



Lecture 1: An Introduction to the Global Energy Economy

James Henderson November 2018

The Economics of Energy Corporations

Introduction to the Course

- 1. Global energy situation and current trends
- 2. Value chain and prices
- 3. Companies and governments
- 4. The impact of new energy
- 5. Decision-making at energy corporations
- 6. The Russian oil sector and its impact
- 7. The Russian gas sector and its impact
- 8. Russian energy and geo-politics



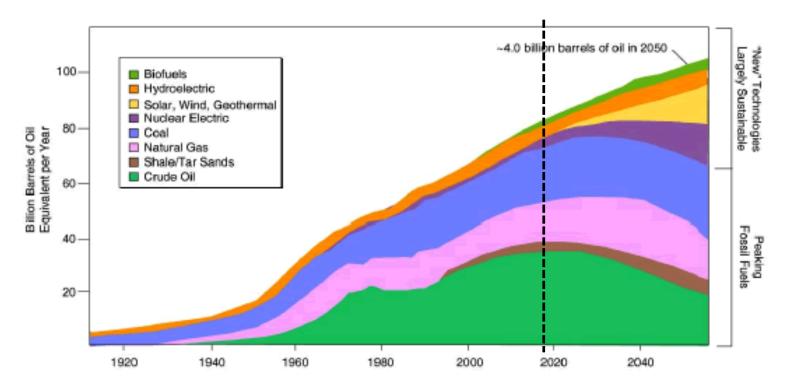
The Question

- What are the economic and related political issues that will most affect short and long-term decision-making at one of the following:
 - ExxonMobil?
 - Rosneft?
 - CNPC?
 - Saudi Aramco?
 - Gazprom?
 - A Japanese energy utility?



World Energy Consumption – A Long-Term View

World Energy Demand—Long-Term Energy Sources

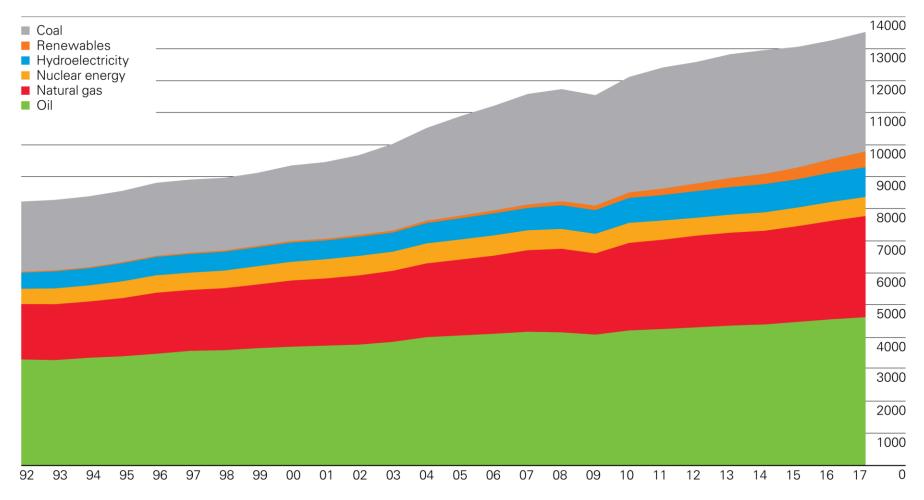


Sources: Lynn Orr, Changing the World's Energy Systems, Stanford University Global Climate & Energy Project (after John Edwards, American Association of Petroleum Geologists); SRI Consulting.

- World energy consumption has grown dramatically in the past century, driven by and catalysing economic growth
- Energy availability supports modern living standards and human development

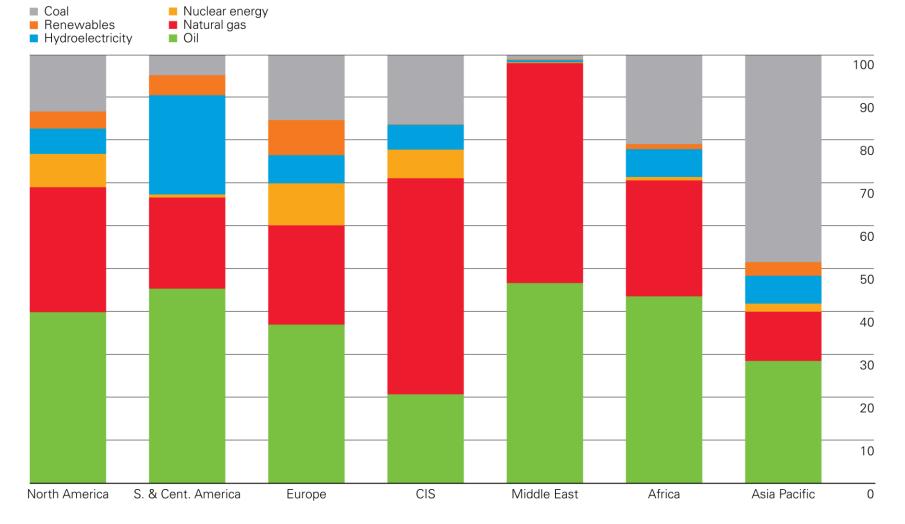


Primary energy consumption since 1990 (mmtoe)



- Overall energy demand has been growing by around 1% per annum
- The key primary fuels have been hydrocarbons, which account for 80%+ of total energy consumption
- Renewables are growing fast but from a very low base

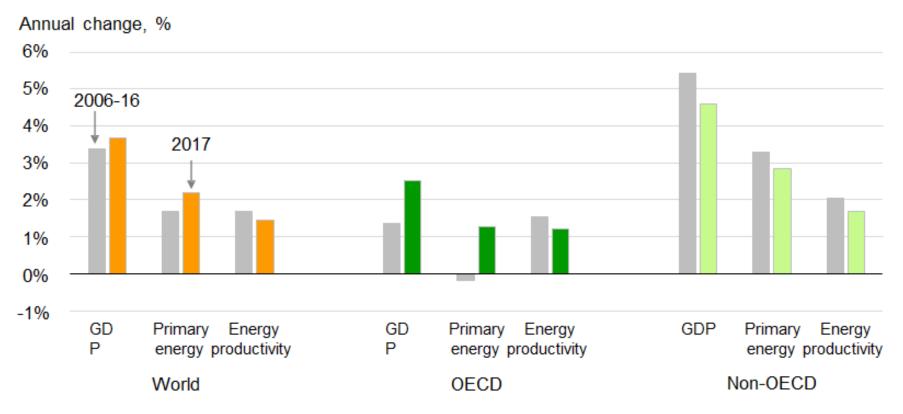
Primary energy regional consumption by fuel (2017, %)



- Fuel split is very different by region, and is generally driven by indigenous supply
- Countries are reluctant to be over-committed to imports



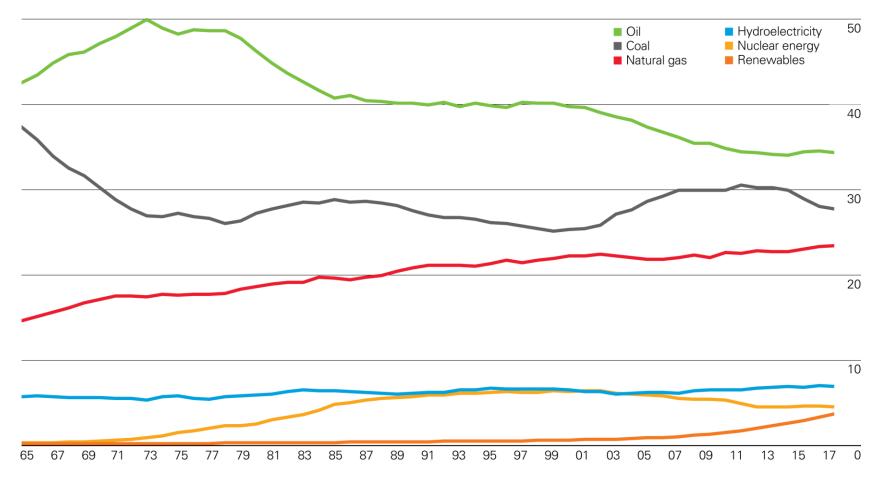
Energy productivity is improving but we need to do better



- Energy efficiency measures are helping to break the link between economic growth and energy demand growth
- However, the situation worsened in 2017 and governments need to refocus on efficiency efforts
- World not helped by climate change deniers like President Trump



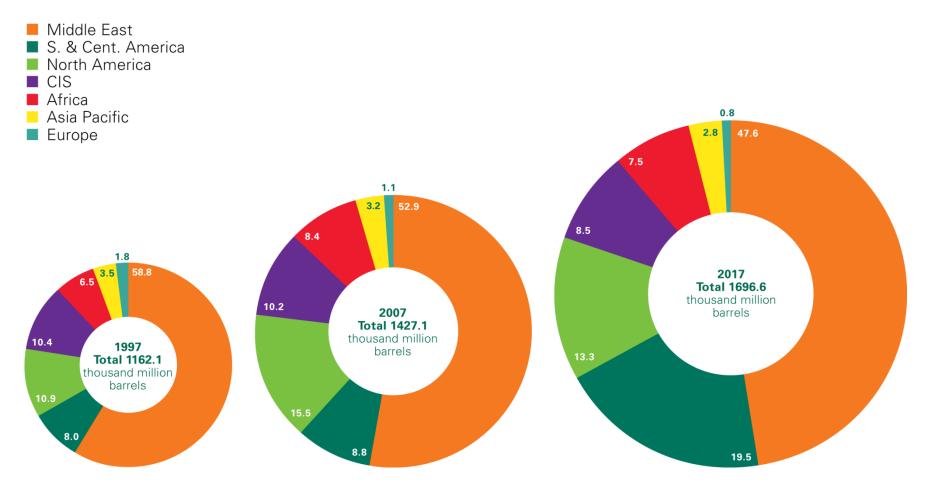
Split of Primary Energy by Fuel



- Oil demand has been declining, although has flattened
- Coal share is the same as in 1970s
- Gas has been rising consistently, but is still only in 3rd place
- Renewables share growing fast from a low base



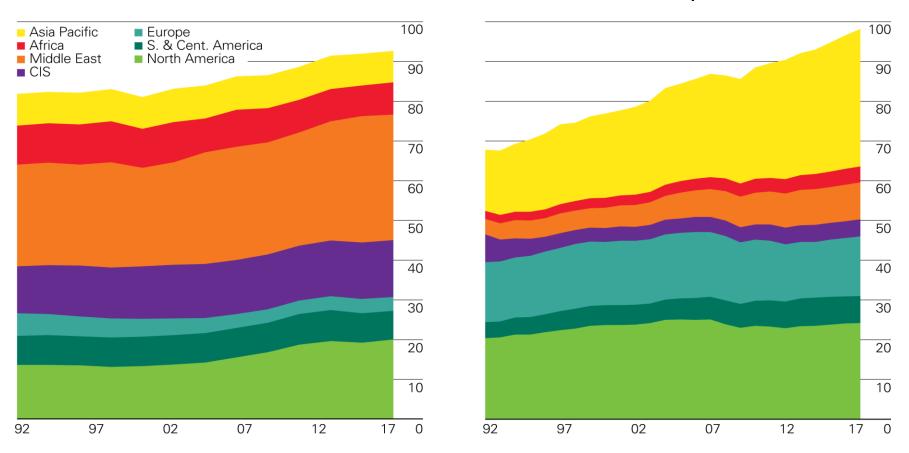
The growth in oil reserves and the regional split



- Oil is not running out proved reserves are up by 50% since 1995
- Middle East continues to dominate, but other regions are growing the Americas in particular



Oil production and consumption by region (mmbpd)



