

CLIMATE CHANGE REALITY AND IMPLICATIONS FOR THE OIL AND GAS INDUSTRY

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Summary

Climate change is now occurring with various influences on the Earth's system, starting from changes in rain patterns, water systems to sea level and many other extreme weather events. The evidences are clear and the governments of many countries have shown solid commitments in the Paris Agreement adopted at the 21st Conference of Parties (COP21) in 2015. Such natural and regulatory changes mean a lot to the oil and gas industry and require immediate actions. This article shows that moving towards natural gas is the right direction that is already happening; but in a longer term, revaluation of assets and investments in renewable energy will even be more beneficial to oil and gas companies in a low-carbon future.

Key words: Climate change, greenhouse gases, oil and gas companies, renewables, risk management.

1. Introduction

The oil and gas industry is experiencing difficult times since the price of crude oil, a benchmark for financial results, has been falling sharply since mid-2014: The lowest value was recorded in early 2016 at USD 28/barrel before the price stabilised at around USD 50/barrel in mid-2016, less than half of the price two years ago [1]. Global economic growth, especially in China and Asia, has not yet been proven to be sustained and still contains downside risks [2]. Most importantly for the long-term operation and development of oil and gas companies: climate change has become a real challenge.

2015 was the hottest year on record, but 2016 is on track to become even hotter by a significant margin. In particular, June 2016 was the hottest June ever for the globe (land and sea), and it is the 14th month in a row that broke the world temperature record, with data dated back to 1880 [3, 4] (The U.S. National Aeronautics and Space Administration - NASA, the U.S. National Oceanic and Atmospheric Administration - NOAA, and the Japan Meteorological Agency - JMA conducted separate measurements, but their figures show similar and consistent trends). Other indirect observations are also alarming: for example, ice in Greenland melted so early and so fast this year that scientists initially thought their data was wrong [5]. Even considering the impacts of El Niño which ends this year, it is obvious that the world is warming and changing. So this article will start with scientific evidences and causes of climate change, before discussing its global impacts and actions by governments and the international community.

After that, specific impacts on the energy sector will be analysed, before concluding with implications for traditional oil and gas companies.

2. Climate change facts and figures

2.1. A short history of climate change

The science of climate and the earth system had a very long history but had not drawn much attention until the term "Climate change" first appeared in a scientific paper by an American scientist in 1975 [6]. During the 1970s, thanks to the development of climate science and technology, especially efforts from governments and the international community, climate change has become an important issue and a part of the agenda for economic-social-environmental discussion. The establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, together with the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the Kyoto Protocol in 1997 and particularly the Paris Agreement at the 21st Conference of Parties (COP21) in 2015 lead to increasing awareness and actions among countries and international companies.

2.2. Evidence and drivers of climate change

To have a big picture about climate change and the role of oil and gas companies, it is necessary to make sure that: (i) the climate is really changing, not just in 2015 or 2016 but in longer periods; (ii) the reasons are mostly human-related; and (iii) oil and gas companies are in the centre of the story.

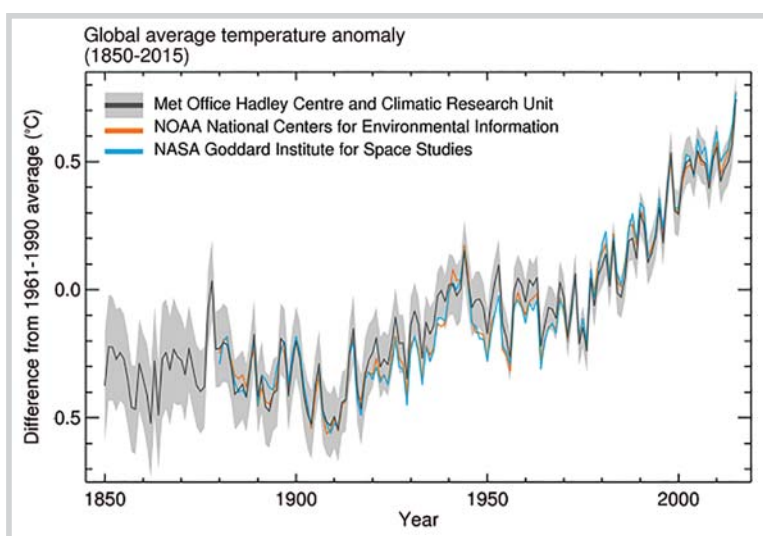
A global surface temperature dataset produced by the MET Office Hadley Centre in collaboration with the University of East Anglia's Climatic Research Unit (CRU) shows that global average land and sea surface temperatures have increased by about 0.9°C since 1850. Despite the differences in the methodologies used, many of the features of this time series are very similar to surface temperature datasets recorded by the National Aeronautics and Space Administration's Goddard Institute for Space Studies (NASA GISS) and the National Oceanic and Atmospheric Administration - National Climatic Data Centre (NOAA) (Figure 1). Indirect estimates of temperature change from sources such as tree rings and ice cores also indicate that 1983 - 2012 was probably the warmest 30-year period in more than 800 years [7].

