 2010 levels in the INDC scenario.



Oil still dominates transport, gas enters the mix

Transport accounted for 18% of total energy use and 19% of emissions in 2010. Energy consumption by the transport sector increases under INDC by 37% by 2030 and 116% by 2050, versus 2010 levels.

Within this, as shown by chart 21, oil's share as a feedstock is down 26% and grows 60% in absolute terms. The largest growth in demand from this sector is for gas (up from 0.5% to 19.4%), which will increasingly be used as liquefied natural gas (LNG) in shipping (up 3,726%).



Buildings demand more energy via power, as wood burning declines

The buildings sector sees growth in total energy consumption of 125,977PJ in 2030 (up 15% on 2010) and an increase of 158,627PJ in 2050 (up 45% in 2050).

Electricity (up 7% by 2030 and 19% by 2050) sees the biggest increase in demand, illustrated by Chart 22, while biomass decreases as countries such as India shift from burning wood in the home, while global demand for gas in buildings roughly doubles by 2050.

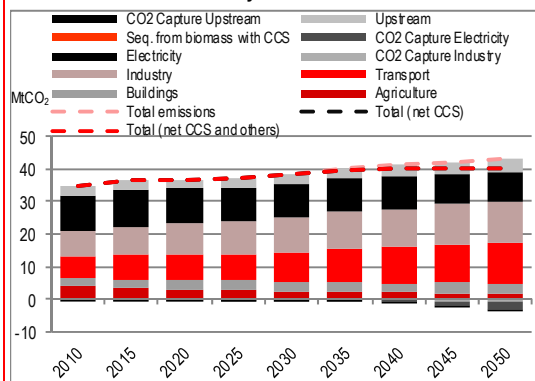
GHG emissions increase to 53GtCO₂e warming, leading to 3.4°C warming under the INDC scenario in 2100

The principal constraint put on the TIAM-UCL model for this scenario was to limit emissions in line with pledges within the INDCs.

TIAM-UCL delivers a temperature increase at 2100 of 3.4°C, at a 60% probability, under this scenario. Emissions reach 53 GtCO₂e in 2050. This indicates that current pledges, under the COP21 process, fall significantly short of achieving the type of reductions necessary by 2050 to ensure a reasonable probability of meeting the 2°C target. Emissions in 2050 will be 10% higher than 2010 levels, not a desirable outcome when compared with the IPCC's recommendation for a 40-70% reduction over this timeframe, and the 2°C emissions threshold surpassed in 2040 – i.e. the level of atmospheric greenhouse gases likely to lead to 2°C warming is reached by 2040. On an annual basis, the emissions level is more than double that observed in the 2°C scenario.

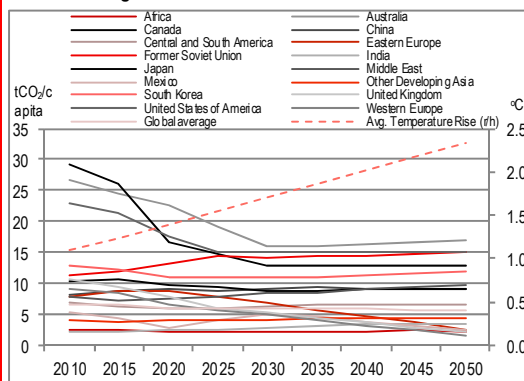
TIAM-UCL also tells us that the pathway to these outcomes sees emissions up most in the industry and transport sectors, by 65% and 84%. However, emissions in power are down from 31% in 2010 to 27% in 2030 and to 21% in 2050. Chart 23 shows this and also illustrates the growing importance of sequestration – via CCS at the point of fossil fuel combustion in industry and power generation and via use of biomass – in bringing emissions down in line with the INDCs.

Chart 23: GHG emissions by sector under the INDC scenario



Source: UCL, HSBC

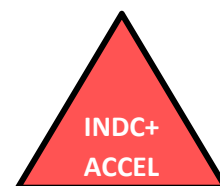
Chart 24: Regional emissions under the INDC scenario



Source: UCL, HSBC

Conclusion

Decarbonisation is focussed on the power sector, under this scenario, albeit absolute emission declines are tempered by rising demand for electricity. The INDCs substantially catalyse the renewable energy sector. Emissions actually increase from power, buildings and transport over coming decades, illustrated in chart 23. Chart 24 shows a mixed picture for regional per capita emissions, although most reduce to 2030, the end of the INDC period. Fossil fuels will maintain demand in all sectors, with the exception of coal use in power, which declines due to emissions declines required under INDC targets. Coal use in industry, including metallurgical coal use in metal-making processes, increases however. Industry as a whole remains heavily fossil-fuel dependent, as gas, oil and coal all rise materially.



The INDC+ACCEL energy transition

- ▶ Coal demand increases 23% from 2010-50. Coal use in power is down 22%, as renewables grow six times to 40% feedstock share
- ▶ Gas demand grows by 44% from 2010-30 and 73% to 2050, driven by growth in all sectors, with oil up 32% as car use soars
- ▶ Investment in power generation increases by four times in 2010-30, to USD820bn pa; by 2050, it reaches USD1.81trn pa

27% more energy consumed in 2030 under INDC+ACCEL

The INDC scenario makes the assumption that a Universal Climate Agreement is signed at the Conference of Parties in Paris later this year. It then assumes that the world ceases to pursue efforts to stay below 2°C in the long term and instead countries aim only to meet their INDCs. This is achieved by varying both the climate module to achieve emissions reductions in line with the INDCs and by varying the technology module to increase the speeds of cost reduction for key clean technologies, then allowing other variables to adjust in a cost-optimal manner, against the backdrop of more energy consumption across the economy, 27% higher in 2030 than 2010 and 68% higher in 2050.

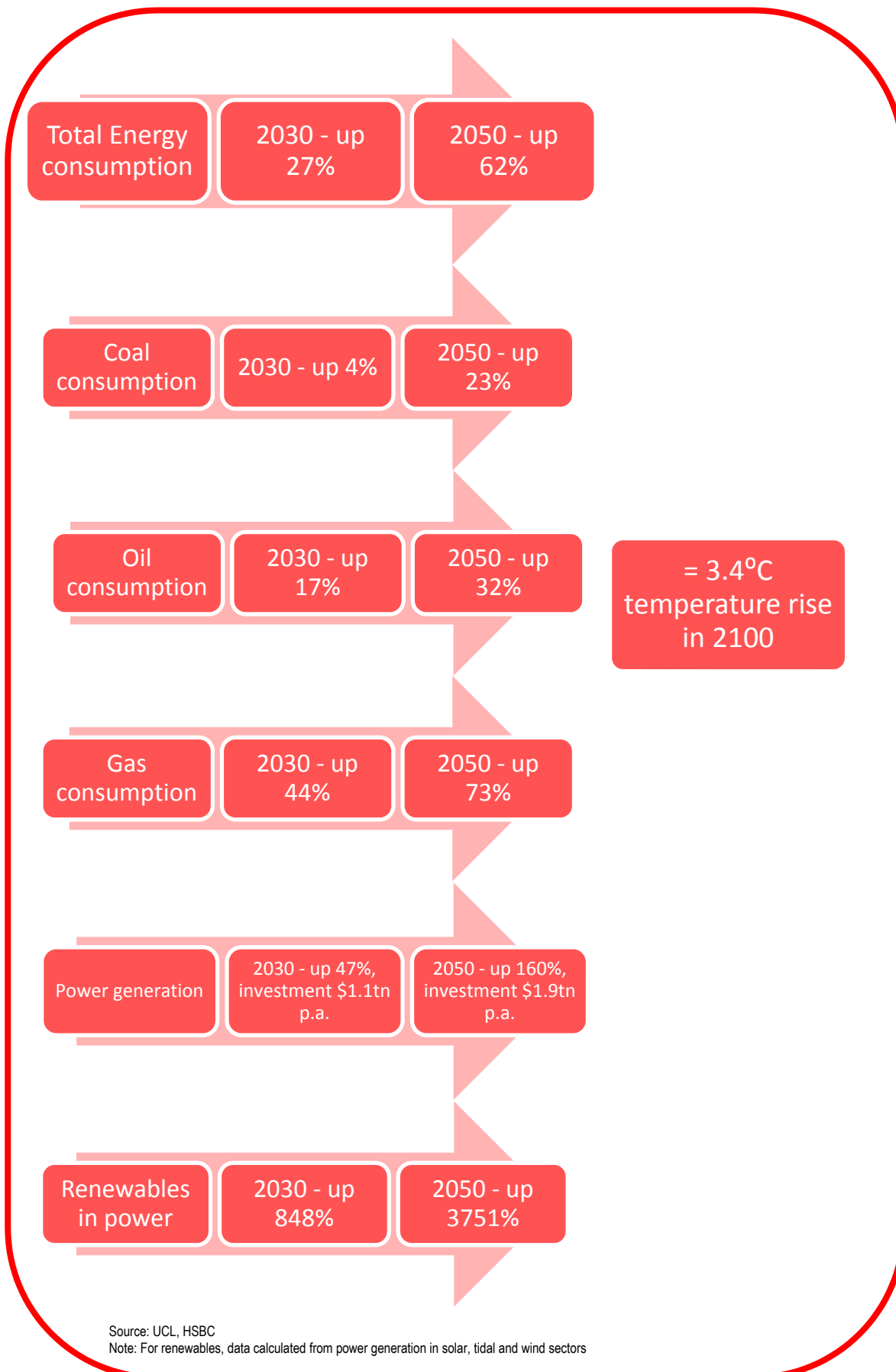
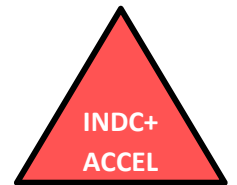
In this section, we consider key findings from data generated by the TIAM-UCL model suggesting what the cost-optimal energy system will look like in 2015 under the INDC Scenario. This is broken down into sections for fuel consumption per fossil fuel, power generation (including investment costs), fuel consumption per sector and greenhouse gas emissions (including temperature rise).

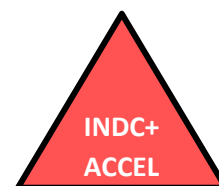
Fossil fuel consumption under INDC+ACCEL – more coal to power EVs than in the INDC scenario, less oil demand but still up

Coal consumption increases by 23% from 2010 to 2050

Under the INDC+ACCEL scenario global coal consumption actually increases, by just 4% by 2030 on 2010 levels but by 23% by 2050. Most of the new demand is from the power and industry sectors, where coal is increased used in chemical production. Coal use in electricity sees a marginal absolute decline under the INDC+ACCEL scenario, largely due to the increased uptake of other low carbon sources; solar is cheaper under this scenario.

Figure 5: Key tenets of the energy system under the INDC+ACCEL Scenario





Gas consumption catalysed by all sectors

Consumption of natural gas is up by 44% in 2030 and 73% in 2050 vs 2010, reflecting the importance of this commodity in the future. Unlike in the 2°C scenario, more gas is used in buildings (up 84% in 2030 and 117% in 2050) while consumption in transport up 11 times in 2030 and 31 times in 2050. There is also strong growth in demand in the industry sectors.

