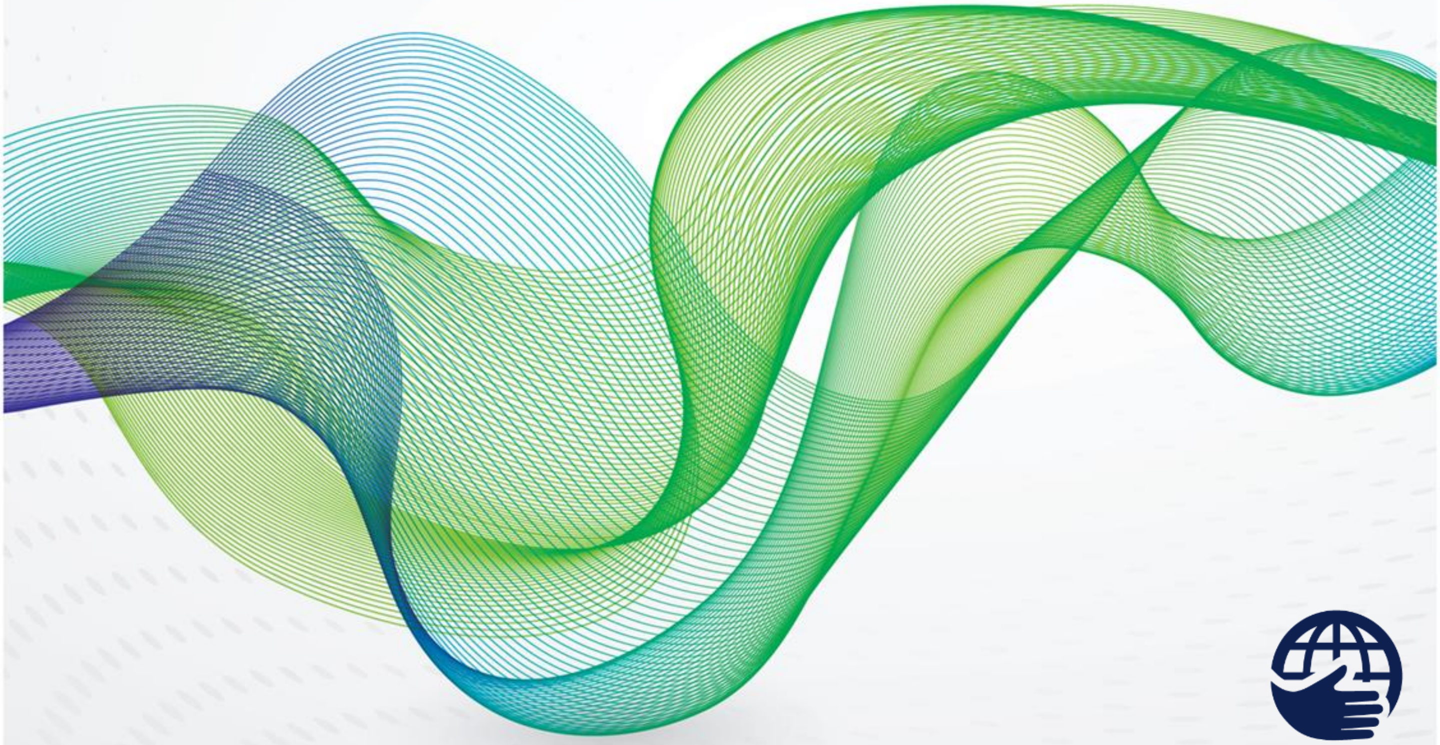
THE OXFORD INSTITUTE FOR ENERGY STUDIES

September 2021

The Energy Transition:

Key challenges for incumbent and new players in the global energy system



Energy Transition

OIES Paper: ET:01

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ISBN 978-1-78467-181-5

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Introduction

The IPCC report on climate change published in August 2021 has provided a stark reminder that human activity is unequivocally responsible for global warming and changing environmental conditions on Earth.[1] Having said this, the growing commitment of governments and companies across the world to net zero emissions targets is both an encouraging sign that the reality of the world's climate crisis is now being understood while also being a sharp reminder that actions, not just words, will be needed if the rise in global temperatures is to be limited to 1.5^{o} C this century. A number of institutions have produced detailed analyses of various pathways to achieve this goal, with the most recent being the IEA's "Net Zero by 2050" report. Although the IEA analysis only presented one potential pathway to achieve the net zero goal, it highlighted the more general point that the next three decades will require substantial emissions reduction and/or removal which will in turn require unparalleled levels of investment and international cooperation, as it is the "greatest challenge of our times [and requires] nothing short of a total transformation of the energy systems that underpin our economies."[2]

For some energy companies this creates an existential threat, although opportunities will also emerge based on technological innovation and new business development. One of the key drivers of the energy transition is the electrification of the energy system, powered as far as possible by renewable energy sources, and it is to the elecricity sector that we can look both for historical precedent as well as guidelines for the future. Electricity companies, particularly in Europe and the US, have been facing the transformational challenges of the energy transition for the past decade as the rapid increase in the supply of renewable power, catalysed by government policy and support, has radically changed the economics of the sector as well as its operational dynamics. For instance, the interaction between intermittent and dispatchable sources of power has necessitated greater system flexibility, storage, and demand side management, as well as a greater focus on the consumer as a buyer and seller of energy.[3] The transformation of the electricity sector has had negative financial consequences for many companies as their business models have been "turned upside down"[4], but it has also allowed new players to emerge and different strategies and business models to be developed, based on greater innovation and consumer engagement.