Although climate system, temperature in particular, is always changing naturally from year to year and from decade to decade in the early part of the 20th century (Figure 1), these anomaly variations are mostly due to natural causes. For examples, the noticeable warm spikes in the temperature series, such as those in the late 1870s and in 1998, show the influence of El Niño events on global temperature trends; and La Niña events in 1999 - 2000 and 2008 are marked by two brief dips in global temperature. These events are expected to recur every three to eight years. On the other hand, temporary cooling of the Earth's surface is associated with large tropical volcanic eruptions, with the largest effects come from Mt. Agung in 1963 and Mt. Pinatubo in 1991 [8]. However, these short-term variations do not contradict the long-term warming trend as scientists, by studying many different types of climate variations, have concluded that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations [9].

Besides the temperature records, the dramatic decrease in the extent of Arctic sea

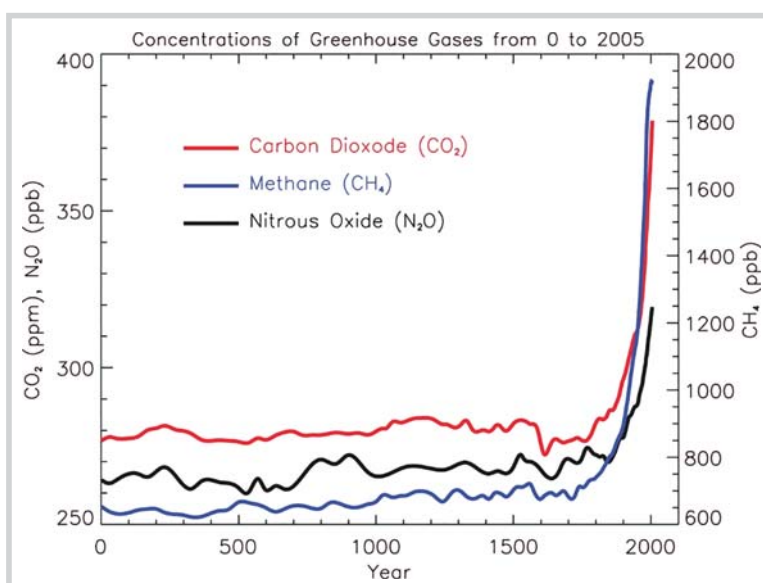
ice is another observational evidence that climate is changing. Ice extent in the North Pole in March 2016 has reached a record low in 13 years for wintertime maximum level [10]. Decreases in Arctic sea ice extent are demonstrated to be much greater than increases in the Antarctic (South Pole). Together with increasing ocean temperature, this has led to the increasing rate of sea level rises, especially in the past decade [11].

Global warming can be simply explained by the "Greenhouse Effect". This process can happen naturally by the effect of atmospheric gases such as water vapour, carbon dioxide, methane and nitrous oxide (e.g. greenhouse gases) absorbing energy from the sun and trapping it within the atmosphere, making the Earth's temperature hospitable for life. However, human activities, primarily fossil fuel burnings and



Source: Met Office UK (Last updated: 13rd May 2016)

Figure 1. Global average temperature anomaly (1850 - 2015)



Source: IPCC, 2007

Figure 2. Atmospheric concentrations of important long-lived greenhouse gases

land use changes, have greatly intensified the natural greenhouse effect and are considered the main driver of observed climate change and increasing average Earth's temperature since the mid-20th century [12].

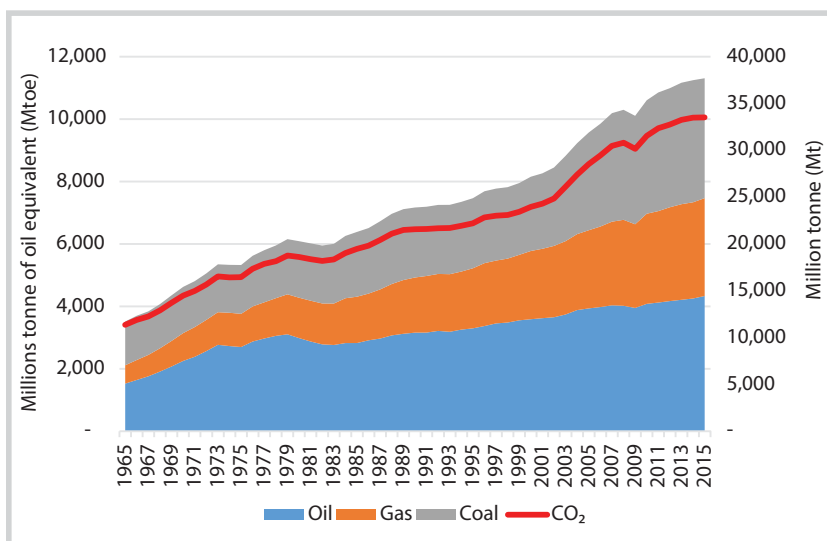
Since 1750, increases have been attributed to the emissions of four principle greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and the halocarbons (a group of gases containing fluorine, chlorine and bromine) caused by human activities in the industrial era (Figure 2); with the largest known contribution coming from the burning of fossil fuels [12]. Although water vapour (H₂O) is the most abundant and important greenhouse gas in the atmosphere, human activities have only a small direct influence on the amount of atmospheric water vapour. Being the second-most important greenhouse gas, CO₂ becomes the standard measure of climate change for the public.