Production

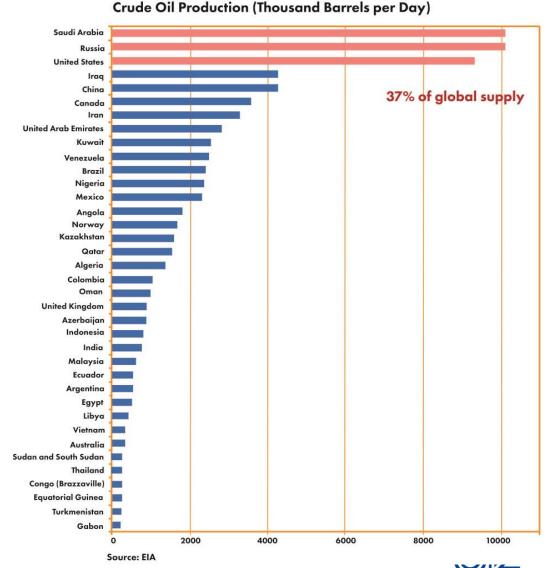
Consumption

- North American production is up sharply, thanks to shale oil
- Middle East production account for around one third of the total
- Europe and Eurasia is only flat thanks to growth in Russia
- Demand growth is almost entirely driven by Asia



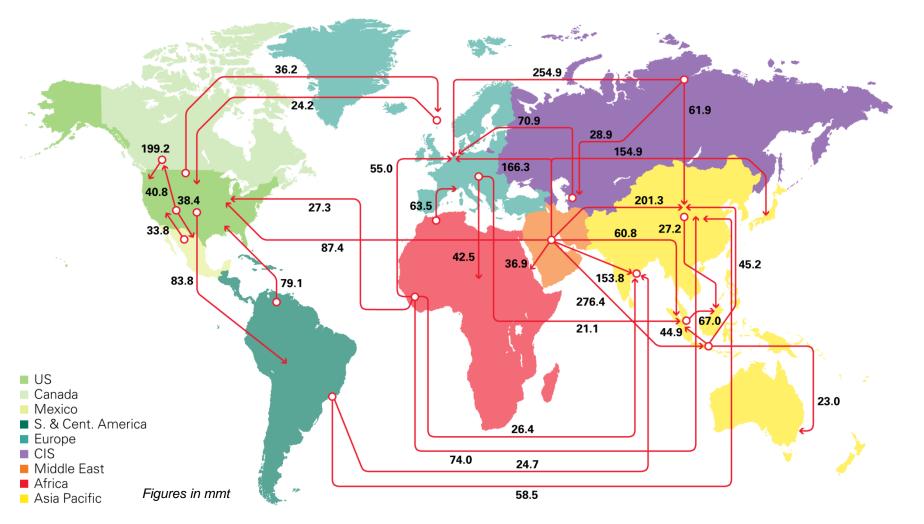
Oil production is dominated by three countries

- Saudi Arabia, Russia and the US account for more than one third of global oil output
- The Middle East is the dominant region, accounting for around 35% of output
- OPEC countries generate 42% of the world's oil, giving the cartel a strong lever over prices
- Many traditional non-OPEC countries are now in decline, other than the US

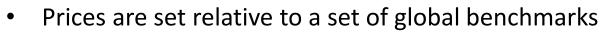




Oil is a global commodity

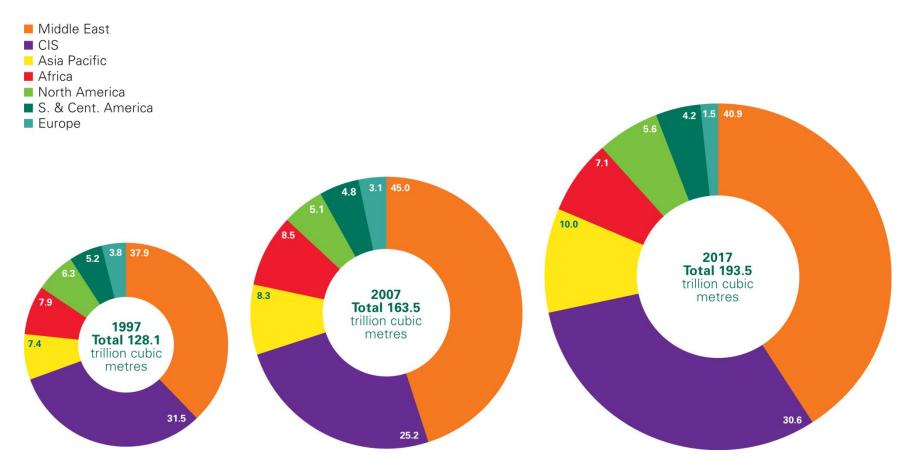


- Oil is traded in multiple directions across the globe
- Much of the trade originates from the Middle East and flows West and East





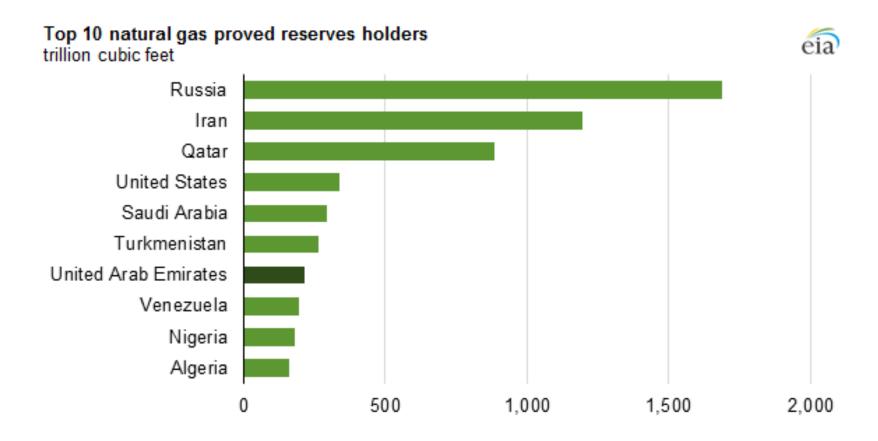
Gas reserves by region (1997, 2007, 2017)



- The Middle East also contains huge amounts of gas, although Russia is the main exporting country
- Gas reserves have grown dramatically as it has increasingly become an important fuel for power generation

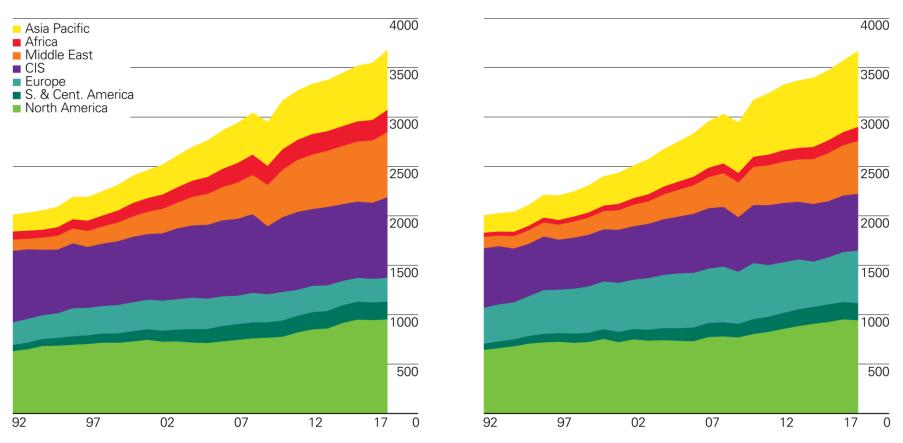


Familiar faces control the world's largest gas reserves



- Oil and gas are often found together, so it is no surprise that the US, Saudi Arabia and Russia are towards the top of the reserves list
- Gas has traditionally been a much more regional fuel, due to the difficulties and cost of transporting it

Gas production and consumption by region (bcm)



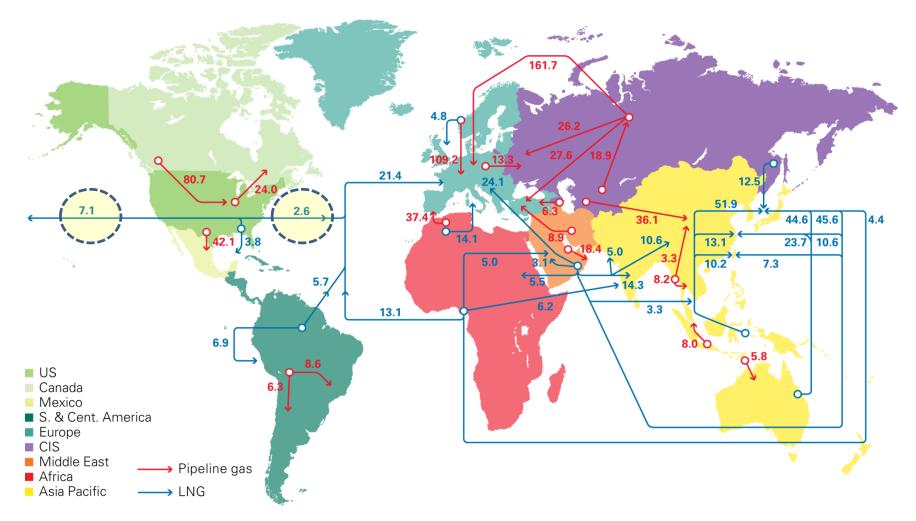
Production

Consumption

- Europe and North America have traditionally been the largest consumers of gas
- Major infrastructure in both regions facilitates indigenous production and imports
- Asia, the Middle East and Latin America are growing fast, however



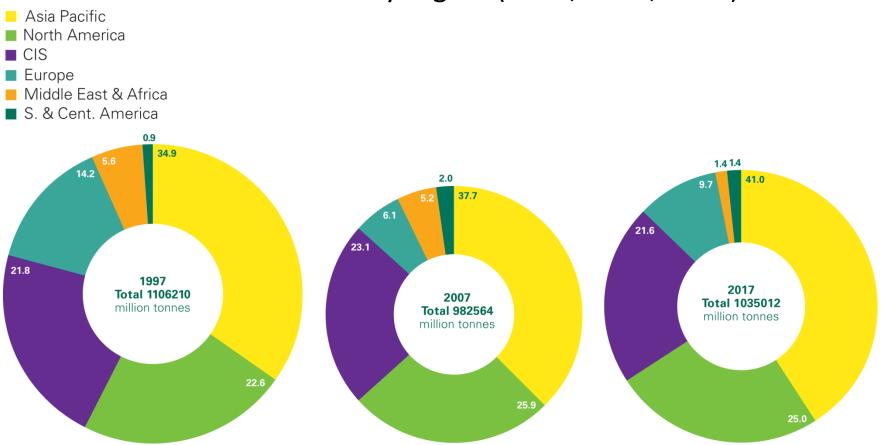
Gas trade flows (bcm)



- Gas trade flows via two transport methods pipeline and LNG
- Historically pipeline flows have dominated, leading to regionalisation
- LNG is now turning gas into a more global commodity

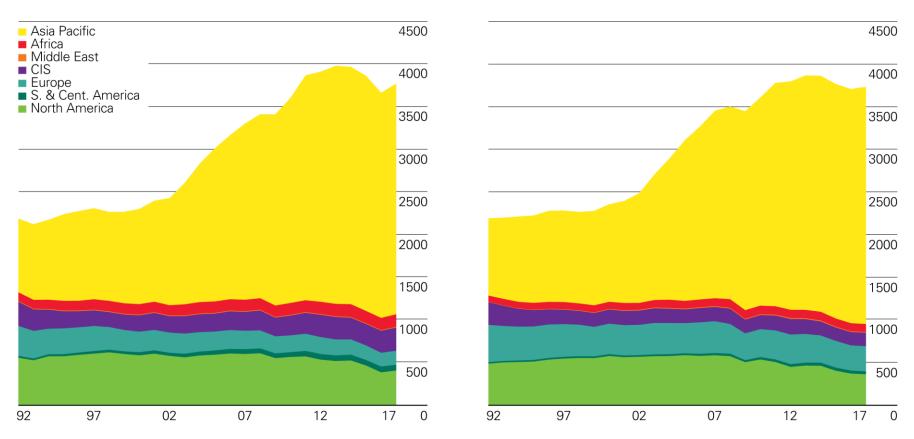


Coal reserves by region (1997, 2007, 2017)