Radical change of a similar magnitude is now facing producers (and consumers) of the hydrocarbons which currently make up more than 80 per cent of the world's total primary energy supply.[5] The challenge of declining demand for hydrocarbon products will be combined with the increasing importance of consumer interaction, system-balancing, energy storage, sector coupling, and the development of a circular economy,[6] with accompanying behavioural change, as well as the more immediate task of abating carbon emissions from the hydrocarbon value chain.[7] This paper attempts to synthesize the key challenges and consequences of the energy transition both for incumbent actors and new entrants, and for the countries in which they operate. While the overall goal of the energy transition is clear, the pathways to efficient decarbonisation are not obvious, and could be varied, based on different contexts. We therefore aim to conceptualise a framework upon which further research can be undertaken on these pathways, and analyse the key consequences of them for the overall energy system.

Acknowledgements: The authors are very grateful to a number of reviewers for commenting on previous drafts of this paper. Any remaining errors are our own.

[1] IPCC (2021).

[2] IEA, Net Zero by 2050 (2021), p.3

[3] Keay, M. (2020)

[4] Robinson, D. (2015)

[5] BP Statistical Review of World Energy (2021), p.11

[6] Sen, A. (2021)

[7] Oxford Energy Forum Issue No. 120 (March 2020)

The paper is structured as follows. Section 1 provides the overall context of the need for a rapid energy transition, and highlights some key initial conclusions from scenario analysis presented by various institutions over the past few years. Section 2 then addresses a number of key issues in the energy transition. It starts with the key drivers of policy and regulation, before highlighting the vital role that technology could play in developing solutions and reducing costs. The potential impact on the value chain is then analysed, looking at the future of networks, the consequences for and interactions with consumers, and the impact on corporate business models. We then consider the evolution and development of markets, both for existing and future energy products, before looking at the changes from the perspectives of different regions and sectors, acknowledging that many countries and industries are embarking on the energy transition from very different starting points and that any attempts to reach a global consensus must take this into account in order to provide a "just and inclusive transition". We then consider the consequences of the adjustments to the global energy economy on geopolitics and energy security, following which Section 3 summarises and concludes. Finally we include a bibliography, including many OIES papers on energy transition issues, which we hope will be of use to readers with a deeper interest in the various topics.

1. The Energy Supply Context

Scientific analysis of the impact of human behaviour on the global environment since the start of the industrial revolution in the mid-19th century, and in particular over the past 75 years since 1945, has established that the growth in emissions of CO_2 and other gases with global warming potential has led, and is leading, to a rapid increase in global temperatures.[8] Since the pre-industrial period, human activity has contributed to an increase in the Earth's global average temperature of around 1 degree Celsius; however, this growth is accelerating and it is estimated that the world is currently warming by around 0.2 degrees per decade.[9] The impact of this level of warming would be dramatic in terms of rising sea levels, increased frequency of major weather events (storms, droughts, floods etc.) and the disruption to human activity resulting from the potential destruction of habitats (including whole cities and low-lying countries). As a result, a global response to what has been called the "climate emergency" is being coordinated by the UN under the auspices of the UNFCCC (United Nations Framework Convention on Climate Change) and in coordination with the IPCC (Intergovernmental Panel on Climate Change), with the former organising a series of conventions (COPs)[10] which gather all member countries together to review data, set targets, and make key decisions on the coordination of a global reaction to climate change. Arguably the most important of these was COP21, held in Paris in 2015, which saw countries setting voluntary emissions targets (Nationally Determined Contributions or NDCs) that would limit global warming to a maximum of 2 degrees above pre-industrial levels by 2050, with a stretch goal of 1.5 degrees. This latter target was then reiterated at COP24 following a report on the impact of 1.5 degree warming by the IPCC, confirming the global commitment towards decarbonising the energy economy.[11] COP26, to be held in Glasgow in November 2021, will review progress to date, re-commit countries to confirming new targets and implementing promises and encourage the use of post-coronavirus fiscal packages to stimulate a "green recovery."[12] Much of the focus will be on the energy sector, which currently accounts for just under 75 per cent of greenhouse gas (GHG) emissions, generated from the burning of hydrocarbons in the power, industry, transport, and heat sectors.[13] As a result, the decarbonisation of the energy sector is the most urgent priority, in particular because at the current rate of GHG emissions the world's total remaining "carbon budget" to meet the 1.5^o increase in

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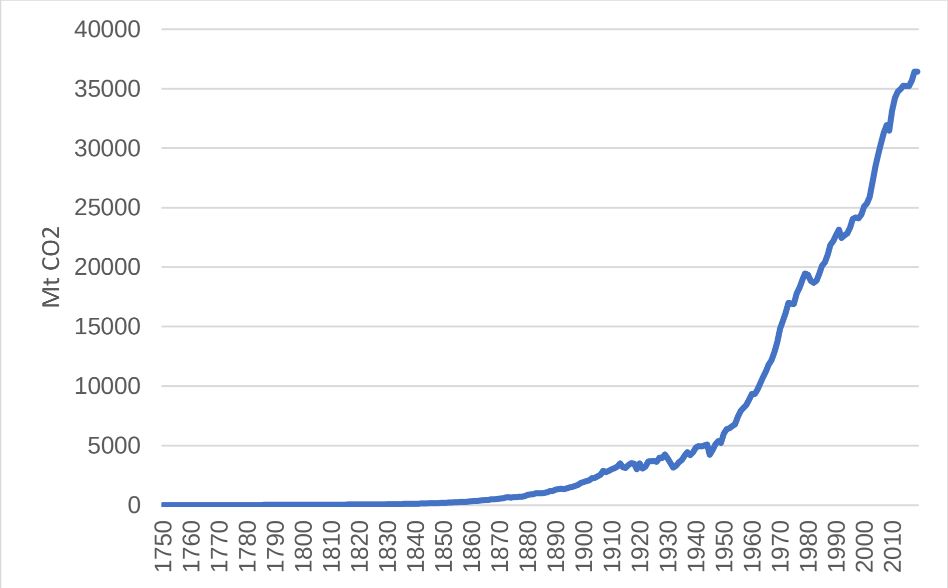
[8] IPCC (2021)
[9] https://climate.nasa.gov/resources/global-warming-vs-climate-change/
[10] Conference of the Parties
[11] Rogelj et al. (2018)
[12] https://ukcop26.org/uk-presidency/
[13] Climate Watch, the World Resources Institute, 2020

global temperature target would be used up in only around 17 years.[14] As there is already almost five times this amount of carbon in existing global reserves of coal, oil, and gas,[15] radical steps clearly need to be taken both to decarbonise the existing energy system and to introduce new carbon-free sources of energy.