Prior to the pre-industrial time, the atmospheric mixing ratio of CO₂ remained relatively steady between 260 and 285ppm. Because of anthropogenic emissions, atmospheric CO₂ has climbed to levels that are presently 36% higher (approximately 100ppm) than before the industrial revolution [13]. Since 1750, the concentration of CO₂ in the atmosphere has gradually risen, to nearly 390ppm in 2005 (Figure 2). During this period, the absolute growth rate of CO₂ in the atmosphere also increased substantially. Disruption of the carbon cycle by human activities primarily comes from burning of fossil fuels and deforestation, and also cement production and other changes in land use and management such as biomass burning, crop production and conversion of grasslands to croplands [12]. Figure 3 shows that the global acceleration of CO₂ emissions mainly reflects the world's fossil energy consumption. Over the last 50 years, total consumption of oil, gas and coal has approximately tripled, from 4,623 million tons of oil equivalent (Mtoe) in 1970 to 11,306Mtoe in 2015, equivalent to an increase of roughly 20,000Mt in atmospheric CO₂ concentration. Fossil fuel combustion is responsible for almost 75% of anthropogenic CO₂ emissions [12].

Despite being in relatively smaller abundances compared to CO₂, CH₄ and N₂O are demonstrated to be initially far more devastating to the climate because of their greater ability to absorb radiation [14]. In fact, over a 100-year period, the comparative impact of CH₄ on climate change is more than 25 times greater than CO₂ and that of N₂O is approximately 300 times greater compared to CO₂ [15]. Methane is the primary component of natural gas and also an important greenhouse gas that is currently contributing to about 15% of global anthropogenic greenhouse gas emission every year [12]. Methane is emitted to the atmosphere from a variety of natural and anthropogenic sources [16]. Among the anthropogenic sources, the oil and gas industry is considered one of the main contributors, accounting for 63Tg CH₄ per year [17]. The link between the operation and transportation in the gas industry and CH₄ emissions will be discussed in more details later in this article.

3. Climate change - impacts and actions

Climate change has been affecting many countries and regions in the past decades. Weather extremes, such as heat waves, droughts, and floods, etc, have become more frequent and unpredictable; changes in the rain pattern and the melting of ice/snow have already affected water resources; consequently, water and marine species have migrated differently, while crops in many places have been adversely affected [18]. While it is not obvious to identify and separate the current impacts of climate change alone, it is even more difficult to forecast the impacts in the future - which will be uncertain due to both the complexity of climate science and possible responses of governments, companies, and the people. Therefore, an approach to