- Coal reserves are in decline the uncertain future of the fuel in a decarbonising world is creating a disincentive to invest
- Europe has the largest reserve base, with Asia close behind, but individual O
 countries are key to understanding coal's position in global energy economy

Coal production and consumption by region (mt)

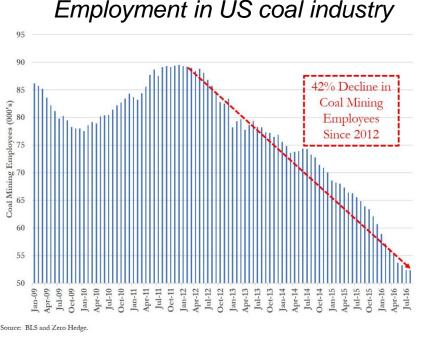


Production

Consumption

- The majority of production and consumption is in Asia, and has grown rapidly
- China and India are the key players, as coal is both countries' major indigenous energy resource
- Decline in North America driven by the arrival of shale gas

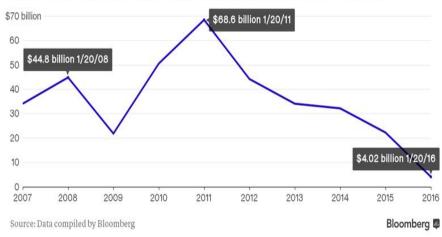
Decline in US coal industry



ustry Market value of US coal companies

Plunging Coal

The combined market cap of publicly traded U.S. coal miners has cratered since 2011.



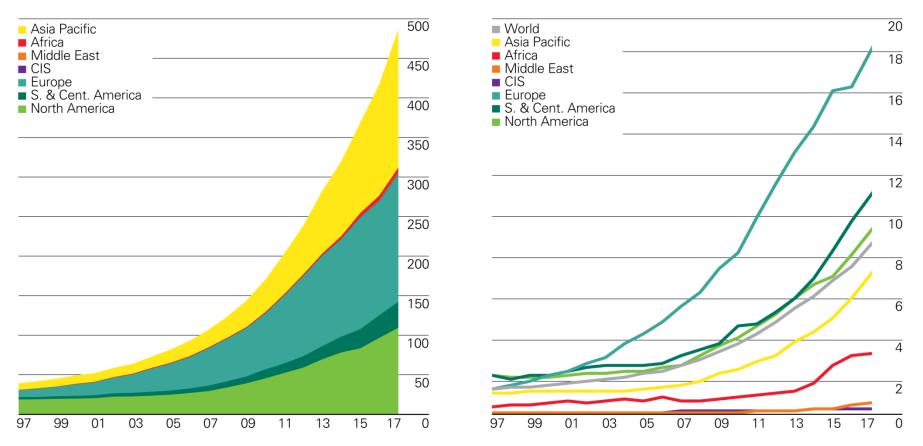
- The US coal industry has collapsed over the past five years
- Although the environment has been a background cause, in fact it has been all about economics – cheap gas prices
- Ironically, US coal has been exported to regions where gas is more expensive – Europe being a prime example



Renewable energy consumption / share of power by region

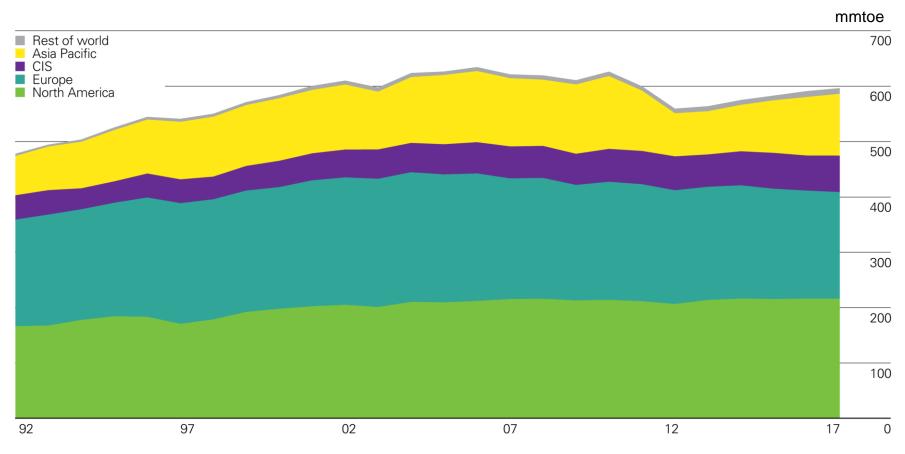
Share of power generation (%)

Consumption (MMTOE)



- Growth in renewable energy has been dramatic it now accounts for around 7% of the global input to electricity
- Europe has been leading the way, catalysed by policy initiatives in Germany
- Growth in Asia accelerating, as search for indigenous energy continues

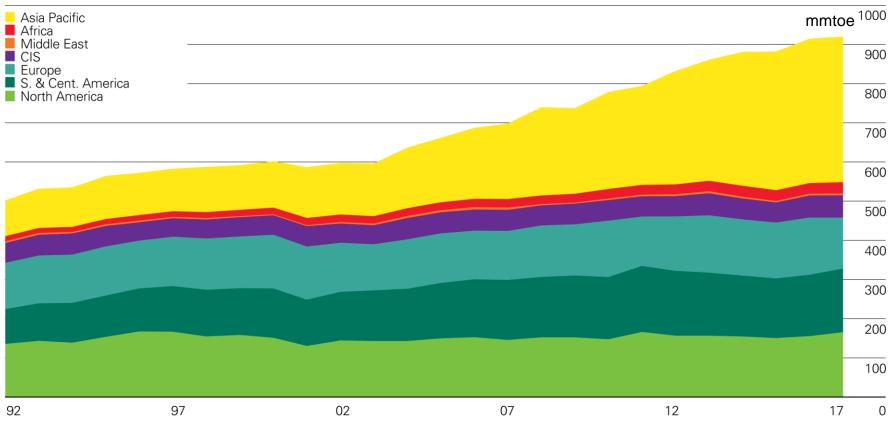
Nuclear Energy – A Relatively Stagnant Story



- 1.3%pa growth since 2015, but long-term trend is flat
- Trend is away from traditional regions of Europe and US towards Asia
- China is at the forefront of new nuclear growth, in the search for indigenous energy production



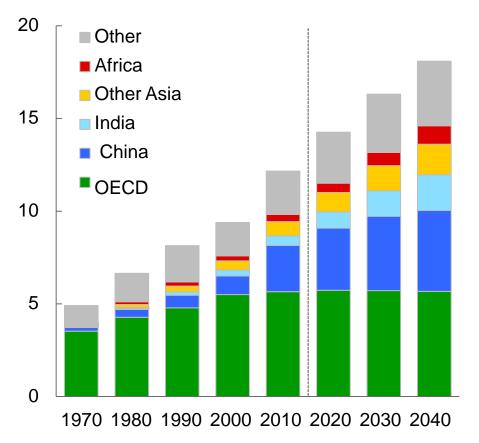
Hydro-electric – reaching its limits?



- A similar story for hydro, with more growth
- 1% growth overall in 2015, held back by drought in South America and some parts of Central Europe
- Upside potential limited from here, other than in Asia



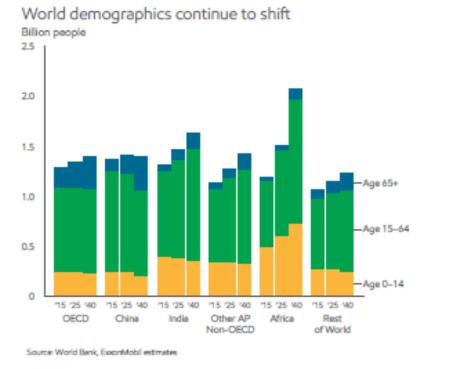
Energy demand growth is moving away from OECD countries



- Growth in energy demand is moving towards the developing world
- After a slight slowdown in 2015 China has remained the fastest growing energy consumer in the world
- Africa, the Middle East and SE Asia are also growing from low bases



Key drivers of energy consumption



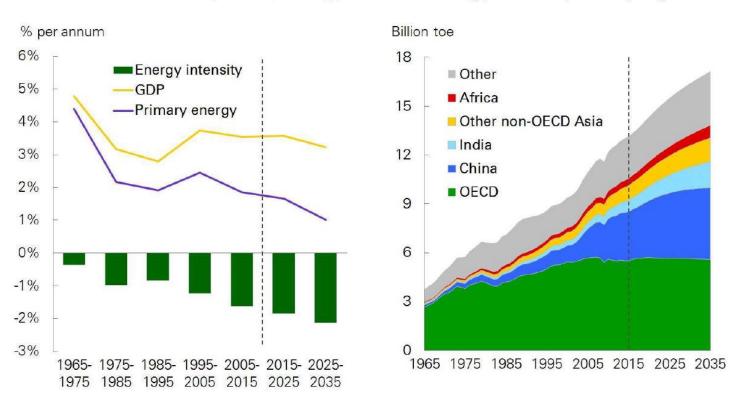
GDP, year-over-year average in percent 5 4 3 - ncome 2 1 Population n 80,415 25-40 25-40 15-25 90,45 15-25 OECD Non-OECD

Non-OECD leads economic expansion

- Global population currently 7.3 billion, expected to reach 9.1 billion by 2040
- Population mainly in non-OECD countries, in many of which the alleviation of energy poverty is a huge issue
- Economic growth is another key driver, leading to increased personal wealth and greater use of energy intensive products
- Again non-OECD countries dominate growth, with their share of global GDP set to rise from 35% to 50% by 2040



Energy intensity is improving but demand will still grow



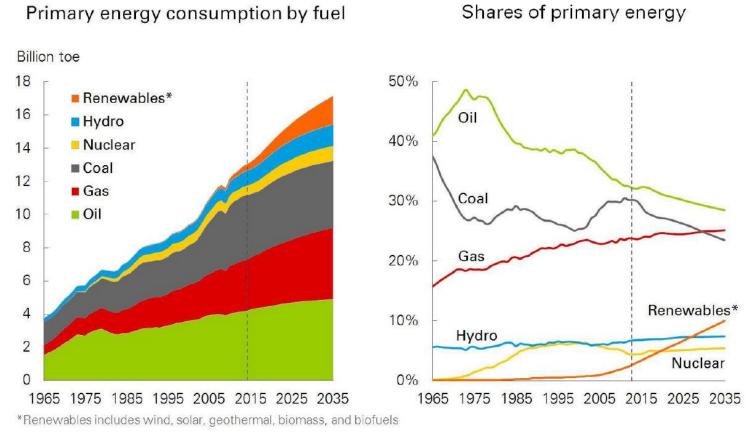
Growth in GDP and primary energy

Energy consumption by region

- Technology is helping the world use energy more efficiently, by reducing the amount of energy used to generate each unit of economic output
- Since 1970 global energy intensity has fallen by around 1% per annum
- In 2016, for example, global GDP grew by 3% versus a 1% growth in energy demand

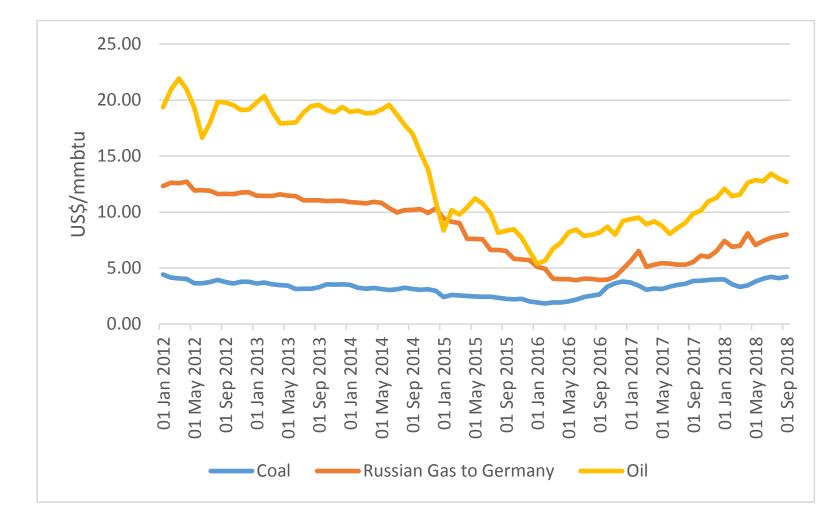


The shifting global energy economy



- Rise of renewables now having a noticeable impact on hydrocarbons
- Incremental demand growth is increasingly being accounted for by non-fossil fuels, leading to oversupply and lower prices
- Are we seeing a new paradigm for oil, gas and coal pricing, with significant commercial and political consequences?