Figure 1: Anthropogenic emissions of CO_2, 1750–2019



Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)

NB: Emissions from the burning of fossil fuels for energy and cement production. Land use change is not included

Recent months have seen a number of countries commit to achieve carbon neutrality ("net zero carbon") by the middle of the century[16] and there are indications to suggest that others may follow suit. The end-goal therefore appears to be firmly set, at least on paper, even if the pathway is as yet uncertain.

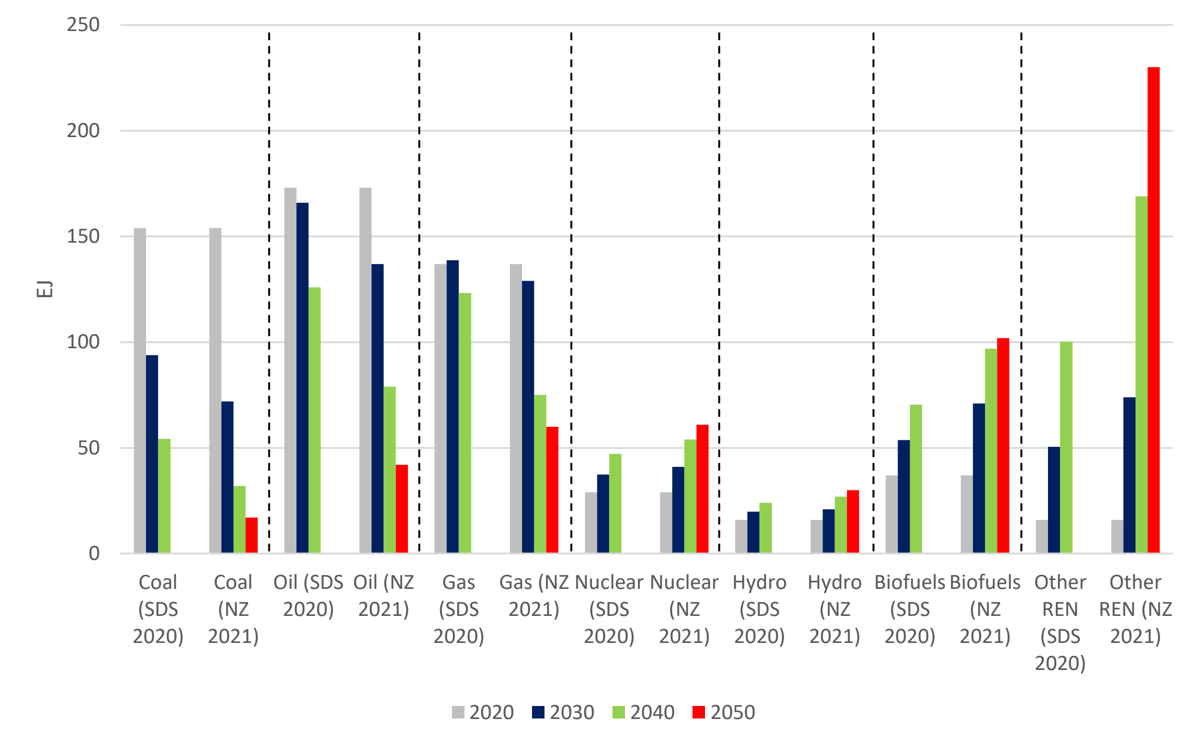
The primary focus of the energy transition is on shifting the world's socio-technical system away from one based almost exclusively on the production and consumption of fossil fuels, towards a system in which renewable energy sources are dominant, although some countries (mainly oil and natural gas exporters) are arguing for a technology neutral approach to emissions reduction which would also allow technologies such as CCUS and direct air capture to be developed. Nevertheless, the overall goal is to reduce emissions both from the combustion of fuels such as oil, gas, and coal and also from across the value chains that produce them. Indeed, the increasing move by countries to set 'net zero emissions' targets implies that hydrocarbon consumption is likely to go into decline in the near future.

The most recent analysis of the outlook for the energy balance in a global "net zero" economy has come from the IEA and is illustrated in Figure 2. The graph shows the change by fuel in the Net Zero (NZ) scenario and also compares it with the IEA's Sustainable Development Scenario (SDS) from 2020, which also provided an outlook that could allow the world to meet the 1.5º target set out by the IPCC in

[14] Calculation based on carbon emissions in 2019 (from BP Statistical Review of World Energy) and remaining carbon budget of 580 $GtCO_2$ calculated by the IPCC in its 2020 Special Report on Global Warming (Rogelj et al).
[15] Total potential emissions from existing hydrocarbon reserves estimated at 2,795 $GtCO_2$ - see Carbon Tracker analysis at https://www.worldbank.org/en/events/2015/03/20/managing-carbon-bubble-how-to-transition-to-low-carbon-economy
[16] These include the EU member states, UK, Bhutan, Costa Rica, Fiji, Japan, the Marshall Islands, China, South Korea, USA, and Uruguay. Additionally, over 100 countries have joined an alliance aiming for net-zero emissions by 2050.

2018.[17] A number of conclusions are immediately obvious. Demand for all hydrocarbons falls much faster in the Net Zero scenario, with the combined share of oil, gas, and coal falling from 79 per cent in 2020 to 22 per cent in 2050 (the SDS scenario only provides forecasts to 2040). On an individual basis, coal demand is forecast to fall by 90 per cent, oil by 76 per cent, and gas by 56 per cent by 2050, with the trajectory in the Net Zero forecast being around 40 per cent lower than the previous SDS outlook in each case. By comparison, the output from wind and solar rises by more than 1400 per cent over the 30-year period, while biofuels supply increases by almost 300 per cent. Indeed, the overall share of renewable energy (including hydro) increases from 12 per cent in 2020 to 67 per cent in 2050, overtaking the share of hydrocarbons by 2035.