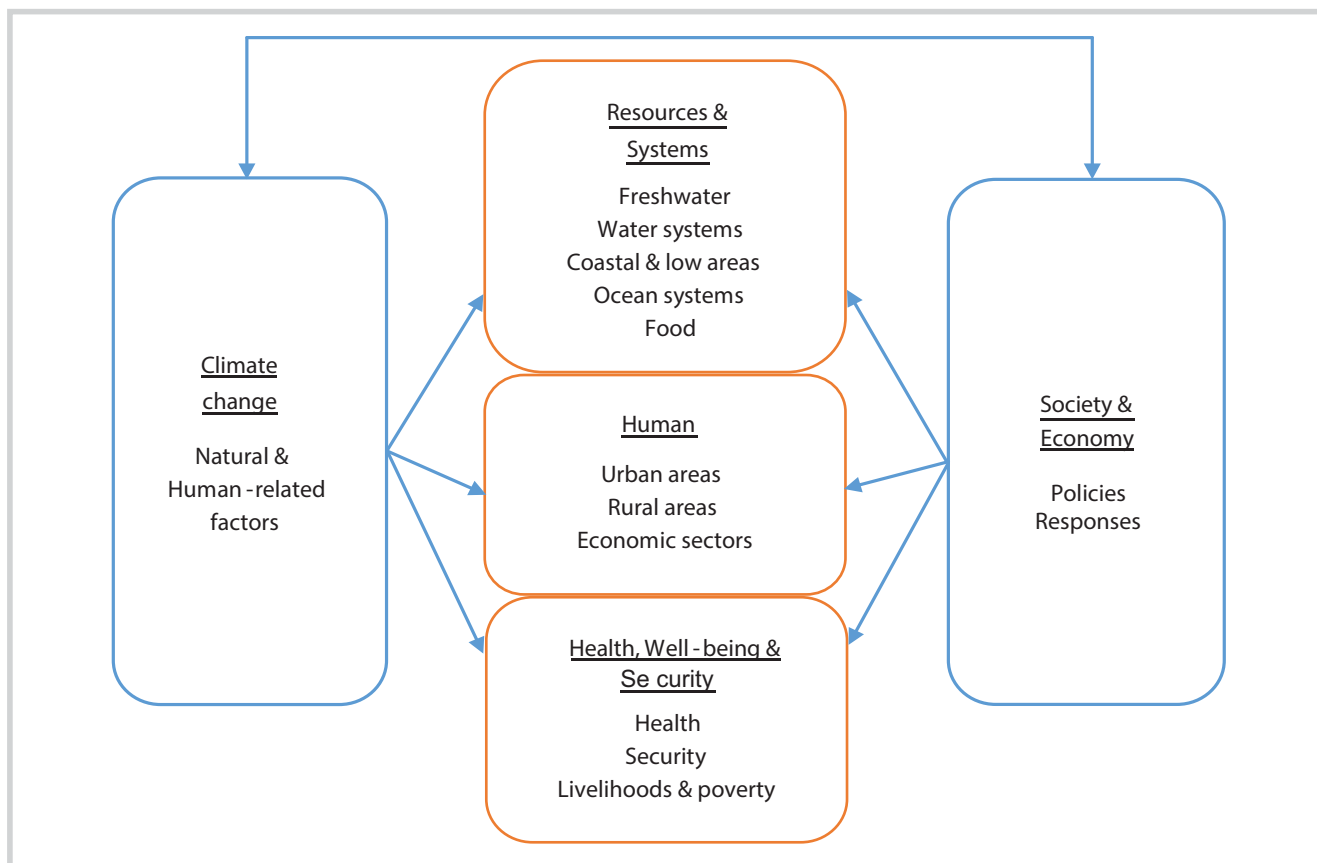
Source: BP
Figure 3. World fossil fuel consumption and CO₂ emissions (1965 - 2015)

identify the general impacts of climate change (Figure 4) will include interaction with the society & economy - whether the actions of the governments, companies, and people can improve or degrade climate conditions. Then, climate change (by both natural and human-related factors) will impact on three major categories: (i) natural or managed resources and systems from water to low-lying lands, species and food supply; (ii) human living in urban or rural areas and a variety of economic sectors; and (iii) human's health, security and poverty.

Based on this approach, it can be seen that the impacts on the oil and gas/energy sector will come from both climate change per se, and from the policy and actions of governments, companies and people. Furthermore, due to the role of energy in almost every aspect of the economy and society, there will be indirect influence from other sectors/issues on energy usage that should be taken into account. While different scenarios for the energy sector will be discussed in Section 4 below, an overall approach to analyse climate change impacts on the energy sector is shown in Figure 5. Climate change and our actions might affect: (i) energy demand, notably