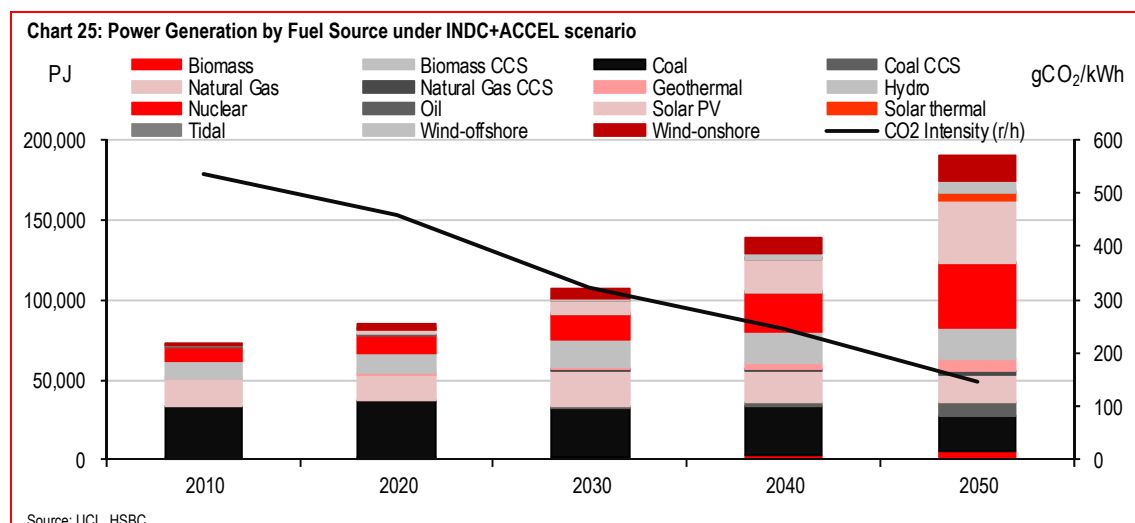
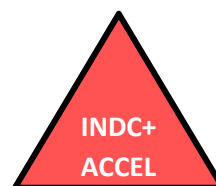
Oil consumption increases by 17% in 2010 to 2030 and 32% by 2050

Current and future use of oil reflects the use of this commodity in both transport and industry sectors, which accounted for 60% and 23% of consumption in 2010 respectively. In the INDC+ACCEL scenario, oil use increases by 17% in 2030 and by 32% in 2050. The largest demand growth comes from transport (up 26%) and industry (up 85%) Oil use can increase because the climate pledges focus cost-optimal emissions mitigation efforts in the power sector rather than the transport sector. The large-scale uptake of electric vehicles, primarily in passenger cars, lowers oil consumption compared to the INDC scenario. However, despite this almost total decarbonisation of road passenger transport, oil use remains higher in INDC+ACCEL than in the 2°C scenario as it continues to rely on oil consumption for freight and international aviation and shipping, although in the latter some oil is displaced by gas.

Power generation under INDC+ACCEL – coal loses share

Coal and gas are dominant in 2010. However, by 2030, coal fuels 29% of total power generation. By 2050, coal represents 12% of the mix. Most of the increase in total power capacity is met by low carbon sources of generation, in particular nuclear, solar and hydro. All major power generation technologies see an increase in capacity. Innovation effects in wind, solar PV and battery-electric vehicles, mean that additional electricity can be provided by lower cost renewables and that there is a net increase in overall electricity demand because of its use in the transport sector. Utilisation of CCS in this scenario is minimal.

The **CO₂ intensity of electricity** falls to 323gCO₂/kWh in 2030, the end of the INDC period, representing a 40% drop from 2010, as seen in chart 25. By 2050, this figure is down to 147gCO₂/kWh, representing almost a 73% drop. This reflects the importance of power in cost-effective decarbonisation of the economy in line with the targets agreed by countries in their INDCs – power is the low-hanging fruit sector in terms of emissions mitigation.



Fossil fuels still invested in but nuclear and renewables see biggest spend

The headroom created by the absence of more stringent climate rules means greater future investment in fossil fuels, although these are lower than under the INDC scenario, driven by lower solar costs. As illustrated in table 6, **coal** investments more than double from USD92.3bn in 2010 to USD210.4bn in 2030 before pulling back to USD136.7bn in 2050. **Natural gas** investments treble from USD38.3bn in 2010 to USD113.3bn in 2030 and rise further to USD154.8bn in 2050. **Solar PV** investments are up 6 times to USD139.2bn in 2030 and 17 times to USD355.7bn in 2050. **Solar thermal** trebles from USD1.1bn in 2010 to USD3.8bn in 2030 before soaring to USD98.2bn in 2050. **Nuclear** also sees dramatic growth under this scenario, as under others, up to USD127.1 bn in 2030 and to USD 428.6 bn in 2050. **Offshore wind** investments increase from USD0.29bn in 2010 to USD91.1bn in 2050, while onshore wind increases from USD35.9bn in 2010 to USD87.9bn in 2030 (an increase of 145%) and USD186.7bn in 2050 (an increase of 420%).

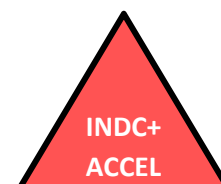


Table 6: Global annualised capacity additions and investment costs in the power sector, under the INDC+ACCEL scenario

	2010		2030		2050	
	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)	Capacity additions (GW)	Investment costs (USDm)
Biomass	1	1,007	5	15,362	13	50,882
Biomass CCS	0	0	0	0	0	0
Coal	101	92,299	22	210,355	20	136,712
Coal CCS	0	0	2	2,861	27	44,573
Natural Gas	90	38,331	57	113,260	90	154,756
Natural Gas CCS	0	0	4	1,836	5	8,397
Geothermal	0	0	5	18,175	13	80,257
Hydro	23	19,134	20	89,401	24	168,521
Nuclear	0	518	31	127,051	69	428,586
Oil	0	24	2	939	0	1,766
Solar PV	10	20,126	88	139,232	267	355,715
Solar thermal	0	1,130	2	3,820	88	98,240
Tidal	0	0	0	0	0	0
Wind-offshore	0	294	5	10,569	53	91,045
Wind-onshore	37	35,879	62	87,880	105	186,674
Total	263	208,744	306	820,740	774	1,806,123

Source: UCL, HSBC. Note: Forward looking capacity additions for 2030 and 2050 are cost-optimal projections. There is some recognition of 2010's actual figures as a base year, however, and capacity additions from that point forwards are calculated by TIAM-UCL with certain roll-out constraints. It should be noted that, in some instances, capacity additions may break through this roll-out 'ceiling'. Shorter term projections for intermittent renewable technologies through to 2015 and to 2020 (based on 2010), for instance, have been surpassed by some distance by the actual numbers seen to date.

Low carbon energy grows as power generation soars

Technological advances made under INDC+ACCEL result in larger deployment of intermittent renewables. Increased levels of power generation also result from assumed innovation drivers, primarily due to increased use of electric vehicles and therefore demand for electricity to fuel them.

Industry – fossil fuel share remains constant

The direct fossil fuel share in industry is similar to that observed in 2010, at around 70% of industry consumption (chart 26 breaks this down by industrial subsector). Broadly, this highlights the growth in energy consumption across industry to 2030 and 2050. Coal use shows a strong increase in the metals sectors and those that are less energy intensive. The stronger growth in coal consumption in INDC+ACCEL relative to INDC reflects the shift of abatement to the transport sector, as described earlier. The use of gas increases by just under 50%. Similar to gas, oil use increases significantly, by over 80% in 2050.

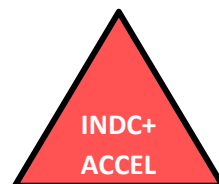
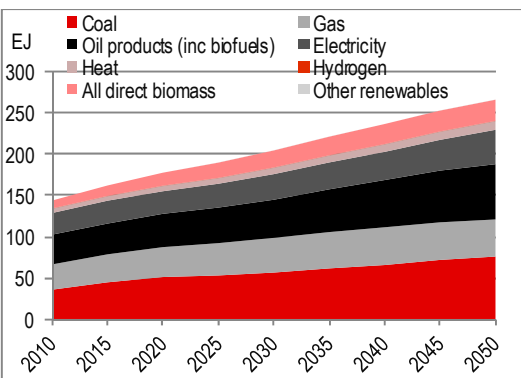


Chart 26: Industry fuel consumption under the INDC+ACCEL scenario

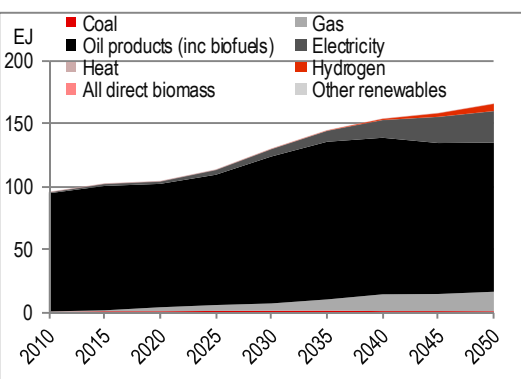


Source: UCL, HSBC

Transport demands more of everything

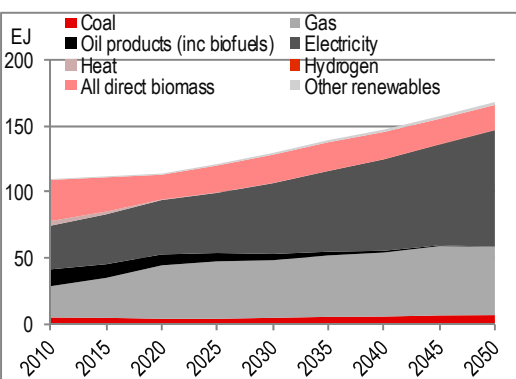
The increase in EV use as their cost come down rapidly under the INDC+ACCEL scenario results in greater demand for electricity, which accounts for 5% of the mix by 2030 and 15% in 2050. There is also more demand for gas (from 1% of share in 2010 to 4% in 2030 and 9% in 2050) and, to a lesser degree, hydrogen, as oil broadly maintains absolute levels (up 26%, representing 71% of share in 2050), illustrated in chart 27.

Chart 27: Transport fuel consumption under the INDC+ACCEL scenario



Source: UCL, HSBC

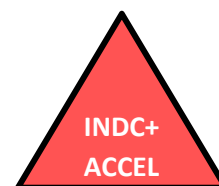
Chart 28: Buildings fuel consumption under the INDC+ACCEL scenario



Source: UCL, HSBC

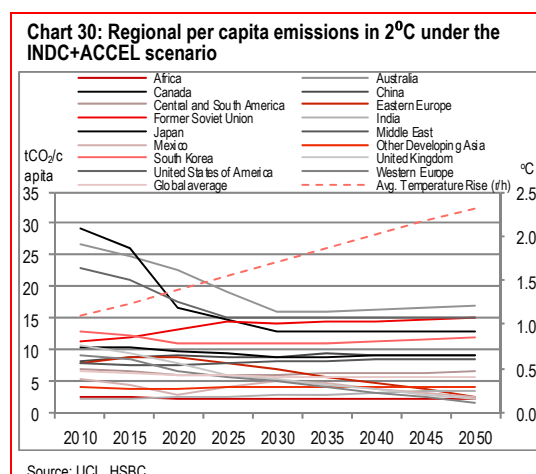
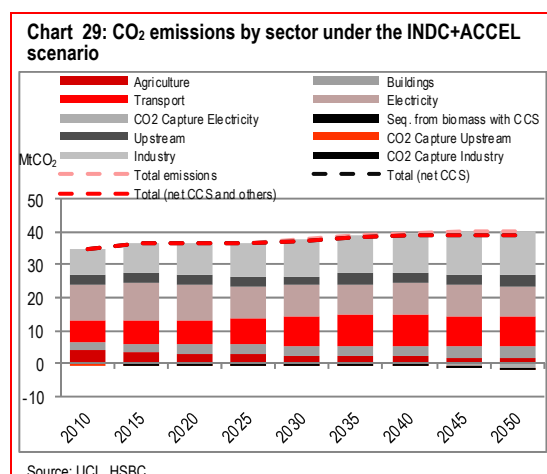
Buildings use more power, more gas in the future

Increased energy consumption is driven by use of power up 166% in 2050 and gas which is up 117% in 2050, as oil leaves the mix entirely by 2040 and biomass use declines by 39% in 2050.



GHG emissions increase to 52GtCO₂e warming, allowing 3.4°C under INDC+ACCEL in 2100

Emissions from the transport sector go down, since oil-based transport is displaced. As discussed on pages 42-43, emissions from the power sector are also lower, given lower coal use and greater use of renewables, as illustrated in Chart 29. However, this does not change the overall level of emissions-mitigation ambition under the INDCs, and actually means there is additional space for emissions to increase from other sectors. While a limited amount of coal is displaced from the power sector compared with the standard INDC scenario, there is a strong relative increase in coal consumption and overall emissions from the industry sector. The decrease in coal consumption in the electricity sector is therefore more than compensated for by a larger increase in coal use in industry compared to the INDC scenario.