Figure 2: The IEA's Net Zero (NZ) and Sustainable Development Scenarios (SDS) compared



Source: Data from IEA World Energy Outlook 2020 and IEA Net Zero by 2050 reports

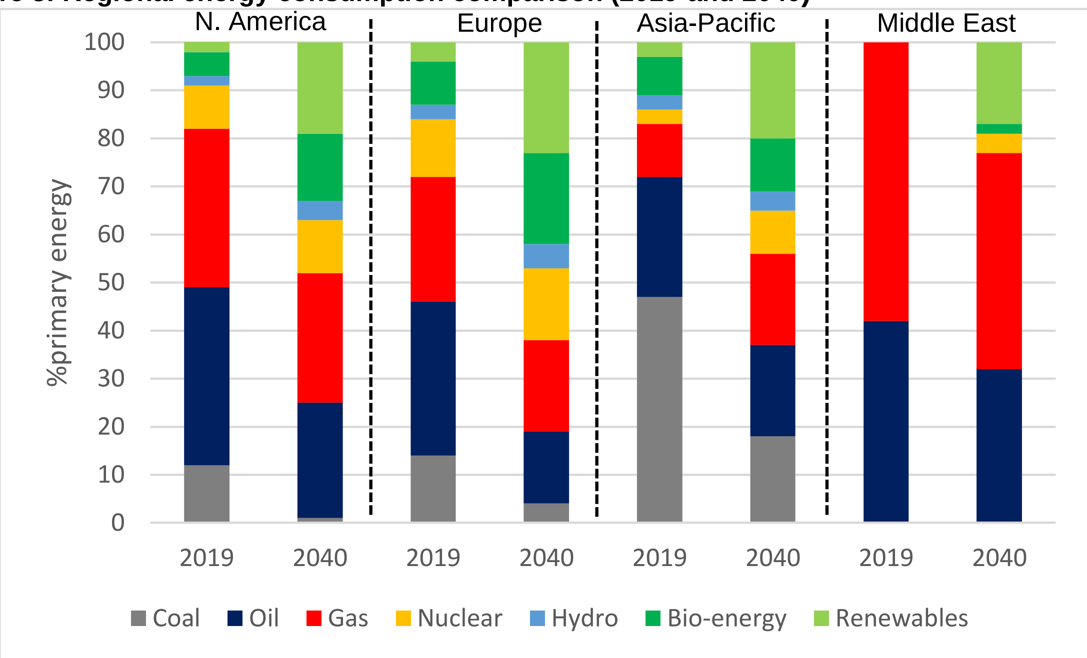
However, there are a number of somewhat less obvious conclusions that also need to be recognised. The first is that there is significant variation across regions. Decarbonisation and the Energy Transition refer to very different outcomes in Europe, the US, Asia, and the Middle East. The IEA Net Zero report does not provide a regional breakdown in its analysis, but the IEA Sustainable Development Scenario, which is also compatible with the 1.5º target, demonstrates the point. In North America and Europe, coal almost disappears from the mix and is replaced largely by renewable energy, with a decline across all hydrocarbon consumption. By contrast, although coal consumption declines in Asia it remains a significant part of the mix and is replaced by gas as well as by renewables, meaning that the share of gas rises sharply and hydrocarbons overall still account for well over 50 per cent of primary energy demand in 2040. Meanwhile, in the Middle East hydrocarbons continue to account for more than 75 per cent of the energy mix even in 2040, with gas again playing a very prominent role while renewables

[17] The IEA SDS scenario would hold the global temperature rise below 1.8ºC with a 66 per cent probability and below 1.65ºC with a 50 per cent probability, with net zero emissions met by 2070. The Net Zero scenario shows a pathway for the world to meet a net zero emissions target by 2050, providing a 50 per cent probability of limiting the global temperature rise to 1.5ºC.

also enter the system, largely at the expense of oil. As such, it is important to consider the regional context of the energy transition as the outlook for fuels differs considerably (see Figure 3).

The combination of these various regional shifts provides a second important high level conclusion, namely that although hydrocarbon consumption will go into sharp decline over the period to 2050, there will still be a significant level of demand during the next three decades. The IEA Net Zero report has concluded that no new investment in new oil, gas, or coal fields is required from 2021, although it does acknowledge that to varying degrees all three fuels will continue to play some role. Indeed, if one compares demand over the past 30 years (1989-2019) with the three decades to 2050 it would seem that total coal demand over the period may be down by 50 per cent while total oil demand is set to be 34 per cent lower. However, it is interesting to note that total gas demand to 2050 is assumed to be almost exactly the same as the amount consumed in the previous three decades.[18] As a result, although investment in new oil and coal may be challenging for financiers, governments and investing companies and may be limited to enhancement of existing assets, it is less clear how the role envisaged for gas in a scenario that meets the net zero targets, such as the one above, could be achieved without spending on new fields. This suggests the possibility of short to medium-term supply shortages as an unintended consequence of rapid disinvestment without an equivalently rapid scaling up of production from alternative energy sources, even in a global energy system where rapid decarbonisation is the key objective and demand for all hydrocarbons is expected to be significantly lower in 2050 than today.[19]

Figure 3: Regional energy consumption comparison (2019 and 2040)



Source: Data from IEA World Energy Outlook, using Sustainable Development Scenario