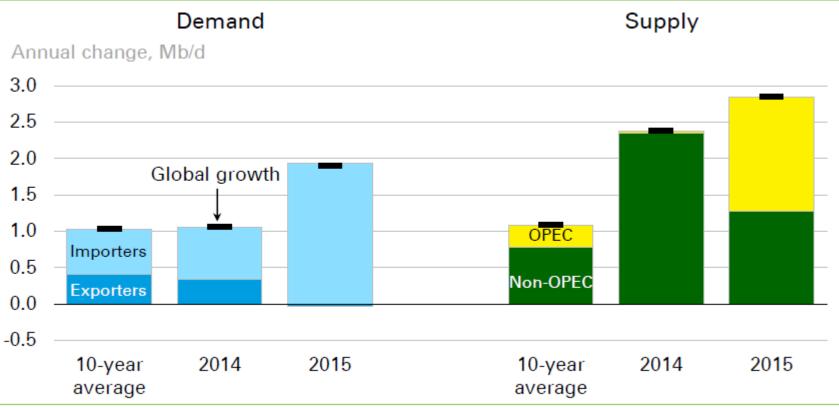
Global energy prices – short and long-term trends



• Are we in a new era of lower commodity prices, or will there be a further rebound as supply and demand re-balance?



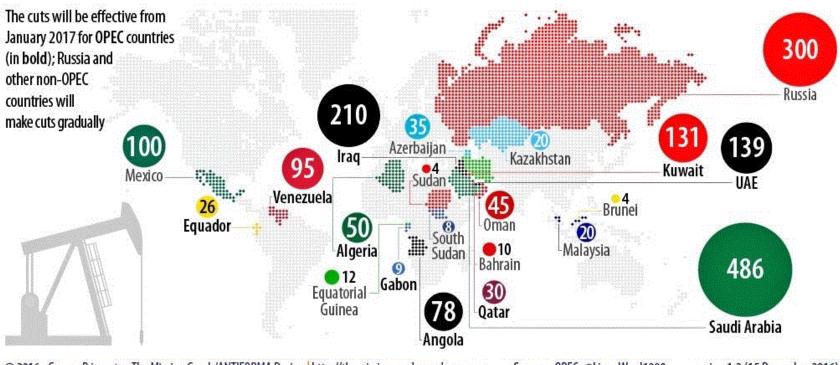
In 2014-2016 the oil market was significantly oversupplied



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- Oil demand growth has been fairly consistent at 1-2mmbpd per annum
- 2015 was a strong year as the market responded to lower prices
- Saudi Arabia (and OPEC) were competing for market share with Russia and the US, in particular US shale oil

OPEC and Non-OPEC countries agreed to cut production



OPEC & non-OPEC countries: Crude Oil Production Cuts (in thousands of barrels per day)

© 2016 - George Primentas, The Missing Graph/ANTIFORMA Design http://themissinggraph.wordpress.com Sources: OPEC, @Lisa_Ward1990 version 1.2 (15 December 2016)

- Saudi Arabia changed its production and market share strategy
- Russia agreed to co-operate to encourage higher oil prices
- Other OPEC countries were dragged along and encouraged to cut output



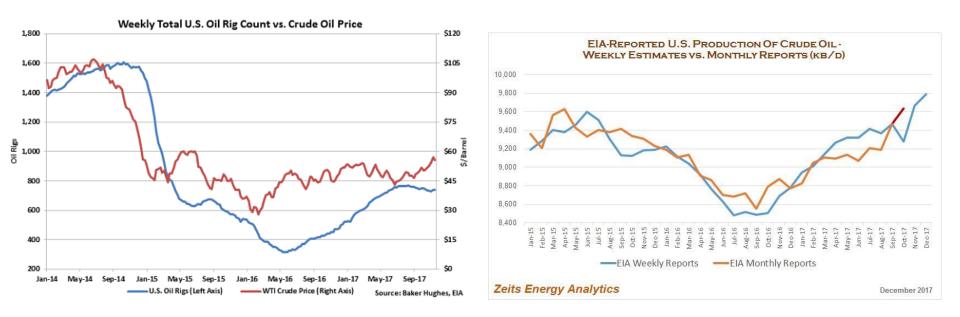
US shale producers have taken advantage



- Original Saudi plan had been to test US shale producers with lower oil prices
- Although this worked to an extent it hurt Saudi more
- However, Saudi cuts allowed US companies to increase output rapidly



US oil production reacted very fast to lower oil price

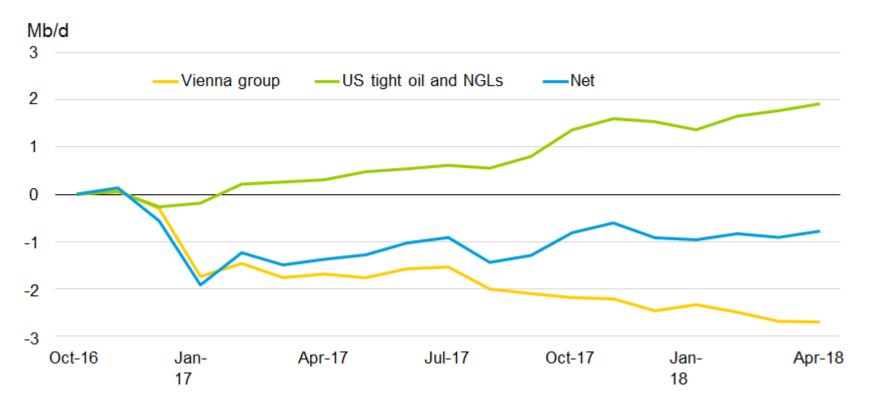


- Lower oil prices led to a reduction in US drilling and a decline in production
- Nevertheless, OPEC was forced to constrain its own output at the beginning of 2017
- As oil prices have rebounded so US production has risen again, acting as something of a cap on prices



Overall impact – Vienna Group helps everyone

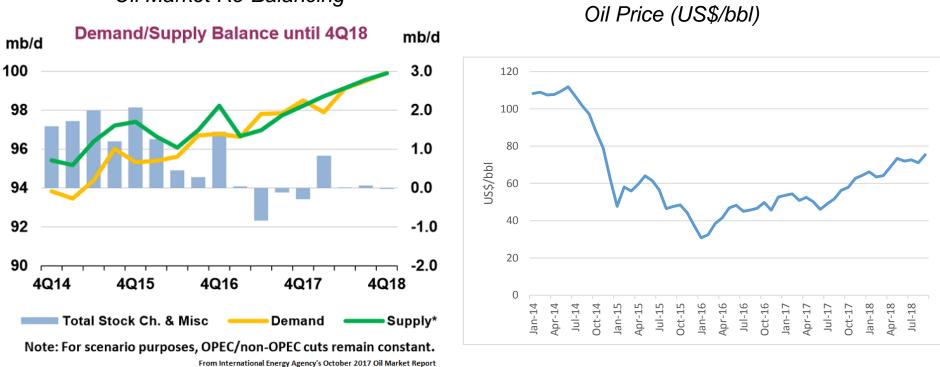
Change in supply relative to October 2016



- US oil production growth offset OPEC cuts to an extent
- Nevertheless, oil prices rebounded so everyone benefitted in the end
- OPEC and Saudi remain the swing producers, with US oil production as another balancing item



Oil market has re-balanced and oil prices have responded

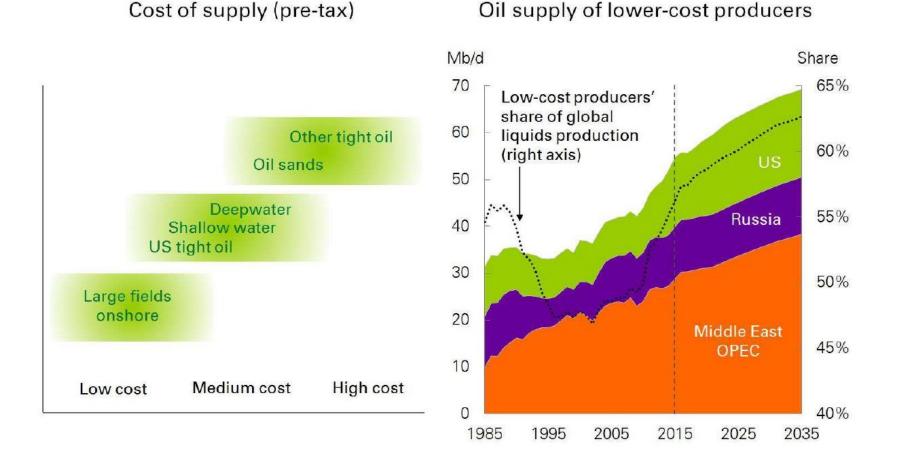


Oil Market Re-Balancing

- Inventories had been very high relative to historical norms
- The oil price moved in an equal and opposite direction
- Re-balancing of the market has encouraged prices to rebound, helped by political tension



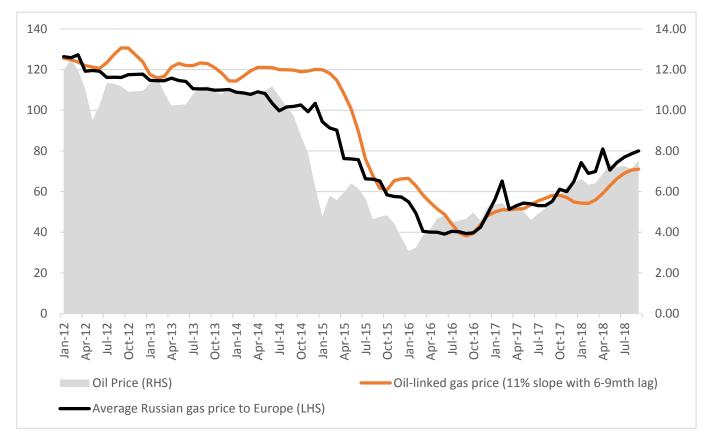
Abundance of oil resources can lead to change in behaviour



- Low cost producers may decide they need to get oil out of the ground sooner rather than later
- Middle East versus Russia versus US a key future battle