From a climate perspective, when action under INDCs is combined with strong technology cost reductions, this has a minimal impact on emissions. It is not removed from the wider energy system as there is an increased level of consumption observed in the industry sector. As in the INDC scenario, again despite the per capita emissions reductions seen globally to 2030 in Chart 30, the 2°C threshold is surpassed in 2040, leading to a world where temperature rises are estimated at around 3.4 °C, at a 60% probability. Even with major technological innovation in zero-carbon electricity and transport, stronger national and international policy or regulatory mechanisms are required, significantly beyond the current INDC ambition level, to keep within the 2°C threshold, otherwise emissions mitigation gains made through rapid deployment of clean tech will be lost through increased use of fossil fuels elsewhere.

Conclusion

The backdrop of the INDCs and accelerated cost reductions for clean technologies means that growth for renewables in the power sector is extremely fast. This penetration removes coal from the power mix, although it is still used substantially in industry. As in the INDC scenario, massive investment needs in the power sector will require substantial flows of capital. The gas sector sees significant growth in this scenario, as in others.

Enabling 2°C

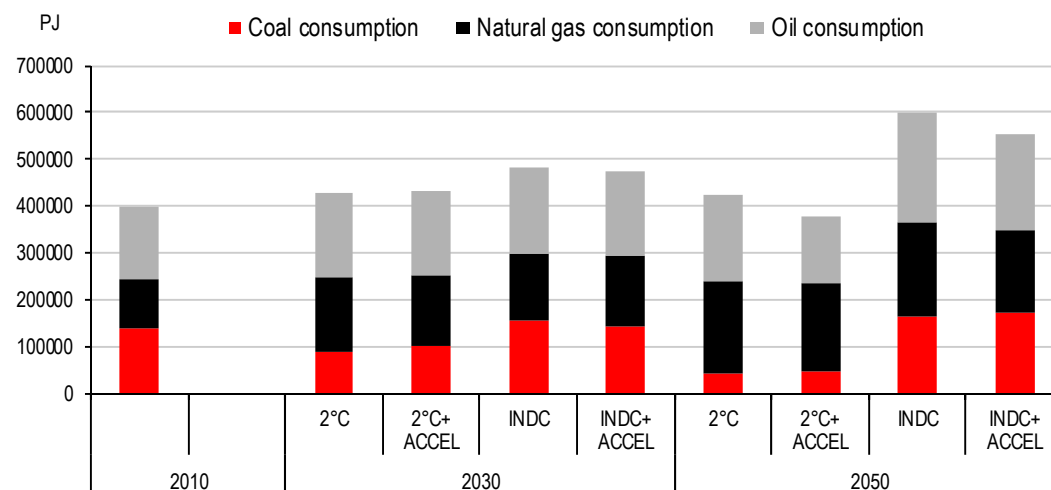
- ▶ Policy is important – total coal consumption under 2°C scenarios is approximately a quarter of that in INDC-based scenarios
- ▶ Countries vary – the US reduces fossil fuel consumption in the cost optimal 2°C system, while China and India increase use
- ▶ An agreement in Paris will be a big step – however >2°C warming will ensue without a ratcheting up of ambition in future decades

The 2°C, 2°C+ACCEL, INDC and INDC+ACCEL scenarios deliver energy systems with many interesting disparities. These cost-optimal outcomes suggest where there will be future growth of energy supply in some areas and contraction in others. They also show the sectors where consumption is likely to change against a backdrop of soaring overall demand for energy, with more future demand in the INDC-based sectors. In this section, we compare the scenarios, focussing on the future for fossil fuels and for power, and looking forward in more detail to 2050 – limiting global warming to 2°C requires a focus on the long-term after all. We also drill down into the global picture to better understand how the big future energy systems of China, the US and India will evolve for 2°C to be achieved.

A mixed picture for fossil fuels

We have seen in the chapters on the four scenarios that the stringency of climate regulation and the cost reduction paths for clean technologies are key to determining how specific fossil fuels are used in the future. Chart 31 shows that total fossil fuel consumption rises under all scenarios to 2030. Only under 2°C+ACCEL is it down in 2050.

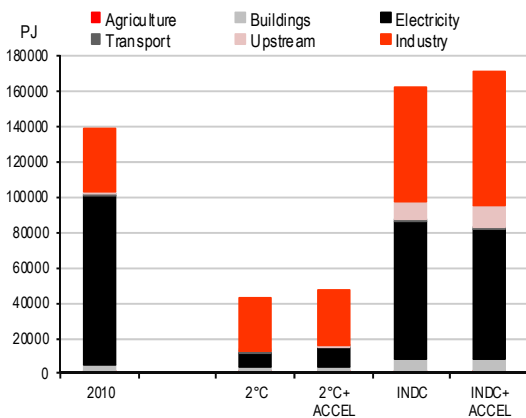
Chart 31: Global fossil use in HSBC's future energy system scenarios



Source: UCL, HSBC

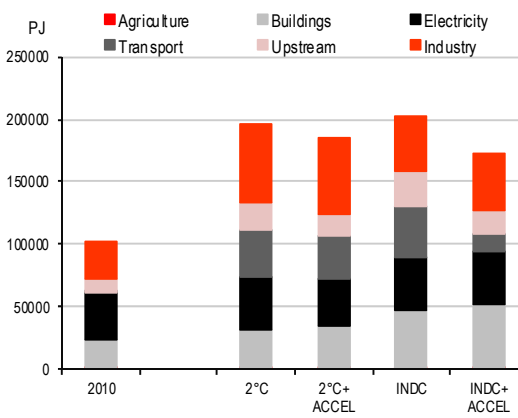
Under both the 2°C scenarios, overall coal use declines relatively sharply, with most of this reduction coming through decarbonisation of the power sector. Chart 32 shows in which sectors coal will be used under each scenario.

Chart 32: Global coal consumption, 2010/2050 by scenario and sector



Source: UCL, HSBC

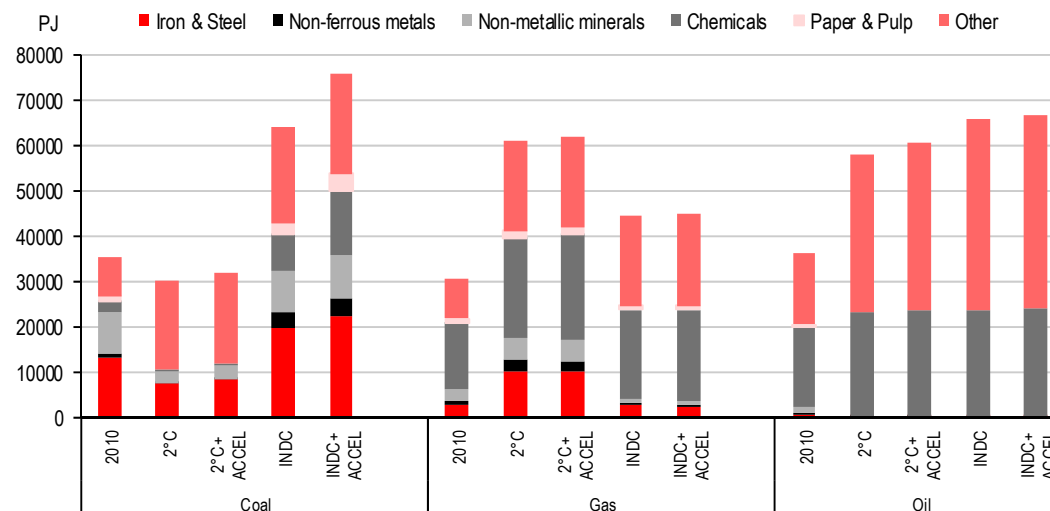
Chart 33: Global gas consumption, 2010/2050 by scenario and sector



Source: UCL, HSBC

In earlier chapters, we noted that industry is more difficult to decarbonise than some other sectors. The other way to express this is that the most cost-effective use of coal is in other sectors, notably industry. Chart 34 illustrates the point that, even in a 2°C world, a material amount of coal will be burned in industry. A much larger amount will be used under the INDC-based scenarios, with much of the balance being met by gas.

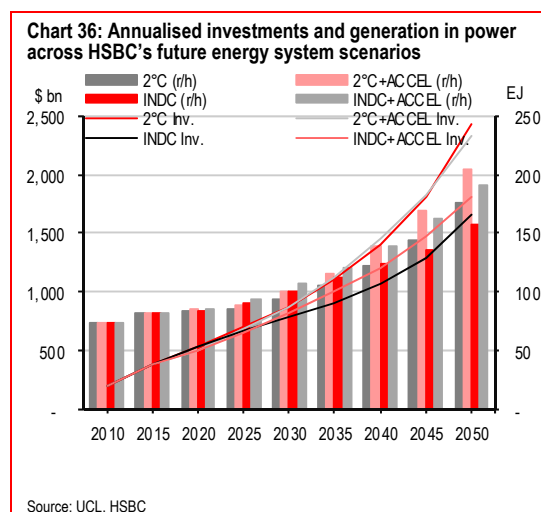
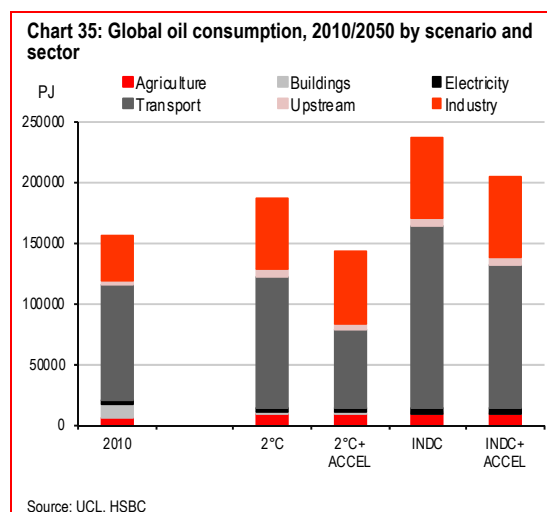
Chart 34: Energy consumption in industry sub-sectors by fossil fuel, 2010/2050



Source: UCL, HSBC

Gas is the fossil fuel commodity where strong growth is observed across all scenarios and consumption use shows a material rise to 2030 and to 2050 under all four scenarios, taking share in the mix. Chart 33 shows in which sectors gas is used in the future, with transport emerging to take share, driven by LNG use in shipping. Under the 2°C case, cost-optimal allocation sees use as an important lower-carbon energy source in industry and transport, and in conjunction with CCS technologies (in industry, upstream and power generation sectors). It does, however, show less growth as a heating fuel in buildings, due to the lack of emission capture technology and the strong alternative available supply from heat pumps.

Chart 35 shows that the use of oil in industrial processes, particularly in the manufacture of petrochemicals, grows across all scenarios. Oil use also grows in the transport sector, with the exception of under 2°C+ACCEL, where the price of EVs to market falls faster allowing them to take market share. Efficiency gains in the transport sector are large, but the growth in mobility demands in emerging economies more than offsets savings. However, even higher growth in oil demand would be observed without the significant shift to LNG in the shipping sector.