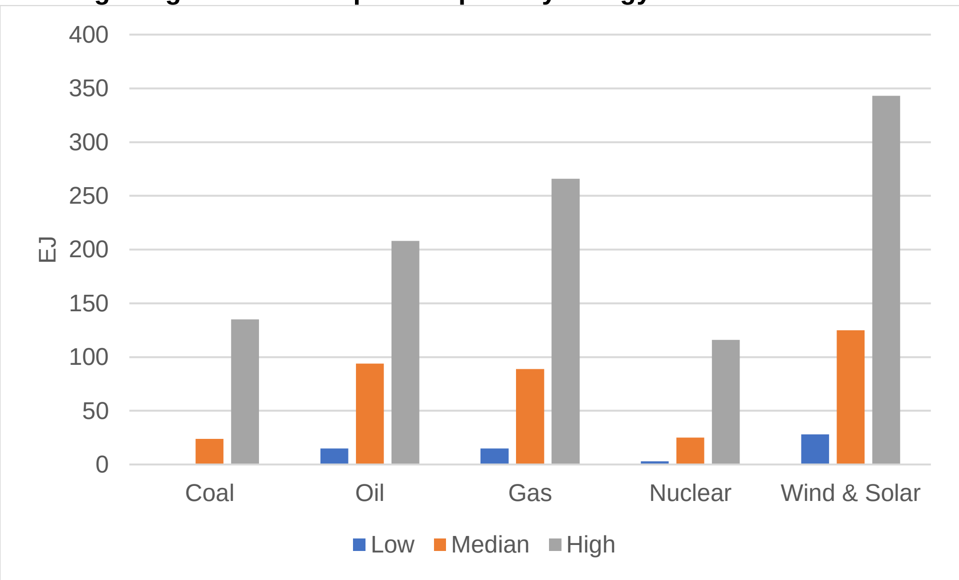
Thirdly, the IEA asserts on the first page of the Executive Summary of its Net Zero report that the scenario it outlines is "a path, not necessarily the path"[20] to a decarbonised world, and it would seem clear that although the direction of travel is necessary and obvious, the range of potential scenarios is

[18] Comparison of historic data from BP Statistical Review with extrapolated total from IEA Net Zero by 2050 report. Total overall figures for 2020-2050 calculated from IEA estimates for 2020, 2030, 2040 and 2050.
[19] Bordoff, J. (2021) *Why shaking up Big Oil could be a Pyrrhic Victory* at https://www.energypolicy.columbia.edu/research/op-ed/why-shaking-big-oil-could-be-pyrrhic-victory
[20] Underlining inserted by authors.

enormous. Although the IEA only provides one scenario, the IPCC, in its 2018 report on "Global Warming of 1.5º C", analyses around 90 different scenarios that reach the temperature target by 2050. Figure 4 below shows the low, median, and high outcomes for 2050 for coal, gas, oil, nuclear, wind, and solar and, although the forecasts themselves are now dated, the extent of the range is clear. To take just one example, consumption of gas could be almost double its 2020 level in the high case or at a level of only 10 per cent of the 2020 figure in the low case. These are obviously extreme outcomes, but they demonstrate the level of risk and uncertainty that is being faced by incumbent energy providers. A similar story is also true for developers of renewable energy, although the uncertainty here surrounds the different pace of growth rather than any potential for decline.

A fourth conclusion is that if a significant amount of hydrocarbons remain part of the energy mix, then abatement is a critical requirement. The role of carbon capture, utilisation and storage (CCUS) will be vital if oil and gas are to have a viable role in a decarbonising world, and in the IPCC scenarios it is estimated (within a broad range) that as much as 1200 Gt of CO2 might be sequestered during the remainder of the 21st century, with the majority of this occurring after 2050. Nevertheless, as much as 300 Gt might need to be sequestered by mid-century if the world is to be on track for its 1.5 degree target, implying an average annual level of sequestration of up to 10Gt during the next three decades.[21] By comparison, the IEA Net Zero scenario sees around 1.7Gt per annum of sequestration by 2030 from a combination of removal and capture technologies, rising to 7.6Gt per annum by 2050.[22] As a result, company and country strategies that incorporate CCUS into a circular economy model are likely to become increasingly important.

Figure 4: The range of global consumption of primary energy in 2050 from IPCC Scenarios[23]



Source: Rogelj et al (2018) – IPCC 1.5º Pathway report – p.133

A fifth point is that it is also clear that improvements in energy efficiency must continue to play a key role in reducing per capita energy demand. The median case for the IPCC scenarios sees total primary energy demand at almost the same level in 2050 as in 2020, but by then the population is estimated to have grown by around 2 billion people and the world's GDP to have doubled or more.[24] However, a key

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[21] Rogelj et al. (2018), Chapter 2, p.122
[22] IEA Net Zero by 2050 report (2021), p.199
[23] The IPCC provides the median, maximum, and minimum scores from the full range of 90 available 1.5º scenarios in its analysis.
[24] Rogelj et al. (2018). Chapter 2, p.111

point is that in developing countries this economic growth cannot justifiably be constrained by energy use during the energy transition, and so a fair balance will need to be found.

Finally, the growth in renewable energy leads to three conclusions. Firstly, that the energy transition will be driven by electrification, which in turn will rely on wind and solar energy as its key sources. Secondly, that the growth in these sources of supply will need to be rapid. The median growth rate of primary energy supply from wind and solar in the IPCC scenarios between 2020 and 2050 is approximately 11.5 per cent per annum,[25] implying a twelvefold increase in primary energy supply from wind and solar in 30 years. Meanwhile the IEA Net Zero report shows a pathway that implies the addition of over 13,500GW of solar capacity by 2050 and more than 7,500GW of wind capacity.[26] A third conclusion would then be that this rapid growth in intermittent renewable energy will require the significant adaptation of all elements of the existing energy sytem, which has traditionally been organised around large, centralised, and dispatchable energy sources.