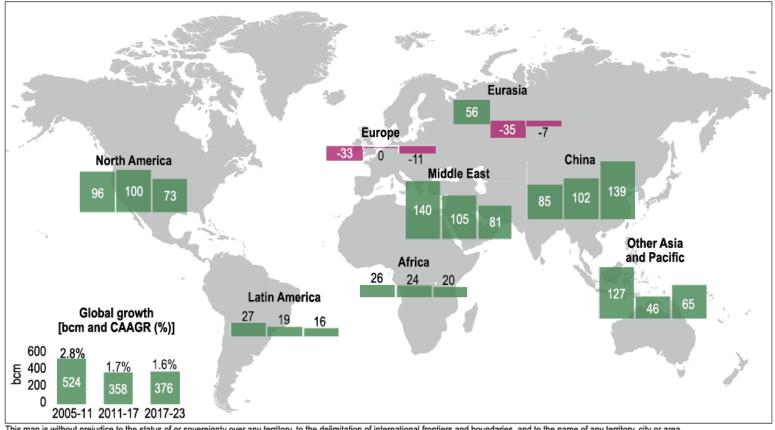


Gas prices continue to have a strong link to oil prices



- Gas prices fell sharply in 2016, led by oil prices
- The average decline in Asia was 46%, in Europe 21% and the US 40%
- Market forces tend to set the price in the US, while in Europe and Asia there is still a strong correlation with the oil price
- The rebound has been equally dramatic, although the link with oil prices is starting to break in Europe

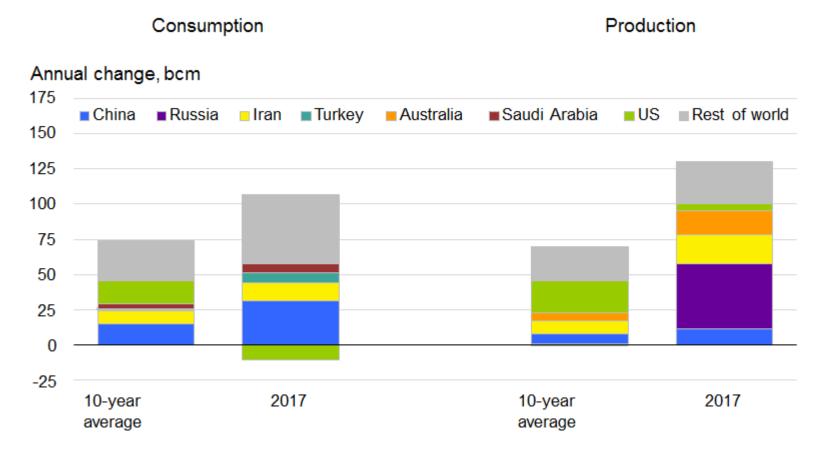
Gas demand growth has remained strong



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

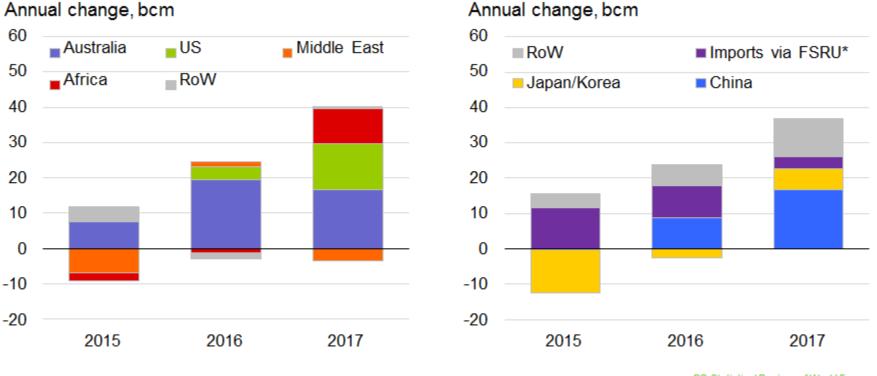
- Gas consumption grew by 1.7% pa in 2011-17, although the regional and sectoral results were mixed
- Gas gained market share in the power sector, displacing coal which had been significantly cheaper for a number of years
- Growth was strongest in Middle East and China, but was stagnant in Europe

Gas demand and supply trends



- Gas demand growth has accelerated in 2017
- China has been the main catalyst thanks to its policy push for cleaner air
- Russia has boosted production significantly, in the absence of alternative supplies to Europe

LNG is making an increasing impact on the global gas market



LNG exports

LNG imports

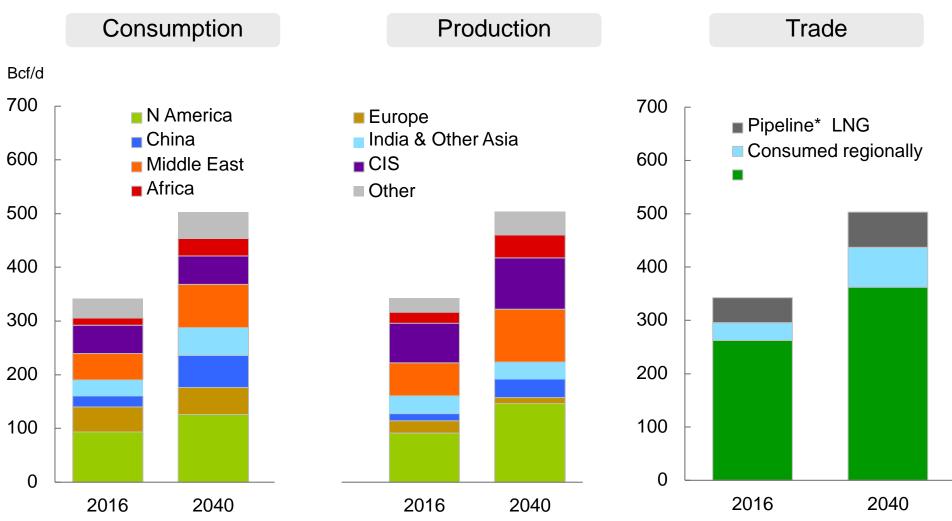
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- New LNG supply has started to come online from the US, Australia and Russia
- Main source of demand is Asia, but new markets are emerging as gas technology improves



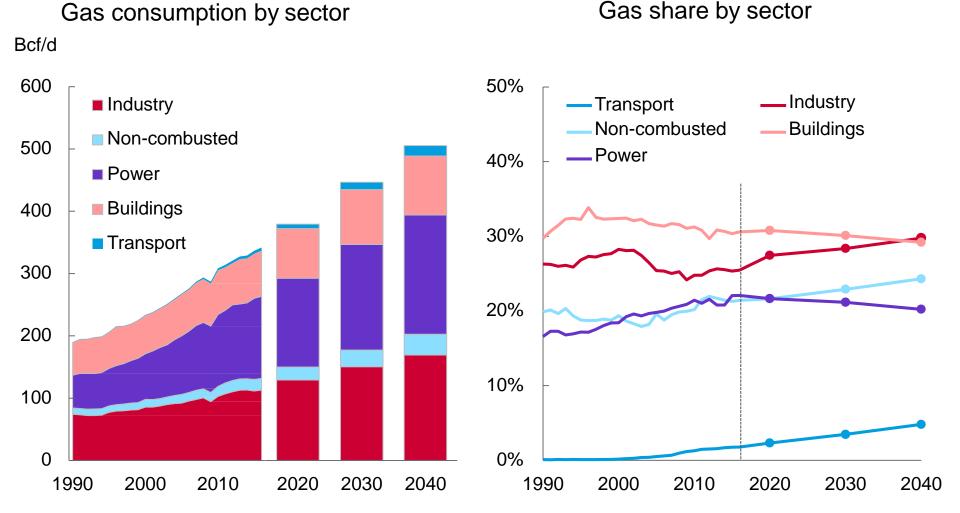
Gas consumption to grow



- Demand continues to be driven by China and Middle East, plus USA
- Shale production in US has a major impact on global output
- Growth of LNG helps top globalise gas market



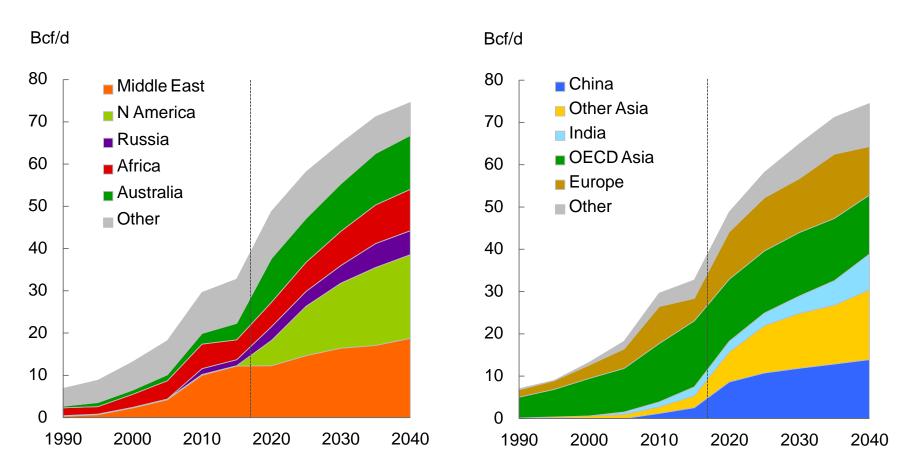
Natural gas demand growth driven by power and industry



- Industrial demand is key to gas growth, especially petrochemicals
- Demand from power sector also grows, although overall share falls



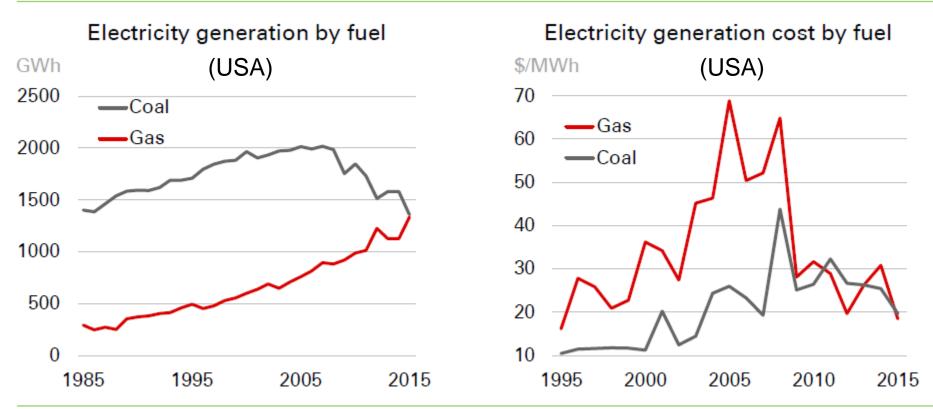
Growing LNG demand adds liquidity to global gas market LNG exports LNG imports



- US, Australia and Middle East to dominate growth of LNG supply
- Asia will be the major customer
- The importance of eastern markets is unavoidable



Ultimately, economics trumps environment



Source: includes data from EIA

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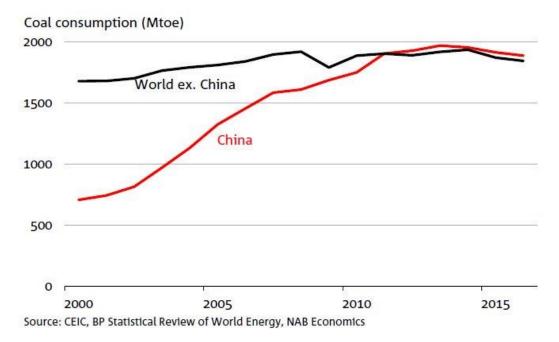
- While coal was cheaper than gas for power generation in the US, its share of the market grew
- As soon as shale gas arrived, and gas prices fell, gas grew more rapidly and coal demand declined
- Ironically, excess coal was exported, reducing the price in Europe and displacing gas in the power sector