Power the sector for greatest transition with USD2.5trn per annum investment in 2050 in a 2°C world

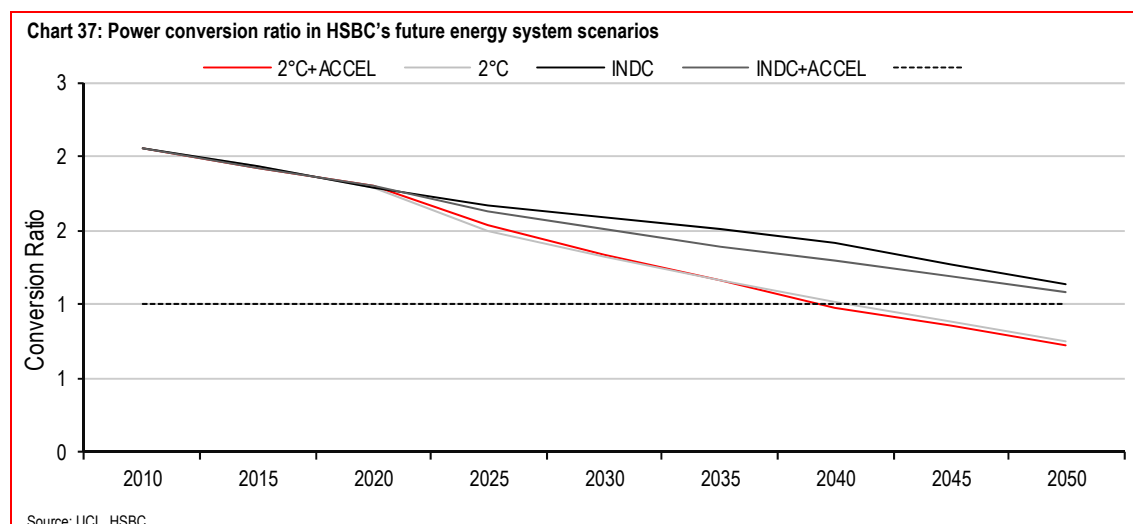
As described in earlier chapters, decarbonising power is the most cost-optimal way of achieving emissions cuts across the economy and complying with mitigation targets. Meanwhile, all four scenarios see substantial growth in overall demand for power. Achieving this transformation of the power sector requires substantial investment. Chart 36 shows this is the case for all four scenarios, with greater investment required to meet the more stringent 2°C target under the two corresponding scenarios. (NB the first 20 years of the period do not include the annualised cost that would be associated with existing capacity, hence the apparent acceleration from around 2035 as replenishment of capacity is required). Annual investment levels reach almost USD2.5trn in 2050 under the 2°C scenario, 35-47% higher than either of the INDC-based scenarios, and showing a marked divergence after 2030 reflecting the need to replace coal in the mix with lower-carbon generation technologies. In the INDC+ACCEL scenario, costs are slightly higher than in the INDC scenario in 2050 due to the 25% higher level of generation required to power the growth in use of EVs, although on a per unit of capacity installed basis, the investments under INDC+ACCEL are lower due to the innovation effects assumed.

The accelerated growth in solar and wind in the 2°C and 2°C+ACCEL scenarios also leads to lower contributions from other low or zero carbon electricity sources, particularly nuclear which is lower here than in the INDC scenario. This suggests the increased cost-competitiveness of renewables would reduce the role of fossil fuels and other low carbon sources, to some extent moderating the decarbonisation of electricity.

Efficiency in power increases

Power generation requires primary energy as a feedstock. As described in previous chapters, this comes in many forms – coal is the biggest feedstock today and natural gas second. Essentially, energy is needed to create energy. Other major feedstocks include nuclear as well as increasingly renewables - solar and wind. How much energy is needed to create electricity from the power sector? A large amount can be 'lost' when finite primary energies, such as fossil fuels, are consumed to generate power. In 2010, the ratio of primary energy – the conversion ratio – measured in joules, consumed to secondary energy generated as electricity, again measured in joules, was 2.06 to 1. This means that 2.1 more energy was consumed than produced by the power sector.

Under all four scenarios, this ratio of energy consumed to energy produced comes down as technology becomes more efficient and as renewables take share in the mix. Chart 37 shows how this will occur over our study period.

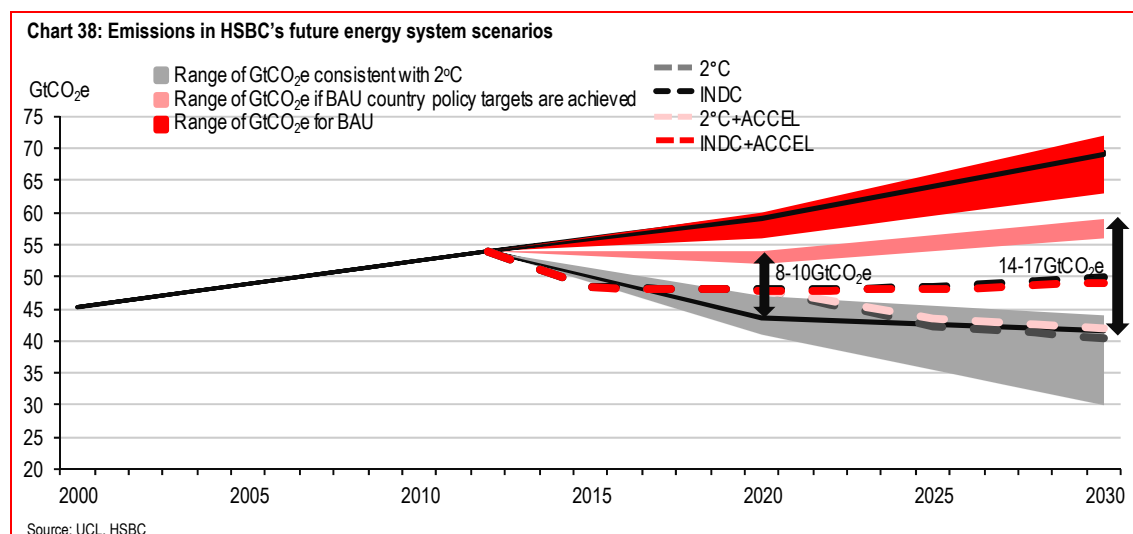


It is notable that under the INDC-based scenarios, the energy conversion ratio comes down dramatically in cost optimal power generation mixes – 1.14 under INDC and 1.09 under INDC+ACCEL. However, under 2°C and 2°C+ACCEL, the ratio changes even more dramatically, to 0.76 and 0.72 respectively. This means that more energy is coming out than going in to power generation, as energy from wind and the sun is not counted – because it is considered infinite, or renewable. This further illustrates the transition from using fossil fuels to renewables as the power generation sector is decarbonised.

Getting to 2°C

In the chapters on the individual scenarios, we noted that strong climate regulation is required to achieve meaningful emissions cuts in line with 2°C of global warming by 2100. Where under INDC+ACCEL the costs of key clean technologies come down quickly, emissions from the power sector are also lower given lower coal use and greater use of renewables. Emissions from the transport sector also go down, since oil-based transport is displaced. However, this does not change the overall level of emissions-mitigation ambition under the INDCs, and actually means there is additional space for emissions to increase from other sectors, which is seen in industry.

The emissions and subsequent temperature increases under INDC and INDC+ACCEL are, therefore, virtually the same. Chart 38 illustrates the different temperature pathways for the four scenarios as dotted lines, compared with the ranges for business-as-usual (BAU) in red, the pink range if pre-INDC country policies are implemented successfully and the grey range which the IPCC has stated is consistent with a 2°C world.



The evidence of TIAM-UCL's outputs suggests that the INDCs are going to put the world on a pathway well above the globally agreed policy target of 2°C, at 3.4°C. This is not to say that they are a failure or that a UCA is meaningless – we believe that it has already been successful in catalysing a large number of countries to better understand their energy systems and how they can address emissions generated by them. It has also brought the two largest polluters, the US and China, to the discussion table on climate change on several occasions, resulting in a stronger pro-policy front being presented to the rest of the world.

Looking forward, the big emitters of the future, in particular, will need to make greater contributions to emissions mitigation, if 2°C of maximum warming is to be achieved, rather than 3.4°C or something in that range. The EU has already made a long-term pledge in line with IPCC recommendations for emissions cuts required for 2°C, with a pledge for 80-95% emissions reductions by 2050 vs 1990. Responsibility moves to China and the US, as the world's biggest emitters, to decarbonise their economies. Countries predicted to experience considerable future economic growth, including China and also India, will need to ensure that energy use, in particular use of fossil fuels, is decoupled from emissions growth, i.e. that they are able to grow their economies without growing emissions at the same rate. While we believe that analysing the impact of faster reductions in the costs of key clean technologies is important, these cannot be relied upon alone to decarbonise the economy. The following section looks at how these three big economies of the future can plot the cost-optimal paths to decarbonisation (without compromising economic growth) to align with a two degrees world, i.e. within the 2°C scenario.

2°C China to decarbonise power, as gas soars across all sectors and oil doubles

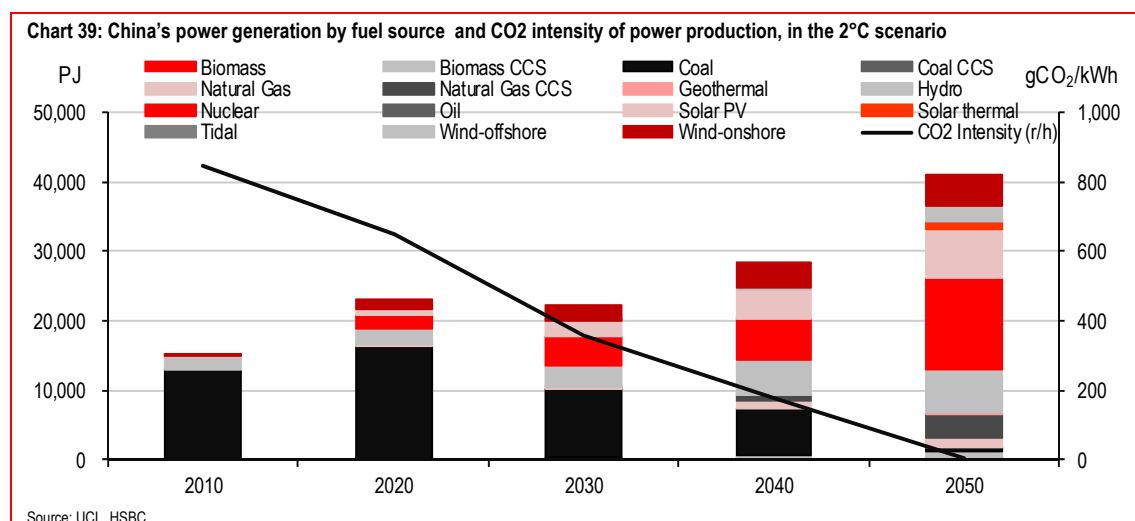
TIAM-UCL's data showed that, in a 2°C world, the expansion of China's power generation demand is dramatic over the study period, where levels are set to increase from 15 EJ to around 30 EJ in 2030 and over 40 EJ (11 PWh) in 2050, up 167% in 40 years, as illustrated by the bars in chart 39.

Globally coal use goes from 45% of the total power feedstock share in 2010 to 0.4% in 2050, in China the difference is equally dramatic as it moves from 84% in 2010 to 45% in 2030 and 1.3% in 2050. It is up to other technologies to plug China's post-coal power generation gap, rather than the coal expansion observed

in recent decades, with Solar PV up from 0.05% of the mix to 10% in 2030 and to 17% - 7,044PJ - in 2050, nuclear up from 1% to 19% in 2030 and to 33% - 13,380PJ - in 2050, and hydro growing from 11% to 14% in 2030 and to 15% - 6,015PJ - in 2050. Gas decreases overall from 214PJ (1%) to 135PJ in 2030 but increases to 4,810 (12%) in 2050, although approximately three quarters of this is for gas with CCS. This brings the carbon intensity of power generation down by 58% by 2030 vs 2010 and by 99% in 2050.