The impact will be felt across the energy value chain

Recent commitments by a number of governments to "net zero" emission targets have underlined both the need and the desire to rapidly reduce hydrocarbon consumption. Societal pressure is visibly increasing, in particular in OECD countries, as scientists, as well as environmental and citizen groups, argue the need for radical change, investors insist on corporate action, and consumers start to make choices based on environmental as well as economic outcomes.[27] Governments and policymakers are both responding to the demands of their electorates and are also driving change, with the issue of air and water quality, as well as global warming, being key drivers of action, although the distribution of the policy costs across society have yet to be addressed. Encouragingly, though, scientific advances through the development of new technology have reduced the cost of renewable energy to levels where in many countries it can now compete with hydrocarbons with reduced or zero subsidies.[28]

The impact of these drivers is being felt across the energy value chain. Demand for primary energy is already changing, and the impact on extractive industries is being felt in demand uncertainty, price volatility and questions over investment strategy. This creates a number of issues for producer companies and countries - the pressure to monetise reserves that are at risk of becoming stranded, the risk of lower prices, the question of whether to commit to new long-term investments, and the option of diversifying into new, non-carbon-intensive, business areas.[29] Meanwhile, for producers of uranium, lithium, cobalt, copper, and other rare earths and minerals, new opportunities are emerging with significant consequences for economic growth, trade flows, and geo-political influence.

Systems of energy conversion and supply are also facing important changes. In the power sector, the increase in renewable energy is creating issues around balancing, decentralisation, and pricing, as the system adapts to rising shares of intermittent and zero marginal cost sources of electricity.[30] Meanwhile, hydrogen is emerging as a possible new source of converted energy, whether it be via methane reforming or electrolysis, which could provide an important link between the gas and electricity sectors (for example as a source of flexible storage to balance renewable intermittency) as well as a source of zero carbon energy (in the case of electrolysis) for many end-users.[31] Finally, the refining industry will also have to deal with a major shift away from traditional fuels towards decarbonised products with much-reduced emissions of CO_2 and particulates.

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[25] Rogelj et al (2018) p.133
[26] Data from IES Renewables 2020 report at https://www.iea.org/reports/renewables-2020
[27] See for example Dryzek, S., Norgaard, R., & Sclosberg, D. (eds) (2011)
[28] IRENA (2020)
[29] For example, see Fattouh, B. (2018).
[30] See for example Xu, Z. (2019).
[31] See for example Lambert, M. (2020).

Moving further along the value chain, energy delivery infrastructure will also face major challenges. The operational security and reliability of electricity grids is being tested by both the introduction of intermittent renewable energy and the emergence of multiple new sources of supply.[32] The question for natural gas infrastructure appears more existential, as it may need to be partially or completely re-purposed for a decarbonised world. Furthermore, the integration of the power and gas grids could be one potential solution in ensuring the efficient provision of secure and economic energy to a wide range of consumers.[33] Meanwhile, for the oil sector the risk of obsolescence across the entire transport infrastructure would appear to be very real, with the rise of electric vehicles, alternative fuels for ships, and hydrogen fuel cells challenging the need for oil and oil product pipelines, tankers, and distribution networks.

Finally, at the interface between supply and consumption vital issues are emerging around consumer choice, demand-side management, and the development of multiple new sources of supply. It seems clear that as consumers become more environmentally aware so their choices will put pressure on suppliers of traditional energy sources. Beyond this, though, new technology can help to improve energy efficiency across the industrial, commercial, and residential sectors, reducing overall demand, while a growing digital revolution can create new sources of flexible energy to balance the overall system and further optimise energy consumption.[34] This transformation is most visible perhaps in the electricity sector, in which new sources of energy and new technologies have meant that generation which was previously centralised is now becoming more decentralised, demand could be increasingly flexed to meet supply instead of the other way around, control and dispatch could occur throughout the system rather than from a central point, and grids could become smart players in the system as opposed to a neutral conduit.[35] When decentralised energy systems such as solar panels, wind farms, and biofuels are added to the mix, the complexity of the energy transition is further exacerbated for producers of primary and final energy supply.

All these issues are already challenging the existing energy system across the value chain, with new technologies, combined with political and consumer demands, causing disruptions that will impact producers, consumers, and intermediaries alike. They also raise the question of interconnectivity between different energy vectors and the ways in which this will be managed through both physical infrastructure, and also through markets, regulation, and consumer participation.

One of the key themes of the energy transition, though, is uncertainty, both in terms of the timing of change, the nature of the alternatives that will ultimately succeed, and the consequences for existing and future actors in the energy economy. In the following sections we outline some of the key questions that will need to be considered, and ultimately answered, if the transition to a decarbonised energy economy is to be successful.

2. Key Issues for the Energy Transition

2.1 Policy and regulation

Perhaps the most important driver of the current energy transition, compared with previous major changes in the global energy system, is that it is being driven by government policy and regulation. In contrast, previous energy transitions have been based on inter-fuel competition, with coal, oil, or gas emerging as efficient energy sources driving industrial development and economic growth. The current energy transition is driven by a different motive – to avert or mitigate global climate change that is occurring as a consequence of energy sector (predominantly hydrocarbon) emissions – and comes,

[32] Billimoria. F. et al (2021)
[33] For one example of this see Lambert, M. (2018)
[34] See IEA Energy Efficiency (2020)
[35] See Keay, M. (2020)

initially at least, at a higher cost than current energy alternatives. However, this highlights one of the main underlying obstacles to the energy transition, namely the current failure of markets to price in environmental externalities. As a result, although renewables and other carbon-free forms of energy will ultimately replace hydrocarbons as a driver of industrial development, at its initial stages the transition has been catalysed by policy and has needed state support to encourage investment. Furthermore, the introduction of new energy sources has and will continue to require changes to current regulation of energy markets, and potentially to the linear paradigm which governs the current system of production and consumption of goods and services (including energy).

However, there are likely to be sharp regional differences in outlook in any discussion of environmental policy, especially between countries in the developed and developing world. In the former, lowering energy demand per capita and decarbonizing energy demand are the key goals. In the latter, where there are competing demands on resources, affordable energy access remains a key priority as does the need to power economic growth, alongside environmental issues.