Coal increasingly under pressure

GLOBAL COAL CONSUMPTION

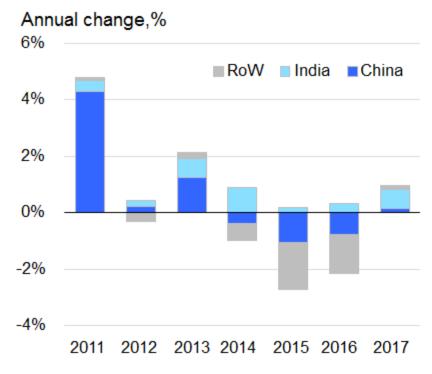
China still burns half the world's total



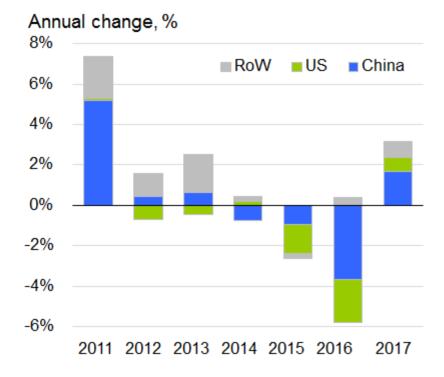
- Coal is under pressure due to environmental concerns
- Demand is naturally in decline, but falling prices are creating an economic dilemma for many countries
- Interesting that production has started to decline in China, but also that it continues to rise in India
- Differing political and economic drivers in each country

Coal production rebounded slightly in 2017, bucking the long-term trend

Consumption growth and regional contributions



Production growth and regional contributions

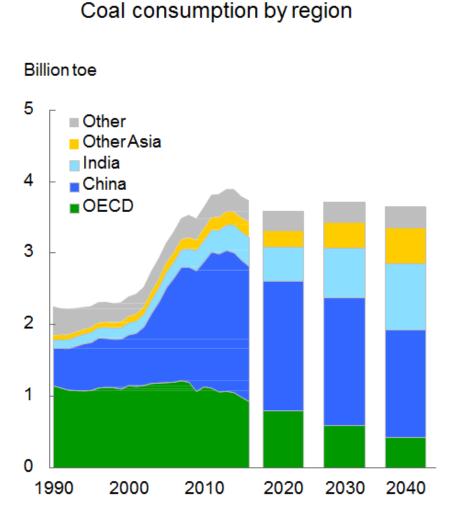


- Rebound in economic growth caused increase in power demand
- Relative coal and gas prices encouraged rise in coal demand
- Economics continues to play a key role despite environmental concerns

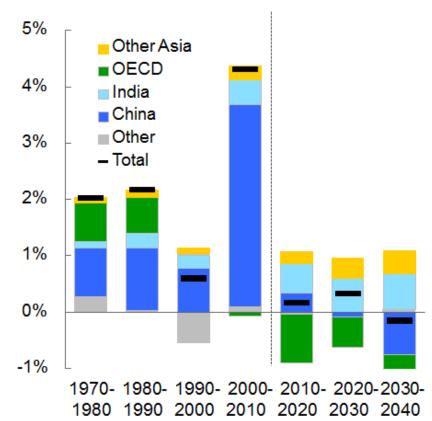


Coal consumption to plateau/decline

% per annum



Coal consumption growth and regional contributions



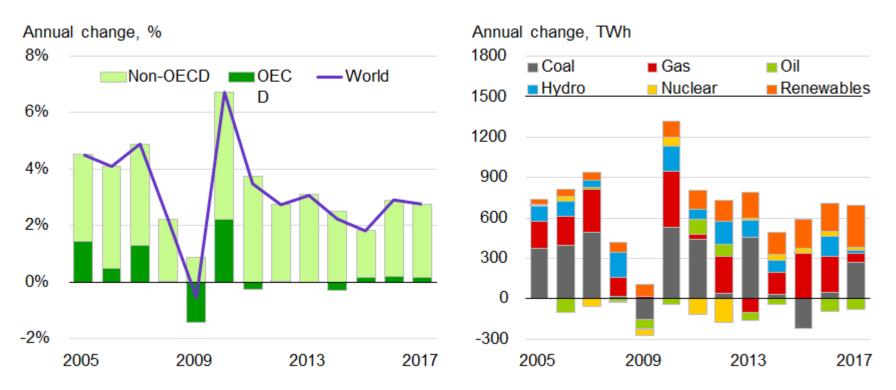
- OECD to lead shift away from coal
- Indigenous producers may find it more difficult to justify diversification



Power Sector Trends

By region

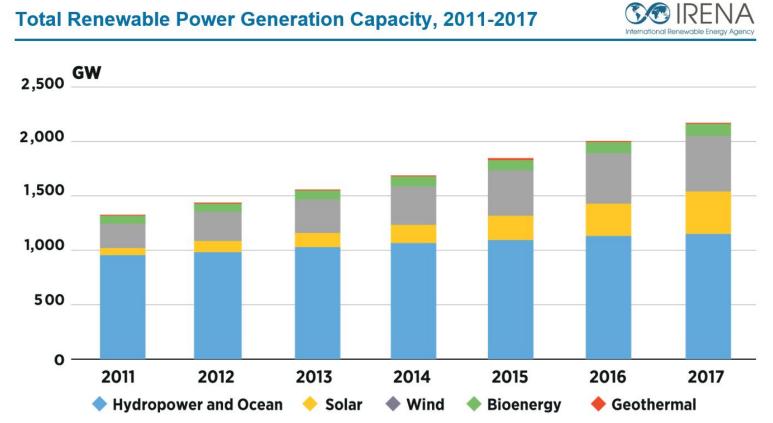




- GDP growth and power demand are closely correlated
- Electricity demand continues to grow but mix of fuels is changing
- Renewables the largest growing segment, but hydrocarbons still playing a major role
- Existing capacity is cheap to use, even if new capacity is less welcome



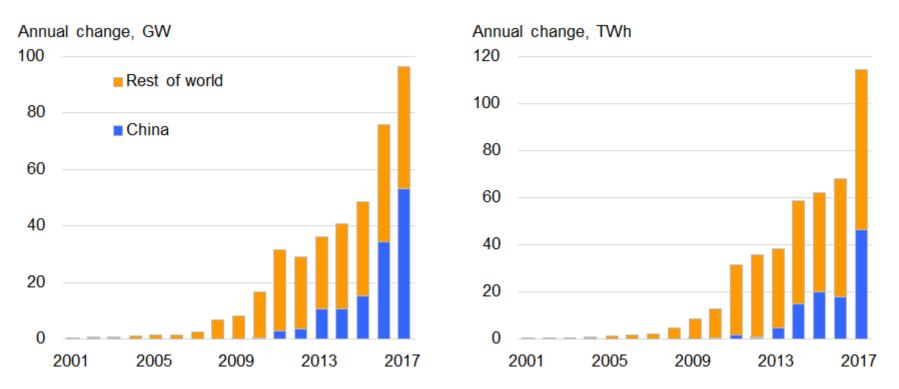
Wind power leads the way for renewables



- Although renewable energy only accounts for 4% of total energy, it grew by 15% in 2017
- It accounted for all the increase in global power generation and nearly 40% of total energy growth
- Solar is growing very fast (33% in 2017) but wind power still leads the way in terms of absolute growth



Solar Power continues to show rapid growth



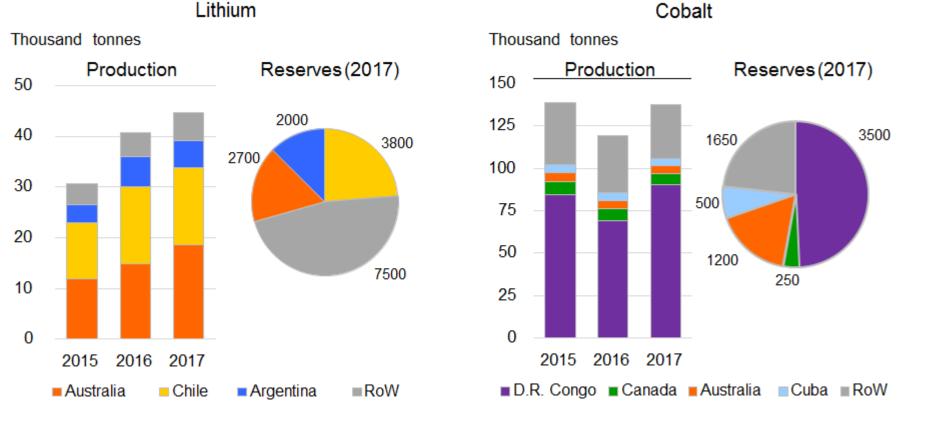
Capacity

Generation

- China is leading the way, both as a consumer and as a developer of technology
- The next generation of solar technology could have a dramatic impact and make a significant change to energy security issues



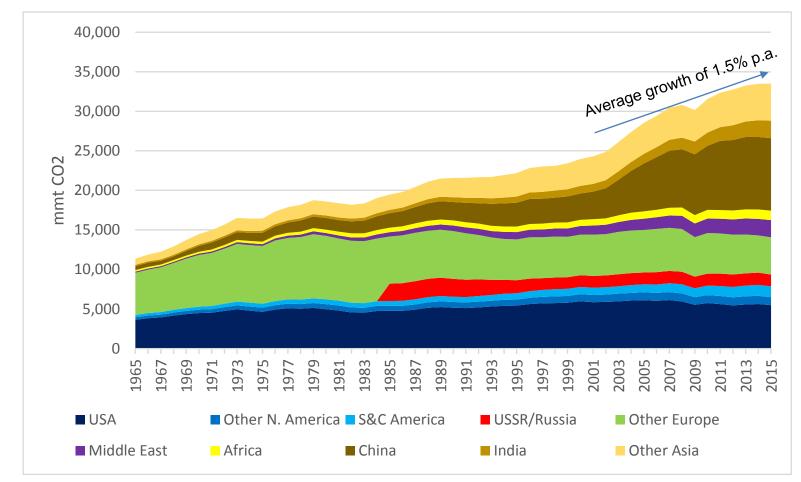
A new source of analysis – sources of battery technology



- Lithium and cobalt are the main inputs for lithium ion batteries
- Countries owning resources for future battery technology could have a huge advantage
- Concerning that Congo has a huge reserve of cobalt
- No surprise that China is making a big diplomatic effort in the country



History of CO2 Emissions



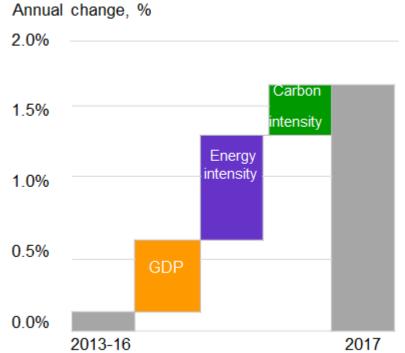
- Carbon emissions have grown consistently to 2014, but were then almost flat in 2015 and 2016 due to sluggish economic growth and greater energy efficiency
- Key question is whether we have reached a peak, or is this just a cyclical downturn?