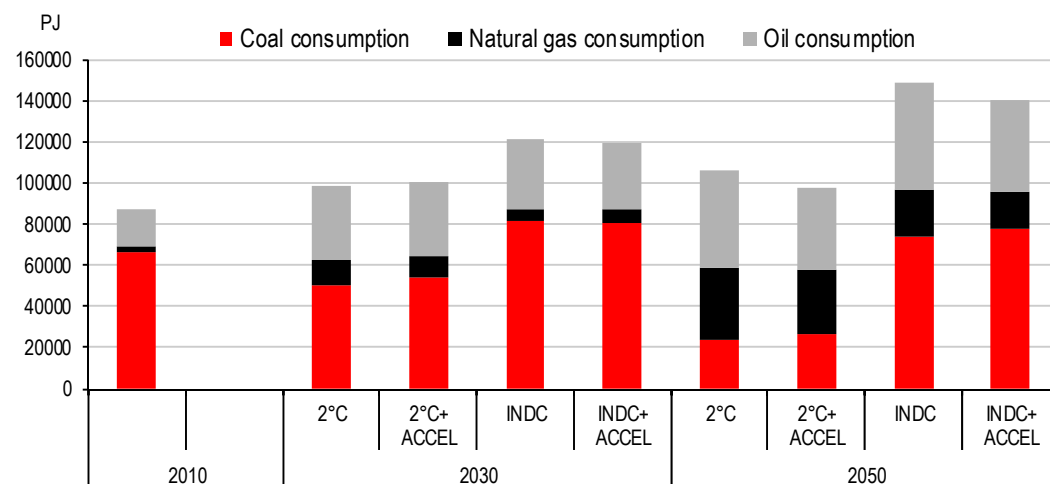
Soaring investment in solar, nuclear, wind brings China's power sector emissions down

Annualised investment costs in Chinese power under the 2°C scenario reach USD287bn in 2030 and USD584bn in 2050, from USD72bn in 2010, with the bulk across solar PV (16% of total investments in 2030 and 18% in 2050), nuclear (14% in 2030, 21% in 2050), wind (15% in 2030, 24% in 2050) and hydro (11% in 2030, 15% in 2050).



Despite the reliance of the industrial sectors on coal, its removal as a power feedstock means that economy-wide coal use under 2°C is lower in 2030 and much lower in 2050, as seen in chart 40. The global 2°C trend for oil is not observed in China, however, where oil consumption in transport grows by more than 2.7x, as car use increases with a growing population and GDP per capita. Gas use also soars, up 2.8x by 2030 and 10x by 2050, driven by substantial growth across all major sectors.

Chart 40: China's fossil use in HSBC's future energy system scenarios



Source: UCL, HSBC

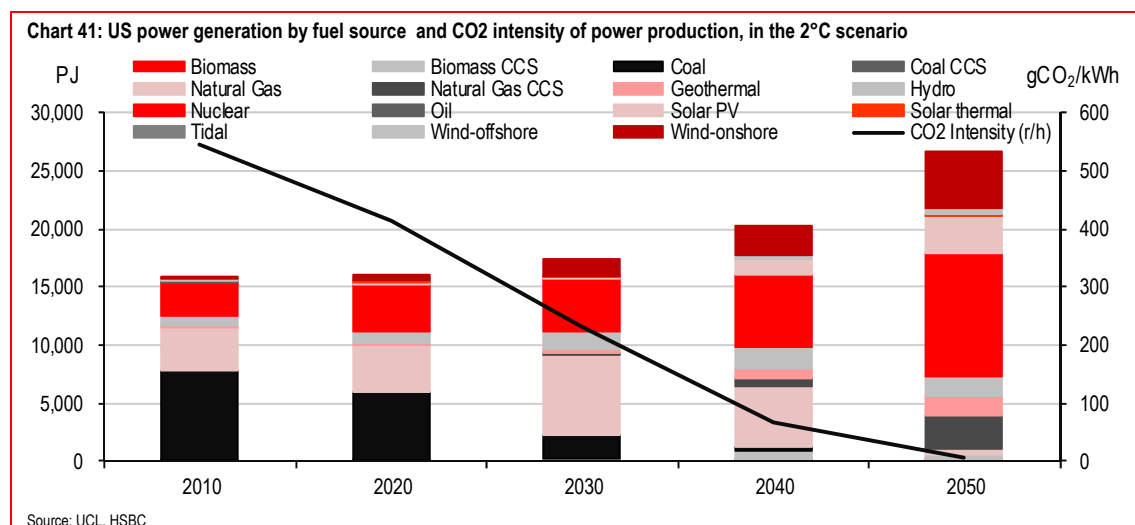
China's emissions down, INDC pledge beings process

In relation to sources of emissions, the picture in China over time is similar to the global picture, although industry counts for a bigger proportion in 2050, 47% vs 33% globally, illustrating the fact that the country is still a major manufacturer compared to the average country. Absolute emissions come down by 50% by 2050 and by 52% on a per capita basis, vs 2010.

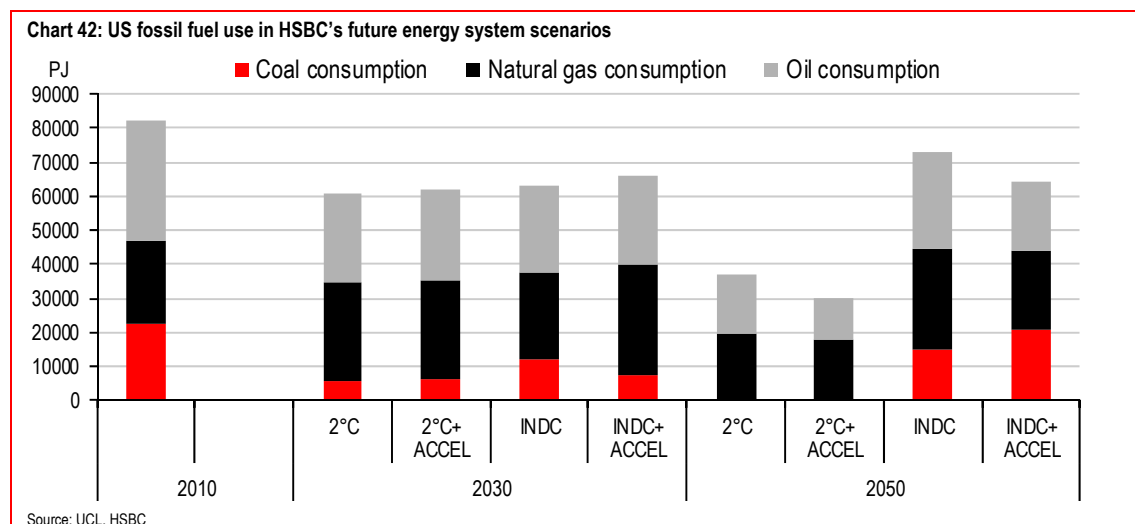
China's INDC plans to decarbonise on a relative basis, by bringing down the carbon intensity of GDP by 60-65% by 2030 vs 2005. The INDC is an important element of China's intensifying focus on the environment. A broader focus was recently announced in a document released by the State Council, the 'Master Plan for an Ecological Civilisation', which set forward aims in relation to taxes, green finance, pricing water, decarbonising energy, carbon trading and trading of other pollutant emissions, enhancing enforcement and tighter environmental legislation. In ['China's ecological civilisation'](#), 24 September 2015, we stated our view that this document should act as a reminder to all officials to feature green development in submissions ahead of the release of the 13th Five-Year-Plan in 2016. Overall, we believe there are indications that Chinese policy is moving in the right direction for stronger decarbonisation and, although its INDC is important, this will not form the final shape of its policy in this area.

2°C US sees fossils drop economy-wide, as renewables dominate 2050 power

In the US, the picture is more closely aligned to the global breakdown. Power generation is up 67% by 2050 vs 2010 in a 2°C world, with almost total declines in generation by coal and very little additional gas capacity, as seen in Chart 41. The growth in power consumption is met largely by nuclear (up 278%), followed by onshore wind (up 14x) and then solar PV (up 200x). Annualised investment costs reach USD132bn in 2030 and USD397bn in 2050, from USD23bn in 2010, with costs in these three areas corresponding - the bulk is across solar PV (9% of the total in 2030 and 18% in 2050), nuclear (30% in 2030, 37% in 2050), and wind (21% in 2030, 25% in 2050). The key role of CCS combined with biomass as a key technology in the 2°C scenario, in this and other regions, is also apparent, providing additional headroom for other sectors to use fossil fuels.



Overall, oil consumption reduces sharply across all economic sectors with the strong decline in demand driven by efficiency gains and switching to alternative fuels. Coal reduces to close to zero by 2050, as seen in Chart 42, and gas use also comes down by 2050 relative to 2010, although much remaining gas-powered generation at this date will incorporate CCS.



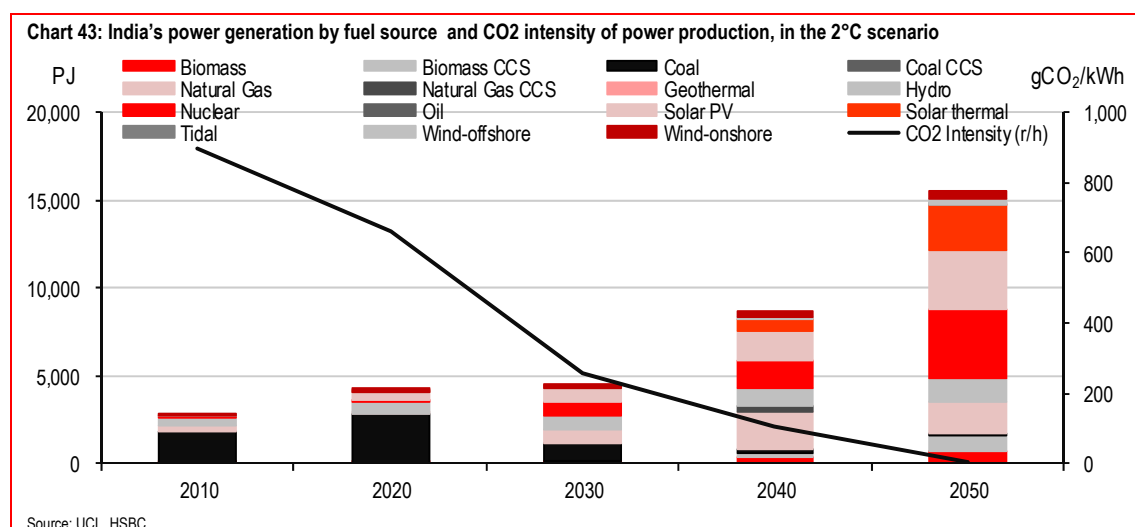
US emissions sharply down in 2°C world

US emissions will need to come down by 75% in the cost-optimal 2°C energy system. On a per capita basis, the cut is slightly greater at 80%. This is far in excess of the 26-28% reduction on 2005 levels by 2025 that it pledged in its INDC submission. However, momentum is moving in the right direction as a raft of rules diminish the role of coal in power generation. The most recent example is the Clean Power Plan, which specifically targets power generation and requires a 32% CO₂ reduction from existing power generation by 2030 vs a 2005 baseline. The power sector represents 35% of CO₂ in the US and in our earlier note [Obama targets coal-fired power](#), 5 August 2015, we showed that the cuts required under the Clean Power Plan were equivalent to the emissions from 166 million cars, 70% of its fleet. While this is

not enough to align the US with a 2°C world, we think it is meaningful as it is more stringent than previous legislation from a country which has not been amongst the leading developed nations in designing climate policy in the past.

2°C India needs huge power investment, as oil in transport and industry soars

It is clear from Chart 44 that India will burn much more coal without more stringent climate regulation, as it is a cheap source of fuelling the substantial growth in power predicted to be required to enable the considerable economic growth predicted for this country, the second most populous after China. India's annualised investment costs in power for a 2°C world reach USD62.7bn in 2030 and USD240.3bn in 2050, from USD12.02bn in 2010, with the bulk across solar thermal (2% in 2030, 27% in 2050), solar PV (25% of the total in 2030 and 19% in 2050), nuclear (18% in 2030, 22% in 2050) and hydro (14% in 2030, 12% in 2050). Investment in new coal-fired power is significant in 2030 at 23% of the total but diminishes to 2% in 2050. As seen in Chart 43, the carbon intensity of power generation is down by 71% by 2030 vs 2010 and by 100% in 2050.