As a result, there are a number of key questions which need to be asked and the responses monitored. Firstly, at the highest level what type of targets are being set to reduce emissions and meet climate goals and how are they being adjusted over time? In relation to this, what are the implications of specific targets for renewable electricity or other forms of decarbonised energy, both for incumbent and new industry players and consumers? Furthermore, what is the impact and relative cost of different technologies on emissions outcomes and what are the efficient routes to achieving climate targets? Establishing these critical starting points for the transition will provide a vital foundation for measuring and assessing progress towards climate goals.

A second related area concerns energy sector fiscal policy, in the form of costs that are being imposed and incentives provided to encourage shifts in the current energy system. Carbon prices and taxes are already having an impact in some regions (especially Europe).[36] However, the increased globalization of trade creates a policy issue, because emissions are generated throughout a supply chain that is widely geographically dispersed. In this 'linear' model, overall decarbonisation is difficult because emissions from energy production need to decline much faster than the expansion in economic output. Further, the boundaries of net-zero carbon targets are not clearly defined or coordinated between different jurisdictions. As a result, international trade enables the costs of decarbonisation to be shifted outside national borders, creating negative externalities elsewhere. The potential introduction of carbon border adjustment mechanisms in certain jurisdictions is an attempt to address this "carbon leakage", but while it could create a catalyst for a more global effort on carbon levies, another consequence is that in hard-to-abate sectors, producers in some countries could find that their goods and products become uncompetitive in the global market. These issues may necessitate the establishment of strong public policy frameworks which recognize and correct for some of these trade-offs while also addressing potential WTO issues.[37]

Meanwhile, more direct rules on ending hydrocarbon usage in some sectors could also be imposed, as has been seen in many countries in Europe concerning the phaseout of coal in the power sector. In addition to these costs on hydrocarbon use, further incentives could be provided to encourage the shift towards greener energy and energy conservation, including sales mandates and efficiency standards, tax incentives, and direct subsidies. Some of the ways in which governments can support new technologies are shown in Figure 6. In addition, there is growing encouragement for governments to increase public spending on green energy as part of a COVID-19 recovery effort,[38] and it will be vital to consider and monitor the impact of any resulting plans.

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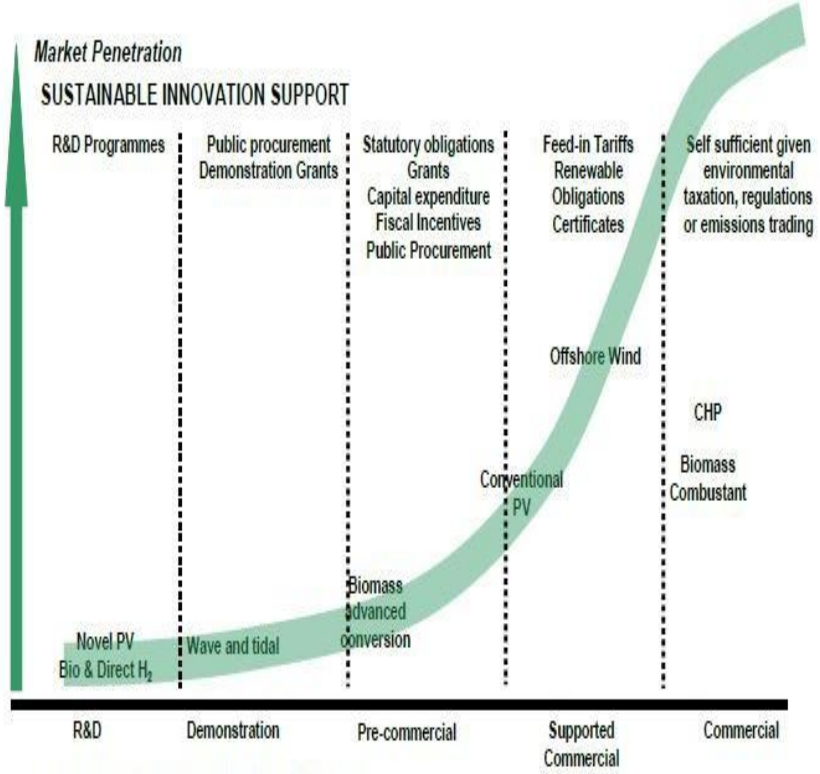
[36] See Barnes, A. (2021)

[37] See Sen et al. (2021)

[38] IEA (2020) "A sustainable recovery plan for the energy sector" at https://www.iea.org/reports/sustainable-recovery/a-sustainable-recovery-plan-for-the-energy-sector

Figure 6: Government support curve for new technology development



Source: Foxon et al, 2005

Thirdly, it will also be important to understand how governments plan to adjust existing market regulation to allow new sources of energy to compete. For example, changes to emission rules by the IMO have allowed alternatives to high sulphur fuel oil to start playing a greater role in the maritime bunker fuel market,[39] but in other markets where competition on price is critical, it may be necessary for regulators to ease competition rules to allow new technologies to flourish, at least initially. One example of this could be the European gas market, where the Third Energy Package prevents coordination across the value chain that could be crucial to the establishment of hydrogen and other decarbonized gases as viable alternatives to natural gas.[40] In the electricity sector, too, new forms of market design and architectures may need to be introduced to allow for the more efficient incorporation of renewable energy into the system and to encourage the development of storage options to manage grid stability.[41]

More generally governments are also becoming more interested in the adoption of circular economy approaches to decarbonisation – based on the creation of closed loop systems of production and consumption, essentially moving away from the dominant linear paradigm. This could require regulation (alongside policy incentives) to encourage more intensive use of the existing stock of resources, the development of secondary markets to enable resource and product life extension, and measures to mitigate any rebound effects from the adoption of such approaches. Some countries that are heavily dependent on the revenues from hydrocarbon resource production are also considering a modified version – the 'circular carbon economy' – which incorporates carbon capture into the overall concept.[42]

[39] For more information see https://www.imo.org/en/OurWork/Environment/Pages/AirPollution-Default.aspx

[40] For an analysis of the Third Energy Package and its impact on the energy transition see Barnes, A. (2020).