Carbon emissions rebounded in 2017

Annual change, % Annual change, % 6% 2.0% GDP 4% 1.5% 2% CO 1.0% 0% -2% 0.5% -4% Energy intensity of GDP Carbon intensity of energy 0.0% -6% 2001 2005 2013 2017 2009

GDP and carbon emissions





- Growing economies = growing energy demand = growing emissions in ۲ the current global energy economy
- Can we change course in time to halt this trend? ۲



Air pollution is becoming an almost more important short-term issue

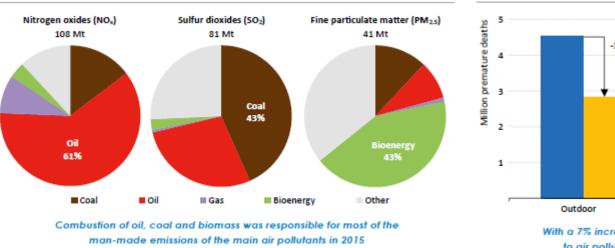
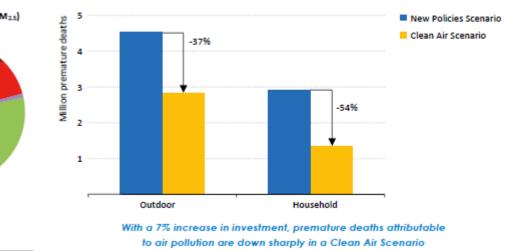


Figure 2.10 >> Estimated anthropogenic emissions of the main air pollutants

by source, 2015

Figure 2.12 Premature deaths attributable to global air pollution in the New Policies and Clean Air Scenarios, 2040

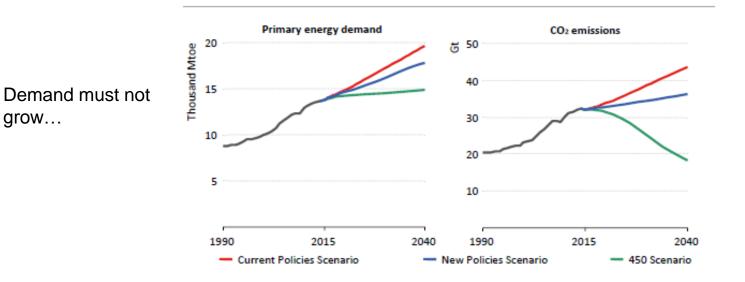


- Air pollution is a more immediate social and political issue than carbon emissions
- China is well known for its poor air quality in many cities, but even in Europe a number of regions are well below acceptable levels
- Governments are aware that a failure to react on a key health issue could lead to a violent backlash
- Air pollution could therefore be a key driver towards a cleaner energy economy

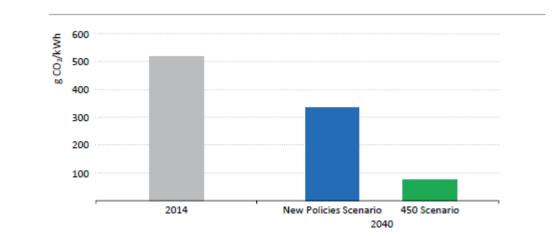


Having said that, in the longer term global warming is the key issue, and things clearly need to change if we are to meet 2 degree target

Energy demand and CO2 emissions in different IEA scenarios



Emissions intensity from power sector

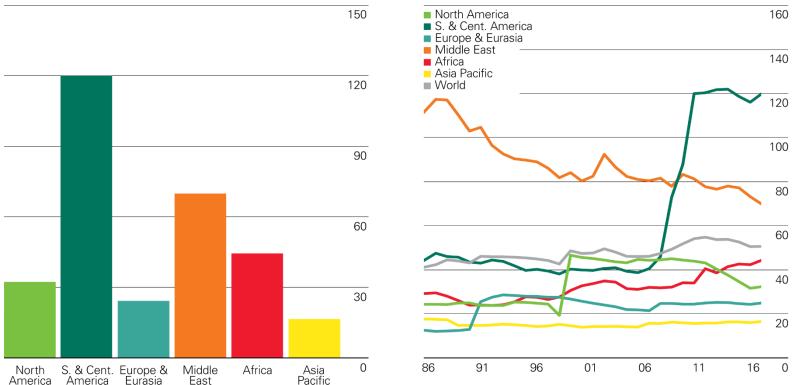




...and renewable output must

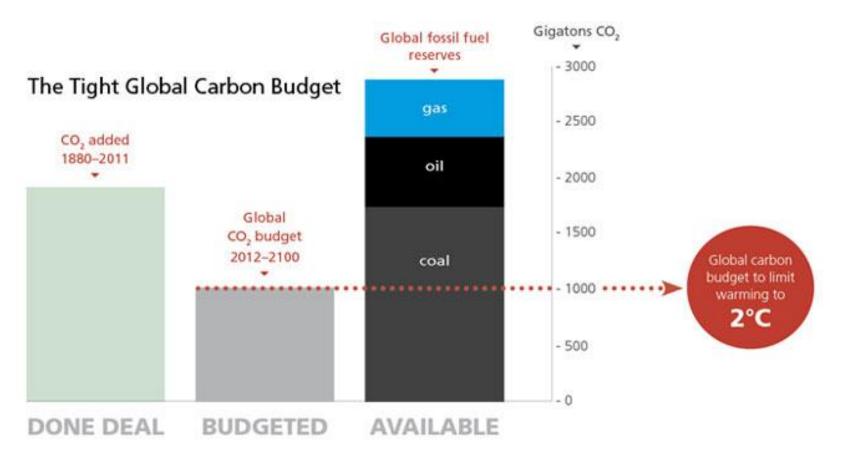
This leaves a vital question for companies / regions with large fossil fuel reserves

Fossil fuels reserves to production ratios (years)



- Coal reserves would last well over 100 years in most regions, while oil and gas reserves have a 50 year reserves life on average
- This assumes that no further exploration is ever carried out
- Will these reserves ever be produced, and perhaps more importantly who can get theirs out of the ground first?

Looking at the global carbon budget, the race is on to produce fossil fuels while you can



- This has vast political and commercial consequences, as countries and companies have to react to a fast changing energy economy
- The futures of Russia and the Middle East are closely bound up to the issue of whether this carbon budget will or can be enforced

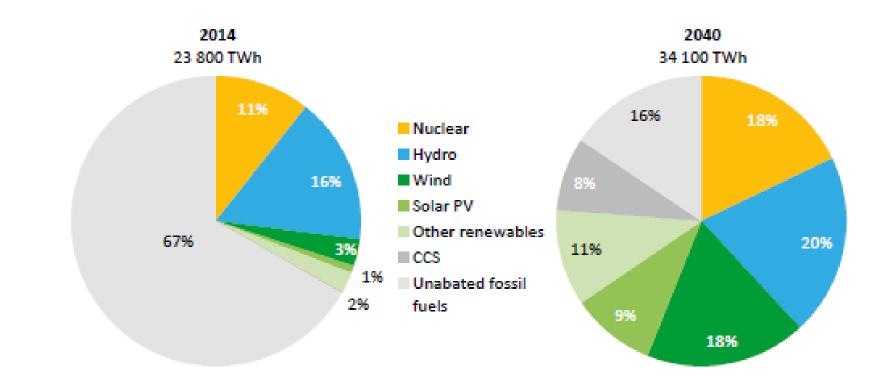
World Energy Demand by Fuel and Scenario

| | | | New Policies | | Current Policies | | 450 Scenario | |
|--------------------------------|---------|--------|--------------|---------|------------------|--------|--------------|--------|
| | 2000 | 2014 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| Coal | 2 316 | 3 926 | 3 955 | (4 140) | 4 361 | 5 327 | 3 175 | 2 000 |
| Oil | 3 669 | 4 266 | 4 577 | 4 775 | 4 751 | 5 402 | 4 169 | 3 326 |
| Gas | 2 071 | 2 893 | 3 390 | (4 313 | 3 508 | 4 718 | 3 292 | 3 301 |
| Nuclear | 676 | 662 | 888 | 1 181 | 865 | 1 032 | 960 | 1 590 |
| Hydro | 225 | 335 | 420 | 536 | 414 | 515 | 429 | 593 |
| Bioenergy* | 1 0 2 6 | 1 421 | 1 633 | 1 883 | 1 619 | 1 834 | 1 733 | 2 310 |
| Other renewables | 60 | 181 | 478 | (1 037) | 420 | 809 | 596 | 1 759 |
| Total | 10 042 | 13 684 | 15 340 | 17 866 | 15 937 | 19 636 | 14 355 | 14 878 |
| Fossil-fuel share | 80% | 81% | 78% | (74%) | 79% | 79% | 74% | 58% |
| CO ₂ emissions (Gt) | 23.0 | 32.2 | 33.6 | 36.3 | 36.0 | 43.7 | 28.9 | 18.4 |

- The outcomes for hydrocarbons are very different in scenarios that look at current likely outcomes versus outcomes needed to meet climate targets
- In a world where we meet the 2 degree target, coal demand would halve from current levels and oil demand would fall by 25%
- However, fossil fuel share would still be 58% in 450 Scenario



Power sector mix in 450 scenario

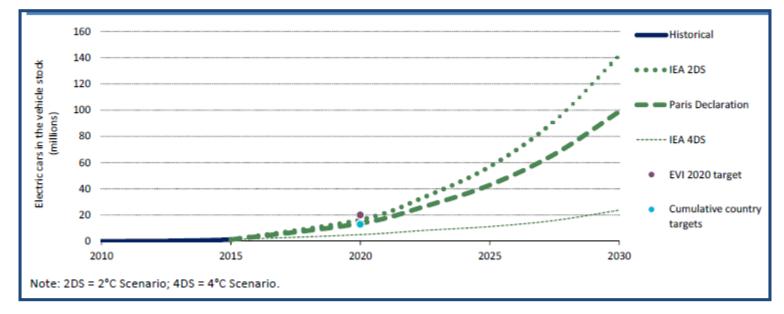


- Radical change is reflected most in the power sector
- Non-fossil fuels would account for 76% of the mix in 2040 in the 450 scenario
- Renewables share would rise from 6% to 37%, with huge implications for the power system and the role of fossil fuels
- Much will depend on how intermittency is managed, with battery technology development a key factor



Change in Transport Sector could also be significant

Electric vehicle scenarios to 2030



- Electric cars currently account for 0.9% of global vehicle fleet (including hybrids
- Various targets have been set for growth over the next 15 years
 - EVI 20 wants 20 million by 2020
 - Paris agreement on electric mobility see 100 million by 2030
 - IEA 2 degree scenario sees requirement for 140 million
 - Current trajectory implies a 4 degree outcome
- At what point can electric cars account for all incremental growth in transport fleet?



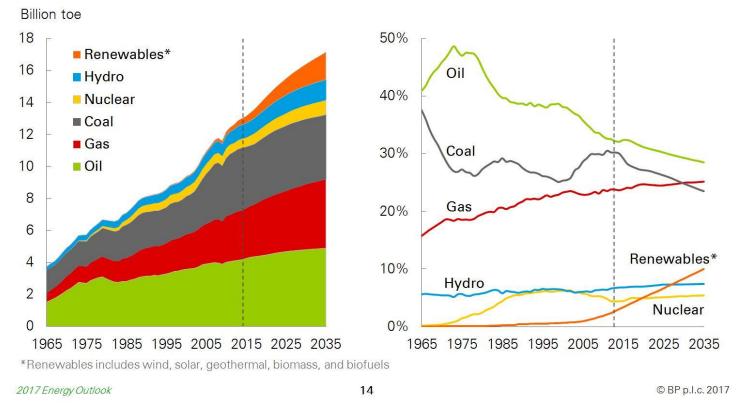
The BP View

The gradual transition in the fuel mix continues...