Overall, the use of fossils in India grows by 52% under the 2°C scenario by 2050, where strong growth in oil consumption is observed in both transport and industry. Use of coal persists but only in industry, where metallurgical coal is required for steel making in particular, to meet the construction boom expected as the population soars and different parts of the economy develop, needing new buildings for manufacture and services as well as infrastructure. By 2050, coal use in power will need to drop close to zero.

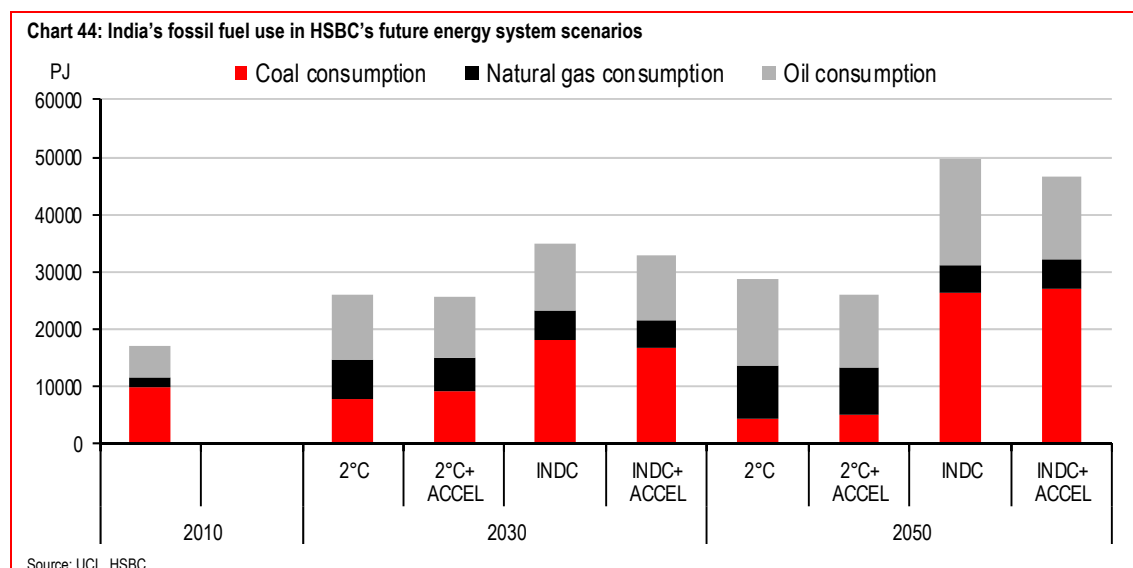


Chart 44 shows that, in relation to gas, and similar to China, growth under the 2°C scenario reflects increased requirements for the power and industrial sectors, with the rapid decline of coal. Gas demand increases by a factor of six times by 2050.

One third per capita emissions cut required in India as the economy grows through 2050

In a 2°C world, by 2050, absolute emissions are down in India by 12% vs 2010, down 34% on a per capita basis, vs 2010. India's INDC, which we analysed in [India's economic climate pledge](#), 9 October 2015, pledged to reduce its emissions intensity of GDP by 33-35% by 2030 vs 2005, which is not in line. However, India also pledged to have 40% of power generation capacity fuelled by low-carbon sources by 2030, which shows ambition although again, as illustrated by Chart 44, it is not in line with 2°C.

Conclusion

The 2°C scenarios show that a focus on the removal of coal from power in all regions, whilst retaining lower carbon fossil fuels, could go a long way to bridging the gap between current pledges and necessary action. The continued use of oil and gas at levels higher than those observed in 2010, particularly for gas, under the 2°C case, reflect two key emerging challenges in this decarbonisation scenario; firstly, industry and transport are difficult sectors to decarbonise, and secondly, CCS technologies, particularly in combination with biomass, are going to be needed to enable the continued use of fossil fuels at the levels modelled in the 2°C case.

While INDC pledges fall short of delivering the required mitigation levels to meet the 2°C target, we have also observed the effect of innovation on key clean technologies in electricity generation and use. Evidently, rapid cost reductions in key renewable generation technologies can displace carbon-intensive technologies, leading to a lower-carbon power generation system. The same is true of strong innovation efforts in electric vehicles, which can drive strong reductions in transport oil use.

Stronger innovation alone has a limited impact on overall emissions levels for two key reasons. First, although renewable generation increases, primarily due to increased demand for transport electricity from electric vehicles, displacing some coal from the power sector, it also displaces other low-carbon

electricity generation (notably nuclear), as the more expensive generation capacities are replaced first. Second, cost reductions for renewables, battery storage and electric vehicles as added constraints under the INDC+ACCEL scenario alone do not have an impact on emissions, as the emissions mitigation parameters of the INDCs remain in place. Therefore, any emissions saved by greater uptake of these cheaper clean technologies in the power and transport sectors mean greater emissions can be generated elsewhere (without breaking targets for the emissions limits set in the INDCs). This demonstrates that regulatory underpins are necessary to achieve specific climate goals, otherwise technology may only decarbonise specific sectors where it is most cost-effective to do so and not overall.

A key output of the TIAM-UCL model, in our view, is the substantial growth in demand for power. Key from an emissions point of view is that the global average carbon intensity of electricity falls in all scenarios. This will mean rapid uptake in low carbon technologies in the next 30-40 years that will need to become increasingly cost-effective, with substantial flows necessary to transition the power sector to be more productive, more efficient and lower carbon.

Climate change is a global problem, meaning that all countries need to contribute and many are doing so in a meaningful way. In December, country delegations will gather in Paris to sign a universal climate agreement that sets out a framework to slow temperature rises and respond to the consequences of existing warmer temperatures. As stated towards the beginning of the note, we believe a UCA will be signed, although the Paris talks will not be easy and that climate finance remains an area where there are conflicting viewpoints. However, all regions have distinct challenges to transition to lower carbon systems whilst growing or maintaining their economies. It is encouraging that so many countries have now submitted INDCs and that such a large proportion of global GHGs are covered by these. Although these may not put us on a pathway to 2°C, they nevertheless represent progress as a number of countries have now considered how emissions can be mitigated from their economies while major emitters such as the EU, China, the US and India have shown commitment to reaching a Universal Climate Agreement.

GLOSSARY

2°C scenario - Scenario in which world collectively acts by raising ambition on emission reduction to limit temperature rises to 2°C

2°C+ACCEL scenario - 2°C scenario incorporated with faster cost reductions in key technologies

ADP - Ad Hoc Working Group on the Durban Platform for Enhanced Action

BAU - Business as usual scenario

CCS - Carbon capture and storage

CO₂ - Carbon Dioxide

CoP21 - 21st Conference of the Parties

EJ – Exa-joules (10¹⁸ Joules)

EU - European Union

EVs - electric vehicles

GDP- Gross Domestic Product

GW - gigawatt

INDC - Intended Nationally Determined Contributions

INDC scenario - Scenario based on existing and publically available country policy and emission reduction goals and shows the cost optimal way to deliver these through the energy system

INDC+ ACCEL scenario - INDC scenario incorporated with faster cost reductions in key technologies

kWH - kilowatt hour

LNG - Liquefied natural gas

MAGICC - Model for the Assessment of Greenhouse Gas Induced Climate Change

MtCO₂e - Million Metric tonnes of Carbon Dioxide equivalent

OPEC - The Organization of the Petroleum Exporting Countries

PJ - Peta Joules (10¹⁵ Joules)

PV - Photovoltaic

PWH - petawatt hour

tCO₂e/capita - metric tonnes of Carbon dioxide equivalent per capita

TIAM-UCL - TIMES Integrated Assessment Model-University College of London

TIMES - The Integrated MARKAL-EFOM System

UCA - Universal Climate Agreement

UCL - University College London

UKERC - UK Energy Research Centre

UNFCCC- United Nations Framework Convention on Climate Change

Upstream - This includes all processes associated with energy production and transformation processes, such as primary fossil fuel extraction and secondary conversion processes (excl. ELC) including oil refining, biofuel production, H₂ production etc.

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APPENDIX 1 – Description of TIAM-UCL model

TIAM-UCL is a multi-layered energy system model, building on previous energy models developed by academic and research institutions over several years, with the predecessors described here:

- ▶ The first layer of the model is the **MARKAL** model, developed as a multinational project over two decades, led by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency. The basic components in a MARKAL model are specific types of energy or emission control technology, represented quantitatively by a set of performance and cost characteristics. The supply and demand sides are integrated, so that one side responds automatically to changes in the other, and the combination of technologies that minimizes total energy system cost are selected. MARKAL can be used to identify least-cost energy systems, cost-effective responses to restrictions on emissions and to perform prospective analysis of long-term energy balances under different scenarios. It can also be used to evaluate new technologies and research priorities, the effects of regulations, taxes, and subsidies and to project inventories of greenhouse gas emissions. MARKAL does not require a ranking of greenhouse gas abatement measures as an input instead choosing preferred technologies and provides the ranking as a result. The choice of abatement measures often depends upon the degree of future abatement that is required.
- ▶ The **TIMES** generator model (TIMES stands for The Integrated MARKAL-EFOM System) models the energy market, such that supply and demand respond to each other, and selects the combination of technologies that minimises the total cost of commodities in the energy system. TIMES has been developed beyond MARKAL by offering flexible time periods for outputs, flexible process flows for specific users of energy and additional commodity-related variables such as total production and total consumption. TIMES utilises detailed energy demand input projections, to the level of amount of room space to be heated and total vehicle miles to be travelled. Energy resource cost and forward-looking assumptions are also inputted. There are also specific variables representing the flows of commodities entering or exiting each process, more detailed and incremental investment periods and capacity to model for concentration of GHGs and global temperature changes resulting from GHG emissions and accumulation in the atmosphere. TIMES then gives outputs for the optimal energy system design – i.e. the least expensive combination of technology to meet that requirement.
- ▶ A global multiregional version of a TIMES Integrated Assessment Model, known as **ETSAP-TIAM**, has been widely used in other research projects and peer-reviewed publications, to analyse the impacts on the energy system of climate change mitigation policies.
- ▶ **TIAM-UCL** builds on the ETSAP-TIAM model and allows additional constraints to be applied. It differs from ETSAP-TIAM, particularly in terms of fossil fuel resources, climate module, demand drivers and key technology groups. The dynamic part of the model – that which can be adjusted to model different futures or scenarios - is determined by the time horizon, the evolutionary development of energy supply and technologies, the growth of the demand for energy services and also policies, for instance mitigation targets and renewable portfolio standards.

Key features of the TIAM-UCL model:

The following are amongst TIAM-UCL's defining characteristics:

- ▶ **Partial-equilibrium model:** General equilibrium is an economics theory use to explain how supply, demand and prices in a whole economy respond to each other. Partial equilibrium is based on only a restricted range of data – for instance it looks at the price of a single product, where the prices of all other products are held fixed during the analysis.
- ▶ **Minimises cost and maximises social welfare:** The model minimises total energy system cost in the standard version and maximises societal welfare (total surplus) in the elastic demand version to compute a partial equilibrium.
- ▶ **Integrated assessment:** The model deals with energy and climate systems in a single framework, showing impacts of the energy system on the climate, and the impact of climate constraints on the energy system.
- ▶ **Technology-rich:** There is a strong representation of the full range of technologies which are or might be used in all major sectors in the energy system, and their technical specifications.
- ▶ **Bottom-up:** The building blocks (see below) are processes, econometric data and commodities, connected by commodity flows in a network.
- ▶ **Whole-system:** The model covers the entire energy system. It models all primary energy sources (oil, gas, coal, nuclear, biomass, and renewables) from resource production through to their conversion, infrastructure requirements, and finally through to sectoral end-use.
- ▶ **Multi-regional:** TIAM-UCL includes 16 regions and provides future scenarios for the energy systems within each of these under different assumptions over climate policy, technological development, and commodity markets. Each region has its own energy system and can trade fossil fuel resources (natural gas, LNG, coal, crude oil, oil fractions), biomass (energy crops and solid biomass) or emission permits with other regions or a central market.
- ▶ **Trade:** Trade is modelled such that regional trade is allowed in assumptions for coal, natural gas, LNG, natural gas liquid, uranium oil and oil products, energy crops and solid biomass.
- ▶ **Commodity prices:** Fossil fuel commodity prices are an output of the model, based on the regional costs of production, and the transport costs to different markets. They do not reflect market prices, but are endogenous to TIAM-UCL – i.e. shadow prices are operated for the commodities under the different scenarios. However, it is important to note that this shadow price is not necessarily close to the oil price in the real world. TIAM-UCL does not levy taxes on production and so does not include one of a key element that determines the actual oil. It also misses out some real-world market factors e.g. political risk or supply quota decision-making. Finally, it is a 5-year averaged price. No subsidies or taxes are assumed in the model.