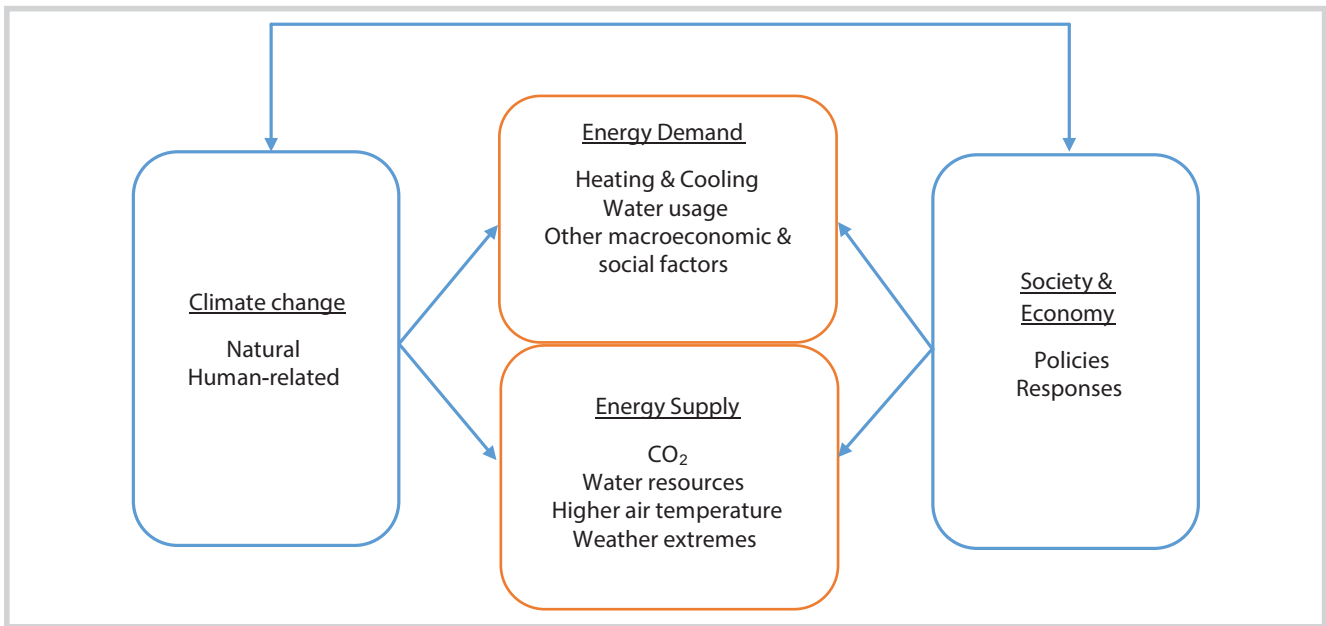
heating and cooling requirements, as well as water, besides other indirect impacts from income, urban and rural living changes; and (ii) energy supply - not only the issue with CO₂ reduction, but also consequences from higher operating temperature, as well as from weather extremes like storms, floods, and hurricanes.

So what have international organisations and governments done about climate change? Their actions will be the key in setting the rules and ground for various stakeholders to behave in the coming decades, especially for energy companies. International efforts to tackle environmental issues started in 1979 at the first World Climate Conference, but only after the setup of the IPCC in 1988, the UNFCCC in 1992, the first Conference of the Parties (COP1) in Berlin in 1995, and especially the Kyoto Protocol in 1997, that concrete results were achieved. The Kyoto Protocol was a binding agreement for 37 industrial countries and the European Community, committing to reduce greenhouse gas emissions through the market mechanism. One outcome was international emissions trading, including the "cap and trade" scheme in the EU (however with limited success on pricing carbon [19]). The



Source: IPCC and compiled by authors

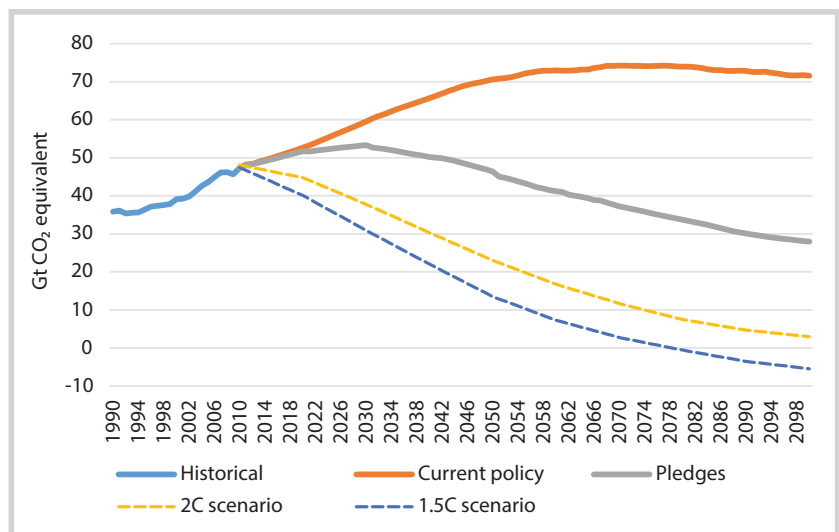
Figure 4. General impacts of climate change on the world



Source: IPCC and compiled by authors
Figure 5. General impacts of climate change on the energy sector

Doha Amendment at COP18 extends the Kyoto commitments from 2012 to 2020, setting the ground for the story of the Paris Agreement at COP21 in 2015.