Primary energy consumption by fuel

Shares of primary energy



 Oil and gas companies show a more balanced outlook, based on the view that policy will not achieve environmental goals

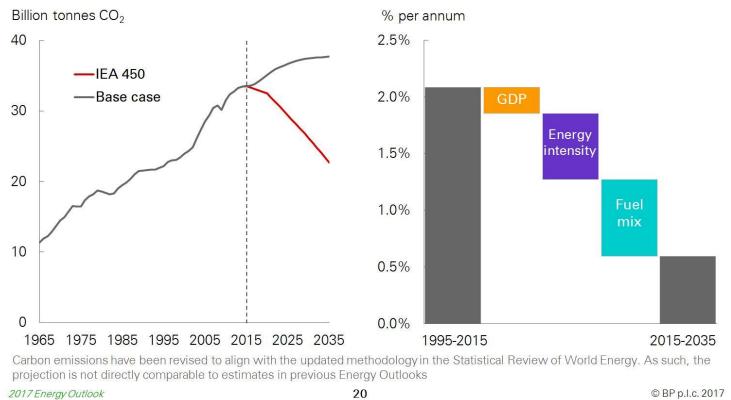
With bad climate consequences

Carbon emissions look set to continue to rise...



Carbon emissions

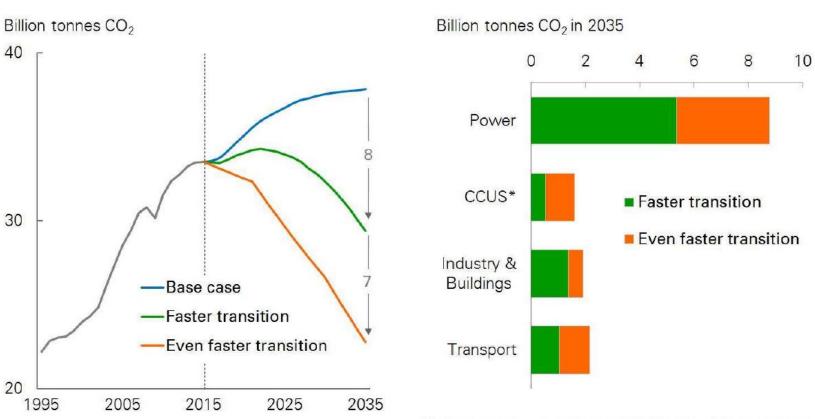
Contributions to slower growth of carbon emissions



 They clearly believe that governments will succumb to commercial pressure and will not have the will to force through change which could have uncomfortable social, political and economic consequences



How aggressive are we going to be on climate change?



Carbon emissions

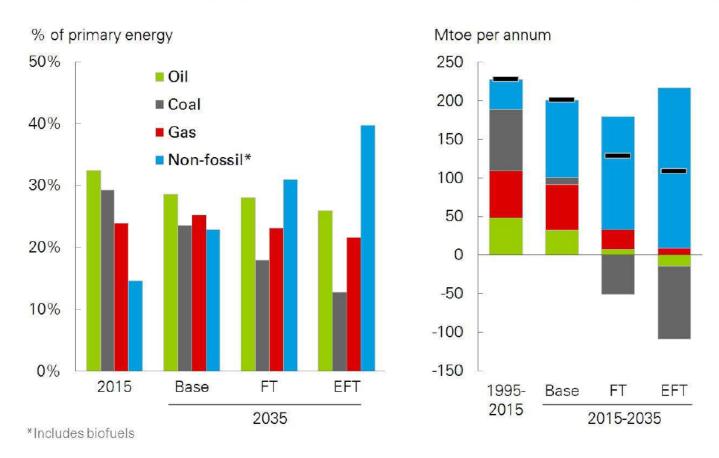
Reductions in emissions versus base case

*Carbon capture, use and storage (predominantly in power sector)

- Most estimates of future energy usage do not meet 2 degree target
- If the world is to avoid excessive warming then measures will need to be taken across all sectors of the economy



Impact of fuel mix of various scenarios



The changing fuel mix

Annual demand growth by fuel

- The future of coal looks bleak if climate targets are to be met
- However, in the long-term oil and gas also face very challenging futures



Non-fossil*

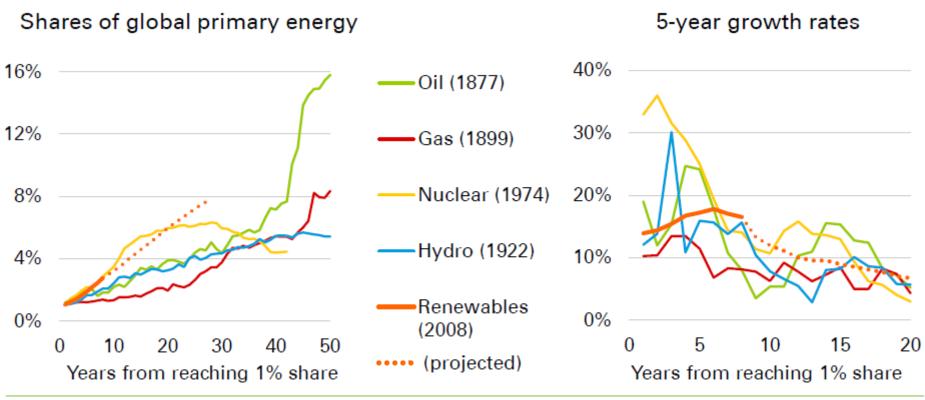
Coal

Gas

Oil

Total

Key question concerns the pace of change – can it be sustained?



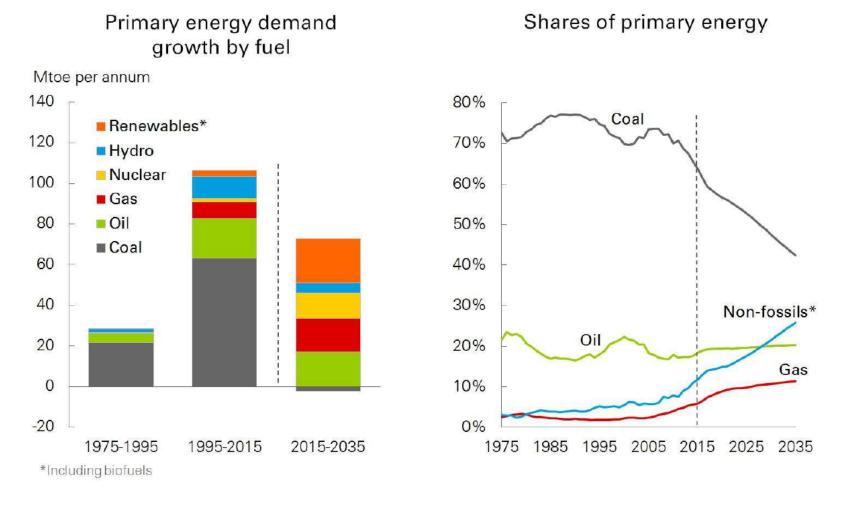
Note: - For sources of data pre-1965 see "Economic development and the demand for energy" by Ruehl et al, Energy Policy, 2012.

BP Statistical Review of World Energy

- A key question is whether transition to a greener energy economy can continue at the rapid initial pace
- History would suggest a slowing in the growth of renewable energy, but the rapid growth of other technologies creates an alternative argument
- Energy companies are currently operating in a world of high uncertainty



The future of Chinese energy demand is key



- Chinese attitudes to energy can shape to world energy landscape
- The speed of shift to non-fossil fuels will be crucial, as will the attitude to energy import security



Capital Spending in the Energy Sector

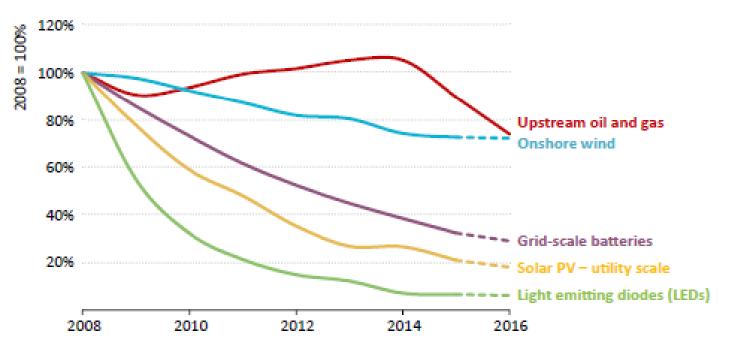
| | 2010-15* | New Po | licies | Current P | olicies | 450 Scenario | |
|----------------------|----------|------------|----------|------------|----------|--------------|----------|
| | Per year | Cumulative | Per year | Cumulative | Per year | Cumulative | Per year |
| Fossil fuels | 1 112 | 26 626 | 1 065 | 32 849 | 1 314 | 17 263 | 691 |
| Renewables | 283 | 7 478 | 299 | 6 130 | 245 | 12 582 | 503 |
| Electricity networks | 229 | 8 059 | 322 | 8 860 | 354 | 7 204 | 288 |
| Other low-carbon** | 13 | 1 446 | 58 | 1 259 | 50 | 2 842 | 114 |
| Total supply | 1 637 | 43 609 | 1 744 | 49 098 | 1 964 | 39 891 | 1 596 |
| Energy efficiency | 221 | 22 980 | 919 | 15 437 | 617 | 35 042 | 1 402 |

* The methodology for energy efficiency investment derives from a baseline of efficiency levels in different end-use sectors in 2014, the annual figure for energy efficiency in this column is the figure only for 2015. ** Includes nuclear and CCS.

- Uncertainty creates a reluctance to invest, but huge amounts of capital will be required to provide energy for a growing population
- Two interesting questions emerge:
 - Will sufficient capital be found to maintain growth in renewables, especially is subsidies start to be removed?
 - Will there be sufficient incentive to invest in the hydrocarbons that will still be needed, if competition drives prices down?
- How much should be left to markets and how might governments intervene?



Cost trends are positive, supporting commercial returns

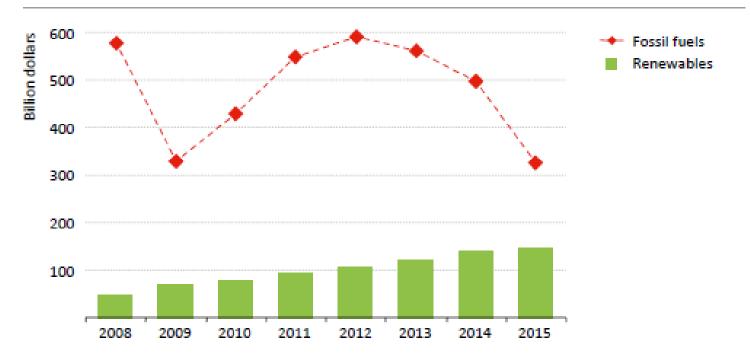


Cost deflation has affected diverse technologies across the energy spectrum

Source: IEA World Energy Investment 2016 (IEA, 2016c).

- Lower oil prices have driven oil and gas costs down
- Innovation and new technologies are reducing renewable costs lower, and battery costs have also fallen fast
- Can these trends be sustained and will full competition in an open market between energy sources ever be the preferred outcome?

Governments have subsidised all forms of energy



The drop in fossil-fuel prices and in the value of subsidies has raised prospects for reform; the fall in technology costs has boosted the effectiveness of subsidies for renewables

- Hydrocarbons have been priced at very low levels in many producing countries, and in developing countries with high levels of poverty
- Renewables have been subsidies via government support, often funded by energy levies
- What government support may/should be required in future?



10 key questions for the Global Energy Economy

- Has the world broken the link between GDP growth, energy demand and CO2 emissions?
- 2. Which fuels and technologies are posed to do well in a post COP21 world?
- 3. Are there limits to the growth of renewable energy?
- 4. What is needed to meet the 2 degree temperature target?
- 5. What can the energy sector do to reduce air pollution?
- 6. Is energy investment capital heading where it is needed?
- 7. How might the main energy security risks evolve?
- 8. Are we on a path to universal access to energy?
- 9. Are global energy subsidies shifting from fossil fuels to renewables?
- 10. How will commercial, political and policy priorities be balanced as the world energy economy develops?