Building blocks of the TIAM-UCL model:

These are the key inputs which are required to set basic social and economic parameters:

- ▶ **Population:** The model uses UN population data for all countries, with global population rising from 6.7b in 2005 to 9.3b in 2050.
- ▶ **GDP and GDP per capita:** Long-range GDP forecasting is uncommon, given the difficulties in accurate prediction. In TIAM-UCL, these economic data points are based on a number of sources, with global GDP assumed to grow from USD50trn in 2010 (based on IMF figure for 2009) to USD 155 trillion in 2050 and USD350trn in 2100 (all figures are in 2005 USD). Growth rates have been based on the Global Computer-Generated Equilibrium Model of International-National Interactions between Economy, Energy and the Environment (GEMINI) and sense-checked for relevance by comparing them to assumptions made for the 4th assessment report of the Intergovernmental Panel for Climate Change (IPCC). Global GDP is hereby assumed to grow from \$49T in 2010 to \$148T in 2050. Amongst the assumptions, GDP growth rates are expected to decline over the course of the 21st century, with growth rates for Western Europe, UK and US assumed to drop from on average of 2.2% to 1.3% in 2050. Another feature of the data is some convergence of GDP per capita between developed and developing countries over the course of this century.
- ▶ **Number of households and GDP per household:** The number of households relies on national statistics and projections where these exist, with ranges adjusted as per level of development and characteristic countries used for larger local regions – these would include South Africa for Africa, Poland for Eastern Europe and Indonesia for Other Developing Asia.
- ▶ **Sectoral drivers:** The model was built with the acknowledgement that no reliable forecasts exist for industrial production, agriculture or service output through to 2100. To address this, initial numbers are based on ETSAP-TIAM, with the development of sectoral growth rates geared to GDP numbers and implying a shift in GDP composition towards services. Economic re-structuring was built into the industry drivers, again originating from the Gemini model, with global production data from the IEA and industrial growth rates calibrated to these. This allowed some manufacturing-to-service restructuring to occur in some countries/regions included in the model.
- ▶ **Energy services demand:** This is modelled by adjusting for four three-month seasons, a 16 hour period of daytime usage levels and an 8 hour period of typical night-time energy usage.
- ▶ **Driver elasticity:** Driver elasticities determine the sensitivity of changes in energy-service demand to changes in the underlying driver. Several energy service demands grow slower than underlying drivers (e.g. than GDP per capita) showing expected decoupling of energy demand and economic growth, as has been witnessed already in some economies. Energy efficiency improvements in future years largely result from the replacement of existing stock by improved versions of similar technologies (e.g. improved internal combustion engine powered vehicle) or the introduction of a new type of technology (e.g. electric vehicles replacing petrol). Even without stringent GHG constraints, the model will typically invest in improved technology vintages when stock retires, due to recognising the cost-effectiveness of such investments – under the model's cost-optimising paradigm.

Sector data inputs:

The model utilises detailed input data for the major energy-consuming sectors. A brief description is given here:

- **Power:** Various sources are used for underlying technology cost and emissions data. Input assumptions for future power prices are projected using assumptions for falling costs and regional disparities (including assumptions that operation and maintenance costs tend to be lower in developing regions and for those regions where there is a manufacturing base for the technology). HSBC's renewable energy equity analyst, Sean McLoughlin, believes that forward-looking input assumptions for renewable energy cost assumptions are broadly in line with those used by companies and investors.

For solar PV, the maximum rates of roll-out in both cumulative and absolute terms, and the maximum penetration level constraint have all been doubled. These constraints work in parallel with share constraints, which have also been relaxed to allow the share of PV relative to other generation types to again more than double. Similar increases in the maximum allowed rates of growth for storage and electric vehicle penetration are also assumed. While constraints on the roll-out of wind technologies are also included in the model, these have not been doubled in INDC+ACCEL: such constraints are rarely binding as the deployment of wind is slowed by its cost relative to other forms of generation. The cost of wind generation in INDC+ACCEL has thus been reduced.

Costs for carbon capture and storage (CCS) are also included in the model, as per table 7. These are taken from the IEA Energy Technology Perspectives 2012 and EIA 2013 report 'Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants'.

Table 7: Costs of carbon capture and storage (CCS)

			2020	2030	2040	2050
CCS Gas CCGT	Standard	\$/kW	1440	1350	1305	1260
CCS Supercritical PF Coal	Standard	\$/kW	3312	3105	3002	2898
CCS Biomass gasification	Standard	\$/kW	4160	3600	3340	3080

Source: UCL, HSBC

- **Transport** is addressed through 14 energy-services, including aviation, bus, truck haulage, cars, shipping, further broken down by distinct types and whether domestic or international. Different fuel types used by different transport technologies are accounted for, as are life spans of vehicles, efficiency rates (broken down by vehicle ages).
- The **industrial sector** is represented through six energy-service demand subsectors – chemicals, iron and steel, pulp and paper, non-ferrous metals, non-metals – as well as other minor industries and non-energy uses. Further granular details on the types of fuel technology needed for industrial processes.
- **Buildings data inputs** are split between residential and commercial. Energy services included in the model are cooling, clothes drying, clothes washing, dishwashing, heating, hot water, cooking, lighting, refrigeration and other. Supply fuels include oil, gas and coal derived fossil fuels, geothermal, biofuels, solar and power. Data is included to characterize these for efficiency, annual utilisation factors, lifetime, operation costs, times of day typically used and investment costs. Commercial buildings are similarly treated, although with fewer categories of energy demand.

Additional points on use of TIAM-UCL

India published its INDC on 2 October 2015. The headline pledges are to reduce the emissions intensity of its GDP by 33-35% by 2030 from 2005 level and to achieve c40% of cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030. While not explicitly included in the modelling, both metrics were compared against the modelling results for India, to give a sense of what additional impact such measures would have – India actually achieves a 42% non-fossil capacity share in 2030, compared to 25% in 2010 (and 55% under the INDC+ACCEL scenario). GHG intensity of GDP improvements is significantly greater than 35%. Therefore, if the INDC proposals from India include such targets, they are unlikely to lead to increased emission reductions, compared with what is already reflected in the INDC case.

APPENDIX 2 – Intended Nationally Determined Contributions (INDCs) to date

Table 8: Summary of INDCs (Intended Nationally Determined Contributions) submitted before the 1 October deadline (in order of first to submit to most recent)

Country	Pledge	Target year	Base year	Long term pledge	Comments
Switzerland	50%	2030	1990	Reduce emissions by 2050 by 70-85% from 1990	Carbon credits from international mechanisms will partly be used
EU	40%	2030	1990	Reduce emissions by 80-95% by 2050 from 1990	No contribution from international credits
Norway	40%	2030	1990	To become a low-emission society by 2050	Target is to be met through collective delivery with the EU
Mexico	25%	2030	BAU	Reduce 50% of emissions by 2050 from 2000	Ambition could increase to 40%, subject to a global agreement
USA	26-28%	2025	2005	Reductions of 80% or more by 2050	Will aim to reduce emissions by 28%
Russia	25-30%	2030	1990	Russia aims to use the 2030 target as a stepping stone towards developing a low-carbon, long-term objective	Commitment to the INDC will be based on the outcome of Paris; Reduction is subject to the absorption capacity of the Russian forests
Gabon	50%	2025	BAU	Scenarios show >50% is possible	Comprehensive adaptation plans
Liechtenstein	40%	2030	1990	None	Emissions down from 1990, despite population/economic growth
Andorra	37%	2030	BAU	None	Low emissions intensity and falling emissions over past decade
Canada	30%	2030	2005	None	Intends to account for the land sector using a net-net approach
Morocco	13%	2030	BAU	None	Target – 13% – unconditional; 19% – conditional; (Total 32%); Requires USD45bn; conditional upon USD35bn of int'l finance, a UCA
Ethiopia	64%	2030	BAU	Long-term vision to become carbon neutral	Equivalent to an absolute decline of 3% by 2030 from 2010; Intends to sell carbon credits
Serbia	9.8%	2030	1990	None	Climate change strategy & action plan to be finalised by 2017
Iceland	40%	2030	1990	Foresees it to be similar to that of the EU	Intends to be a full member of the EU in the future and, therefore, aims fulfil its fair share of the EU's 40% target
China	Peak	2030	NA	None	Cut carbon intensity of GDP by 60-65% by 2030 from 2005
South Korea	37%	2030	BAU	None	Unclear whether target includes land use change and forestry
Singapore	Peak	2030	NA	None	Aims to cut emission intensity of GDP by 36% by 2030 (vs. 2005)
New Zealand	30%	2030	2005	50% below 1990 by 2050	Its 30% target is comparable to a 11% reduction from 1990
Japan	26%	2030	2013	None	Equivalent to 25.4% reduction from 2005 levels
Marshall Islands	32%	2025	2010	Net zero emissions by 2050 or earlier, if possible	Indicative target of 45% reduction by 2030, from 2010 levels
Kenya	30%	2030	BAU	None	Target subject to international support (finance, technology, etc.)
Monaco	50%	2030	1990	80% GHG reduction by 2050	May use units from international mechanism of emission reduction
Macedonia	30-36%	2030	BAU	None	May link to the UNFCCC New Market Mechanism
Trinidad and Tobago	30%	2030	BAU	None	Unconditional 30% GHG reduction by 2030 (BAU), from the transport; conditional additional 15% reduction from power, industry and transport
Benin (revised)	3.5%	2030	BAU	None	Conditional target total -21.4% by 2030 from BAU
Australia	26-28%	2030	2005	None	Reserves right to adjust target should it consider UCA inadequate.
Djibouti (revised)	40%	2030	BAU	Long term adaptation strategy for 2035	Unconditional -40%; conditional -20% (Total -60%); Djibouti requires international financing of USD1.65bn
DR Congo	17%	2030	BAU	None	Conditional on financing of USD30bn; the country is a net sink
Dominican Republic	25%	2030	2010	Post 2030 contributions will be established at the end of the NDS period	The emission target is conditional upon receiving international financing of approximately USD35bn
Algeria (revised)	7%	2030	BAU	None	Conditional total -22%; subject to external support
Colombia	20%	2030	BAU	None	Up to 30% from 2030 BAU with international support
Jordan (revised)	1.5%	2030	BAU	None	Unconditional – 1.5%; conditional – 12.5% (Total – 14%)
Ivory Coast (revised)	28%	2030	BAU	None	42% renewables in the electricity mix by 2030
Tunisia	N/A	2030	2010	None	Unconditional –13% in carbon intensity; conditional –28%; (Total –41%)
Comoros	84%	2030	BAU	None	Aims to be a carbon sink
Grenada (revised)	30%	2025	2010	None	Indicative cut of 40% by 2030 (2010); conditional on external support
Equatorial Guinea	20%	2030	2010	50% GHG reduction by 2050	Conditional on favourable and predictable support, esp. financial with estimated costs of USD3.7bn for mitigation actions
Montenegro	30%	2030	1990	None	Intends to sell carbon credits to contribute towards objectives
Mauritania (revised)	2.7%	2030	BAU	None	Conditional target totals -22.3% (12% of which is unconditional)
Ghana	15%	2030	BAU	None	Conditional target totals -45%. USD16.3bn from int'l sources required
Albania	11.5%	2030	BAU	Aiming for 2tCO ₂ e/capita by 2050 (2.76tCO ₂ e current)	Covers CO ₂ only. Intends to sell carbon credits during the period
Madagascar	14%	2030	BAU	None	Conditional on financial support of USD42bn for all actions
Indonesia	29%	2030	BAU	None	Conditional target totals -41%, subject to agreement & external support
Mongolia	14%	2030	BAU	None	Contingent upon gaining access to finance and new technology
Eritrea	39.2%	2030	BAU	None	Conditional total -80.6%. Needs USD4.7bn to fulfil conditional scenarios
Bangladesh	5%	2030	BAU	None	Only covers power, transport, industry. Conditional total -15%
Seychelles	29%	2030	BAU	None	Currently a net sink. With this INDC, it will remain a net sink in 2030
Georgia	15%	2030	BAU	None	Conditional total - 25% subject to agreement on finance and technology
Belarus	28%	2030	1990	None	May use international carbon market mechanisms
South Africa	NA (34%)	2030	NA (BAU)	None	Peak, plateau and decline (PPD) trajectory range; emissions by 2025-30 to be between 398-614 MtCO ₂ e (2012 was 464MtCO ₂ e [WRI]); Conditional Total -42%
Moldova	64-67%	2030	1990	None	Conditional total -78%. 64% target is based on self-sufficiency in electricity; 67% target assumes 30% of electricity is imported