But the Paris Agreement in 2015 is different and truly a milestone in tackling climate change that all parties, including energy companies, need to pay attention. Legally binding for all 196 parties, the Agreement will start in 2020 and aim to control the temperature increase well below 2°C (with 1.5°C the target) compared with pre-industrial (1850 - 1900) level. This might be a challenging target as seen in Figure 6. Current pledges of countries at Paris COP21, though much better than current policies, are not enough to sufficiently cut CO₂ to limit temperature increase by 2°C, not to mention 1.5°C. But the Agreement is designed to be flexible to make improvements overtime while ensuring the participation of all parties. Specifically, countries will make their own nationally determined contributions (NDC or pledges) for each period and are open to achieve such national targets. But this “soft” and

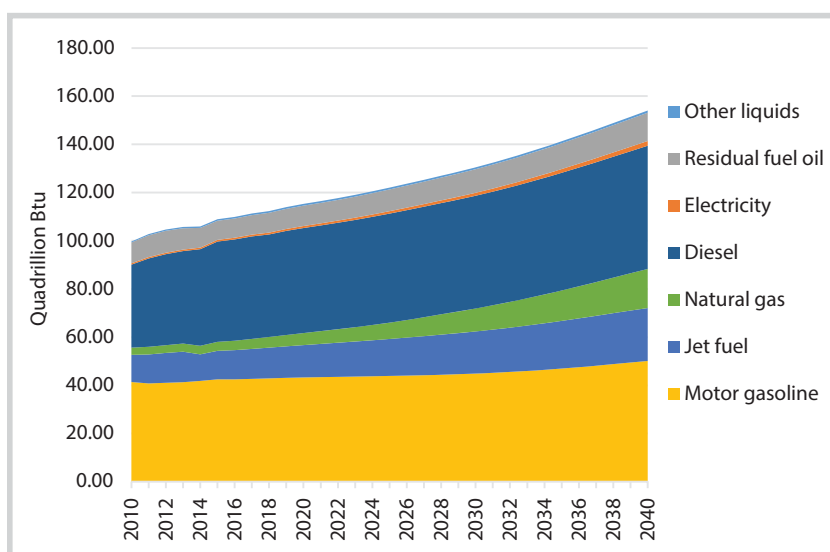


Source: Climate action tracker
Figure 6. CO₂ emission scenarios (2010 - 2100)

“national” enforcement mechanism includes other incentives (even some form of trade sanction) to hopefully make it work better than the “strict” but “international” form in the Kyoto Protocol. Besides, Paris Agreement 2015, for the first time, signals common perspectives of the two largest emitters - the United States and China. This is adequately significant to create more confidence in policy changes across the world [20].

4. Impacts and implications for oil and gas/energy companies

As mentioned above, the interaction between climate change itself and various policy pathways in the future will make it difficult to quantify the impacts of climate change in the oil and gas industry as well as the whole energy sector. Besides, the current research focuses more on energy



Source: EIA

Figure 7. World transport sector delivered energy consumption (2012 - 2040)

demand, while energy supply and especially energy price also need further studies [18]. Therefore, this section will look at various impacts and scenarios for the energy sector up to 2040, rather than focusing on projected figures up to 2100 as for the climate science. The approach presented in Section 3 will be used, while other key themes for the energy sector in the coming decades will be discussed in the context of climate change.

4.1. Energy demand

4.1.1. Heating and cooling

The most obvious impact of climate change is that temperature is generally increasing, leading to more energy demand for cooling and less for heating. The specific outcome will depend on some other factors such as geographic location, heating/cooling appliances, and income. The biggest increase in demand for cooling will happen in low-income countries in warm weather, especially when better income over time leads to more air conditioner usage. Demand for cooling in summer in high-income countries also goes up, resulting in total electricity demand of 4,000TWh in 2050 for residential air conditioning (up from 300TWh in 2000), 25% of which is due to climate change [21]. On the other hand, heating requirements are overall smaller in winter. This makes the net change in demand for the world might be relatively modest. But the net change can be much higher in regions like South Asia - where cooling demand in summer will be much bigger than heating demand in winter due to increasing temperature, which will be challenging for the power sector to meet the peak load at specific times of the day.

4.1.2. Water usage

Climate change will have a huge impact on water system and water resources. The normal cycle of evaporation and precipitation (rain) will be distorted, as warmer weather leads to higher rate of evaporation, and higher capacity of the atmosphere to "hold" water. As a result, many places will be

drier, while other places will face heavier precipitation (though the total rain fall can be smaller). Besides, hotter weather means people and animals need more water to stay healthy, and food crops need more water to be grown. Not to mention competition for water from other sectors (like energy supply), it will be very challenging to provide enough clean water to the world's population, which is constantly exploding. More energy will be needed to find, purify and bring water to the right users in the right places in the near future. For example, the recent drought in Asia has led to a sharp rise in diesel consumption for agricultural irrigation, and the revival of premium for diesel price in 2016 [22]. However, further study in the area of energy and water under climate change will need to be conducted.

4.1.3. Transportation

Since petroleum and other liquid fuels are the dominant sources of transportation energy, the transport sector has always been the second largest contributor to greenhouse gases emissions since 1970. According to International Energy Outlook 2016, energy consumption in the transport sector is expected to increase at an annual average of 1.4% during the projection period of 2012 - 2040, with motor gasoline and diesel being the largest transportation fuel (Figure 7). With efforts to reduce greenhouse gas emissions, the use of natural gas will increase by 11% but still not yet replace the dominance of petroleum and other liquid fuels.

From a few hundred in 2005, the number of electric cars rose to over 700,000 and hit 1.26 million in 2016 - after increasing by 70% in 2014 - 2015 [23]. The biggest markets are now China, the United States, the Netherlands, and Norway; and top producers including

Tesla, Chevy, and Nissan. The Paris Declaration on Electro-Mobility and Climate Change and Call to Action (announced at COP21) aims for 100 million electric cars by 2030; while to achieve the 2°C scenario, IEA estimates about 140 million cars by 2030 will be needed [23]. Such ambitious plan will require various factors: such as governments' support (price, infrastructure), consumers' acceptance (price, fuelling/charging habit), and crucially - lower battery costs. The last factor has been happening in the past few years, with cost decreasing from USD 1,000/kWh in 2008 to USD 268/kWh in 2015, or 73% in 7 years. It is estimated that battery cost can fall to about USD 125/kWh by 2030, a level that makes electric car cost-competitive with conventional engine types [23].

So what will be the impact for oil demand? There have been various projected figures. BNEF [24] claims that 45% annual growth of electric car sales (compared with 70% growth in 2015) will displace about 2 million barrels of oil per day in 2028 - more than the supply surplus that pushed oil price to record low in 2015. Another report [25] forecasts that if climate change commitment can be successfully implemented (CO₂ concentration less than 450ppm), it will make oil demand in 2028 lower than today. Even with moderate success, climate change policy will make oil demand flat around 2028, and be lower in 2040 - compared to today. These figures can even be lower if the trend in car sharing - or mobility as a service (not necessarily owning a car), continues in the future [26]. This all means a lot of work for oil and gas companies in the coming one or two decades.

4.2. Energy supply

4.2.1. CO₂ emission limit

An ambitious plan to cut CO₂ emissions means the energy supply mix, especially for power generation, will change significantly. High-carbon fuel like coal and oil will face difficulties in terms of environmental regulations and price competitiveness - given possibly higher price for carbon and the rise of alternative and renewable energy. Coal-fired power plants growth will come to an end, except for India; and the fuel to replace coal and dominate power generation in the first half of this century will be natural gas with its share hitting 24% in 2030 under the IEA's Bridge Scenario (a medium case between the current pledges by countries and the CO₂-450-ppm scenario to meet 2°C). Notably, renewables (excluding hydro) expand quickly and contribute 19% to power generation in 2030, with wind being the largest (9%) and solar the fastest-

growing (4% of power generation mix) [27]. Projections from Wood Mackenzie [28] also show a similar trend for renewables, with share in the power sector over 20% by 2035. The drive for solar expansion again has been fast falling cost. Up-front project cost for solar in the United States has dropped from 6.3cents/W in 2009 to 3.1cents/W in 2014 (with some as low as 2cents/W). This results in power sale agreements at just 5cents/W in 2014 [29]. So solar costs have cut more than half since 2009, and together with more efficient operation (utility-scale capacity factor up from about 25% in 2012 to 29.4% in 2014), solar is expected to expand quickly in China, India, and Australia besides the United States and Europe. Wood Mackenzie even considers solar the new shale for the energy sector [30].

4.2.2. Water resources

The impact of climate change on water resources and power generation is quite complex. For thermal power plants, the possibility of reduced water sources and somewhat warmer water used for cooling will result in less electricity output, with load reduction from 0.1 to 5.6%. The impact for hydropower is even more complicated, with more or less water for different regions, changing the rain patterns during the year, and different flood control by the authorities because of climate change. In general, it is expected that climate change will bring positive effects (higher generation) to hydropower in Asia, while negative effects to that in Europe [18]. Again, the interaction between water and energy is a big issue especially under the climate change context and requires further studies.

4.2.3. Higher temperatures and weather extremes

Another impact of climate change on the supply and transmission of electricity is reduced operating efficiency due to higher air temperature. This will mostly impact current power plants with older technology, and the economic costs might not be very significant. On the other hand, weather extremes like hurricanes, storms, high wind, heavy rains, and floods can cause severe damages to the production and transportation of energy. One example is the destruction of the Fukushima Daiichi nuclear power plant after an earthquake and the subsequent tsunami in March 2011, resulting in massive radioactive contamination of the Japanese mainland. Such low probability but severe-consequence event will need more research in both climate/earth science and technical solutions. Weather extremes can also have

impacts on the safety and operation of the pipelines and electricity grid, requiring better design and construction standards in the future.