Table 8: Summary of INDCs (Intended Nationally Determined Contributions) submitted before the 1 October deadline (in order of first to submit to most recent)

Country	Pledge	Target year	Base year	Long term pledge	Comments
Kiribati	12.8%	2030	BAU	None	Interim of 13.7% by 2025 from BAU. Conditional total -61.8% by 2030
Senegal	5%	2030	BAU	None	Conditional total -21%; Needs USD5bn to fulfil conditional scenarios
Central African Republic	5%	2030	BAU	25% reduction in 2050 from BAU	Entirely conditional. Requires USD2bn for (conditional) mitigation and USD1.4 for (conditional) adaptation
Brazil	37%	2025	2005	None	Equivalent to 6% below 1990; already achieved 41% below 2005 by 2012. Indicative target of 16% below 1990 by 2030 (equivalent).
Mauritius	30%	2030	BAU	None	Conditional on support (USD1.5bn mitigation; USD4bn adaptation)
Myanmar	NA	NA	NA	None	Was net GHG sink in 2012. Needs a lot of capacity building support.
Cameroon (revised)	32%	2035	BAU	None	25% renewables in electricity mix by 2035
Gambia (revised)	45.4%	2030	BAU		Interim target of 44.4% in 2025 from 2010
Maldives	10%	2030	BAU	None	Conditional total -24% on technical, financial and capacity building
Kazakhstan	15%	2030	1990	None	Conditional total -25% on international investment
Peru	20%	2030	BAU	None	Conditional total -30% on international financing
Chad (revised)	18.2%	2030	BAU	None	Conditional total -71%; needs USD7bn to reach conditional mitigation
Guyana	NA	2025	BAU	None	Believes forest & energy mitigation efforts provide up to 52MtCO ₂ saved
Barbados (revised)	44%	2030	BAU	None	Equivalent to 23% by 2030 (2008). Interim target -37% by 2025 (BAU)
Burkina Faso	6.6%	2030	BAU	None	Conditional total -18.2%; needs USD0.75bn for conditional mitigation
Chile	NA	2030	2007	None	Unconditional reduction in emission intensity of GDP by 30% by 2030 (2007); conditional intensity reduction 35%-45% if financial support
Vanuatu	NA	2030	NA	None	Mitigation target is 100% renewables in electricity by 2030 (which reduces overall energy emissions by 30% from BAU).
Mali	NA	2030	BAU	None	Conditional target; requires USD34.68bn for mitigation (sector wise GHG emission reduction (29% agriculture, 31% energy, 21% forests)
Armenia	NA	2030	NA	Per capita emissions of 5.4tCO ₂ e in 2050	With external support, could achieve 2.07tCO ₂ e per capita in 2050
Niger	3.5%	2030	BAU	None	Conditional total -34.6%. Full INDC requires USD8.7bn
Kyrgyzstan	11.49-13.75%	2030	BAU	12.67-15.69% reduction in 2050 (below BAU)	Conditional total up to -30.89% in 2030 and -36.75% in 2050. Aiming for per capita emissions of up to 1.58tCO ₂ in 2050
Uruguay	NA	2030	1990	None	Different targets depending on the gas. E.g. for CO ₂ , for energy, unconditional 25% reduction in emissions intensity by 2030 (1990)
Namibia	10%	2030	BAU	None	Conditional total -89%. Requires USD33bn to implement INDC in full
Zambia	25%	2030	BAU	None	Unconditional requires USD15bn. Conditional total -47% reduction by 2030 from 2010 requires additional USD35bn
Swaziland	NA	2030	NA	None	Four mitigation actions: 1) develop GHG inventory by 2020; 2) double share of renewables by 2030 (2010); 3) 10% ethanol blend in petrol for all vehicles; 4) Phase out of HFCs, PFCs, SF ₆ .
Tanzania	10-20%	2030	BAU	None	Target is gross emissions. Tanzania believes it is a net GHG sink.
Azerbaijan	35%	2030	1990	None	2010 per capita emissions was 5.4tCO ₂ e
Congo	48%	2025	BAU	None	Reduction of 55% by 2035; Targets subject to support
Dominica	44.7%	2030	2014	None	Gross emissions. Interim 39.2% by 2025. Whole INDC is conditional.
Israel	NA	2030	2005	None	Target 7.7tCO ₂ e per capita by 2030, 26% below the 10.4tCO ₂ e in 2005
Guatemala	11.2%	2030	BAU	None	Conditional total: 22.6%, requires new and additional external resources
Sao Tome and Principe	24%	2030	2005	None	Whole target is conditional – mainly achieved through 47% renewables. The country expects to remain a net carbon sink in 2030
Haiti	5%	2030	BAU	None	Conditional total -26%; Requires USD25.4bn
Ukraine	40%	2030	1990	None	Target is not to exceed 60% of 1990 levels in 2030. 2012 was already 42.6% of 1990 levels. Interim 'target' is 76% of the 1990 level in 2020.
Lebanon	15%	2030	BAU	None	Conditional total -30% by 2030 (BAU)
Burundi	3%	2030	BAU	None	Conditional total -20%; subject to financial and technical support
Guinea Bissau	NA	2030	NA	None	Is a GHG sink. Requires financial assistance USD700mn to meet goals
Vietnam	8%	2030	BAU	None	Conditional total -25% by 2030 from BAU. Carbon intensity of GDP could decline by 30% by 2030 from 2010 with external support.
Cabo Verde	NA	NA	NA	None	Unconditional: improve energy efficiency by 10% by 2030.
Solomon Islands	30%	2030	BAU	Reduction of more than 50% by 2050 (conditional)	Conditional total -45% by 2030 from BAU (requires financial and technical assistance). Interim target -12% below 2015 by 2025
Turkmenistan	NA	2030	2015	None	Targets decoupling of CO ₂ from GDP; stabilisation of GHGs by 2030
Zimbabwe	NA	2030	NA	None	Reduce energy emissions per capita by 33% by 2030 from BAU
Costa Rica	25%	2030	2012	To accomplish zero net emissions by 2085	Max 9.374MtCO ₂ e by 2030, emissions per capita of 1.73tCO ₂ by 2030
Bhutan	NA	2025	NA	None	Intends to remain carbon neutral by not exceeding forest sequestration
Malawi (revised)	NA	2030	2010	None	Presented 33 climate change initiatives. Per capita emissions to be 0.7-0.8tCO ₂ e per capita in 2030 (compared to BAU of 1.5tCO ₂ e).
Cambodia	26.7%	2030	BAU	None	Conditional mitigation target. Per capita emissions 2.04tCO ₂ e by 2030.
Rwanda	NA	2030	BAU	None	Implementation of climate strategy requires USD24.15bn
Lesotho	10%	2030	BAU	None	Conditional total -35% by 2030 (BAU), requires USD1.8bn
Tajikistan	10-20%	2030	1990	None	Unconditional: 1.7-2.2 tCO ₂ e/capita.; Conditional: 25-35% GHG reduction by 2030 (1990) or 1.2-1.7 tCO ₂ e/capita
Liberia	15%	2030	BAU	Carbon neutrality by 2050	Is a GHG sink if LULUCF included
Papa New Guinea	NA	2030	BAU	None	Targets carbon free electricity sector by 2030 (subject to external funds)

Table 8: Summary of INDCs (Intended Nationally Determined Contributions) submitted before the 1 October deadline (in order of first to submit to most recent)

Country	Pledge	Target year	Base year	Long term pledge	Comments
Mozambique (revised)	NA	2030	NA	None	Total reduction of 76.5MtCO ₂ e between 2020-30; Implementation of 12 mitigation policies and programmes subject to external support
Togo	11.4%	2030	2010	None	Conditional total -31.14%; requires USD3.54bn (mitigation USD1.10bn)
Turkey	21%	2030	BAU	None	Should save 246MtCO ₂ e from BAU levels
San Marino	20%	2030	2005	None	Intends to achieve reduction exclusively through domestic measures
Samoa	NA	2025	NA	None	Adopting 100% renewables for electricity by 2017; requires international assistance to maintain the 100% renewables through to 2025
Philippines	70%	2030	BAU	None	Mitigation contribution conditional on international support
Lao PDR	NA	2030	NA	None	Listed 6 mitigation activities; requires USD 1.4bn for mitigation policies
Guinea	13%	2030	BAU	None	Requires USD8.3bn in total (USD6.5bn for mitigation in energy sector)
Thailand	20%	2030	BAU	None	Conditional total -25% subject to financial and technical support
Honduras	15%	2030	BAU	None	Conditional on predictable external climate finance
Sierra Leone	NA	2035	NA	Carbon neutrality by 2050	Intends to keep emission level low (7.58MtCO ₂ e); needs USD0.9bn
Botswana	15%	2030	2010	None	Reductions primarily from energy sources; requires USD18.4bn
Paraguay	10%	2030	BAU	None	Conditional total -20%; subject to International cooperation (technology)
Belize	NA	2033	NA	None	Reduce emissions by 24MtCO ₂ e over 2014-33
India	NA	2030	2005	None	Cut emissions intensity of GDP by 33-35% by 2030 (2005); achieve 40% installed electricity capacity from non-fossil fuel sources
Ecuador	25%	2025	BAU	None	20.1-25% emissions reduction from energy only; with financial and technical support, conditional total in the range of -37.5 to -45.8%
Argentina	15%	2030	BAU	None	Conditional total -30%; subject to financial and technical support
INDCs submitted after the 1 October deadline are listed below – these still contribute towards a universal climate agreement but will not be included in the synthesis report					
Bosnia-Herzegovina	2%	2030	BAU	None	Conditional -23% subject to financial and technical support
Bolivia	NA	2030	NA	None	Zero illegal deforestation by 2020; double renewable share to 79% by 2030; conditional results to be achieved with international cooperation
Afghanistan	13.6%	2030	BAU	None	Conditional on external support; requires USD6.6bn for mitigation (2020-30) and USD10.8bn for adaptation
Uganda	22%	2030	BAU	None	Additional mitigation and adaptation measures subject to financial and technical support
Antigua and Barbuda	NA	2030	NA	None	Listed conditional adaptation and mitigation efforts subject to international support; needs USD0.24bn
Oman	2%	2030	BAU	None	Listed conditional adaptation and mitigation efforts subject to international support
UAE	NA	2021	NA	None	Increase clean energy to 24% in the total energy mix by 2021 from 0.4% in 2014
Sri Lanka	7%	2030	BAU	None	Reduction from Energy-4% and Others -3%; Conditional total -23% (Energy 16% and Others 7%)

Source: HSBC

Notes

Notes

Disclosure appendix

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Issuer of report: HSBC Bank plc