4.3. Implications for energy companies

The many sides of climate change and its impacts mean there are winners and losers in the energy business in the future. Obviously, traditional oil and gas companies - who owns upstream and downstream petroleum assets - will face the biggest challenges. Renewables companies - who invest in wind, solar and biomass - seem to be on the right side of the road, though their business models are yet to mature. Utilities companies - who buy and sell electricity - will face different risks, and have to choose the appropriate generation mix, given technical, economic and regulatory constraints. There are winners and losers due to their geographic locations as well, as for hydropower plants. So this section will look at the most talked about stakeholders - a traditional oil and gas company, with some exposure mentioned above.

4.3.1. Less oil, more gas

The pressure for oil is obvious, not only due to its high-carbon content but also the changing nature of transportation. Oil and gas companies now actually emphasise more on the second part of their name - natural gas. The mega deal recently is Shell's acquisition of BG to own natural gas assets in Australia and become the biggest LNG trader [31]. This is what McKinsey called Big Oil becoming Big Gas [32]. Other companies also take actions to show their favour for the cleanest fossil fuel. Specifically, in time with the Paris COP21, ten of the world big oil companies formed a group called the Oil and Gas Climate Initiative^(*) to confirm their support for climate change targets (though no specific plan or commitments were made). One of their key actions is moving towards gas, with emphasis on safe and sound operation to limit methane (CH₄) emissions. This is also in line with the latest effort by the United States to have for the first time a regulation on methane [33] - requiring companies to stop methane leaks from new and modified drilling wells and storage tanks. Although efforts to reduce greenhouse gas emissions require significant investment, reduction projects that target methane present a unique opportunity by capturing and using it as a source of energy. It is indicated that by only focusing on reducing methane emissions from oil and natural

gas operations, the industry can benefit from increased revenues, enhanced operational efficiency and improved environmental performances [34]. All these developments show that natural gas will be the dominant product of traditional oil and gas companies.

4.3.2. Managing the money

The slide of oil price since mid-2014 might be a good practice for oil and gas companies to transit to a low-carbon economy. Price forecast is always difficult and uncertain, but the old hypothesis that oil price will generally go up because reserves are exhausted and the remaining ones are more difficult and costly to find/produce seems to be out of date now [35]. The shale story from the United States has shaken the oil industry and the used-to-be-powerful OPEC. But climate change commitments and renewable technology are really the long-term trend that affect oil consumption, change oil producers' behaviours, and make oil not the fuel that the world must exhaust to run itself. Besides the cyclical ups and downs of the industry, oil price will be relatively lower for longer. Managing the money received and continuing cost optimisation will be the key for upstream companies. This is not to mention the difficulty in funding fossil fuel investment, triggered by campaign for divestment from coal or oil and gas companies. The campaign includes well-known figures in the industry like the Norway's sovereign wealth fund and the Rockefeller Family Fund [36]. Long-term outcomes to be seen, but oil and gas company must be prepared to reassess their financing options under climate change.

In relation with investment and financing, there is a more popular theme that involves lots of debate at the moment: stranded assets or unburnable carbon. The governor of the Bank of England [37] made headlines in 2015 when publicly warned about the risk that fossil fuel companies' assets could be left "stranded" because of climate change. This means huge corrections in oil and gas companies' valuation, shifts in investment, changes in credit ratings, and possibly other financial market instability due to the size of such companies. This is a big topic and requires further studies, but at least oil and gas companies have to reassess their reserves and other assets in the light of climate change, within the right time horizon. Possibly then, National Oil Companies (rather than International Oil Companies) with reserve/production ratio over 30 years will need to be more prepared [38].

^(*) Current members include BP, CNPC, Eni, Pemex, Reliance Industries, Repsol, Saudi Aramco, Shell, Statoil, Total - none of which are US companies (www.oilandgasclimateinitiative.com)

4.3.3. Into renewables

Perhaps the best answer to climate change is switching to renewables. Some oil and gas companies have already done this: Shell recently put USD 1.7 billion into its New Energies division to cover many areas from wind power, biofuel to hydrogen [39]; while Total pushed even further, buying battery manufacturer Saft for USD 1.1 billion, after already investing USD 1.4 billion in SunPower - one of the largest solar companies in the United States [40]. Such strategies will give traditional oil and gas companies the exposure with the fast-changing renewable energy industry but it should be noted that the distributed/ decentralised nature of renewables will be very different to the centralised feature of the oil and gas industry [38].

5. Conclusions

Climate change has become a risk, rather than something uncertain, for the world. Its impacts are wide-ranging and dependent on the responses of governments, companies, and people. For the energy sector, climate change will bring direct impacts for demand and supply, in key areas such as air temperature, water usage, and weather extremes. But more importantly, climate change has led to new regulations, changes in economics and finance of the oil and gas industry, that related companies must be prepared and take actions. The move to natural gas is happening and looks like the right direction in the medium term. But more efficient management of cash flow from traditional oil and gas business, timely revaluation of such assets, and move into renewable energy will be the solutions for the long-term.

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