[41] For a discussion of market design in the power sector see Robinson, D. & Keay, M. (2020).

[42] See Sen et al. (2021).

Finally, governments may eventually just "pick winners" in terms of technological outcomes if the world's climate goals are to be met in time. Allowing markets to find the optimal economic outcome may be theoretically preferable in a world economy driven by competition and trade, but it may not produce a result fast enough to prevent dangerous climate change. This is discussed further below in the section on markets (Section 2.6 on page 16), but an initial hypothesis is that government policy and regulation may need to play a much greater role in energy markets if transition objectives are to be met.

2.2 Technology

While government support is likely to remain one pre-requisite for the development of new technologies that can support the energy transition for some time, there are clearly other more practical issues that need to be addressed as well. Technical possibilities continue to push new barriers, and it will remain important to monitor scientific and technological progress in order to assess what new carbon-free energy breakthroughs could occur to disrupt the energy system further. Solar power technologies could exploit a wider band of the light spectrum[43] while the exploitation of the globe's wind potential is moving further offshore and higher into the sky, demonstrating that existing sources of energy can be further optimised. Meanwhile the development of options such as small modular nuclear reactors or nuclear fusion could radically alter the energy landscape,[44] while progress with CCUS will need to play a vital role if the global economy's reliance on fossil fuels continues for longer than anticipated.[45] In addition, investments are going into energy storage, both in terms of short-term technologies such as batteries but also via long-term technologies such as hydrogen,[46] ammonia,[47] and other chemical options. A breakthrough in any one or more of these could have significant consequences for the supply of future energy requirements but there is considerable uncertainty over which technologies will be developed to commercial scale.

Allied to the issue of technical possibility is the question of economic feasibility. While governments can support the development of new technologies, they ultimately have to make sense financially, and a number of actors in the energy sector continue to argue that decarbonisation policies should be technology neutral.[48] Figure 7 shows that for some technologies the progression from expensive R&D programme to commercial viability need not necessarily be excessively long, but given the constrained timescales involved, it may be important to allow all possible technologies, including those that involve the removal of carbon from the existing energy system as well as the development of new carbon-free energy sources, to have the opportunity to make an impact. For each technical development there will be a need to understand the current cost and the trajectory to date while also attempting to assess what further progress can be made and how future costs compare with current energy sources. It will also be important to understand the drivers underpinning any cost reductions to assess whether they are sustainable, and therefore to gauge what the key risks and uncertainties are, what type of government support may be required, and for how long.[49]

Finally, regardless of the outcome of various funding and/or investment efforts to commercialise new technologies, certain types of energy markets can incentivise alternative solutions which fulfil the same functions. For example, the development of demand-side management in electricity markets could

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[43] For example Euronews, 21 July 2020, "Invisible light can now be harnessed for solar power" at https://www.euronews.com/green/2020/07/21/invisible-light-can-now-be-harnessed-for-solar-power

[44] See https://www.bbc.co.uk/news/science-environment-54703204 for one example in the UK.

[45] Fattouh, B. et al (2021)

[46] Lambert, M. (2021)

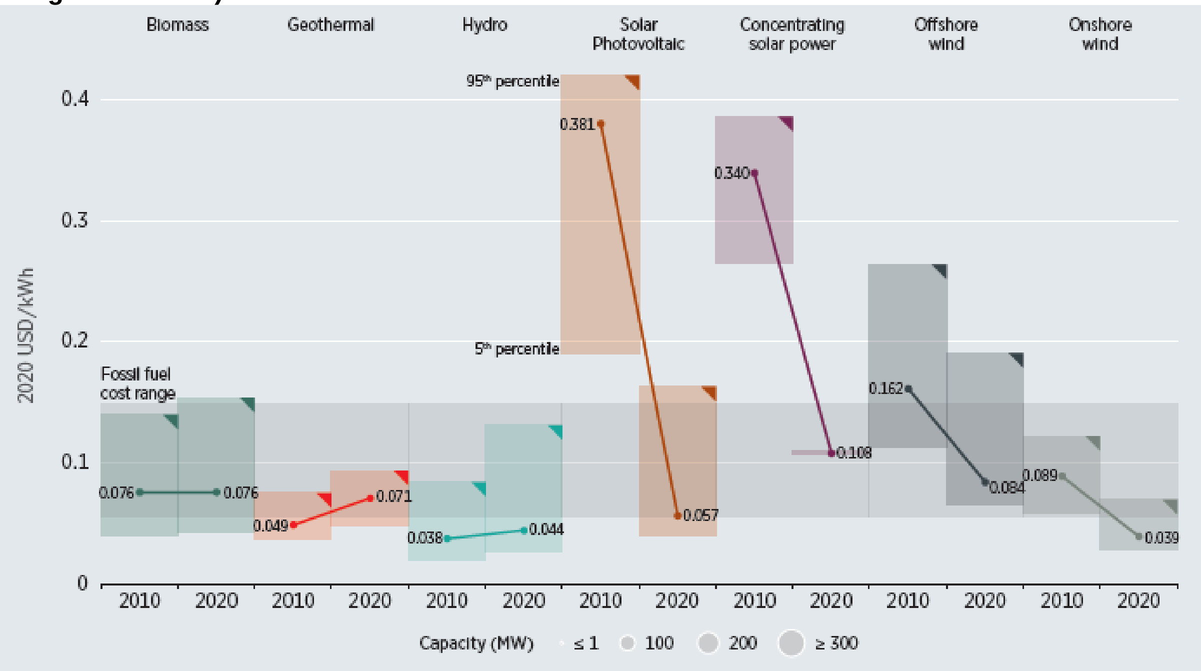
[47] Patonia, A. et al (2020)

[48] For instance, see https://energypost.eu/if-renewables-growth-still-wont-stop-climate-change-do-we-need-tech-neutral-incentives/

[49] For an analysis of cost curves in the solar and wind industries see Grafstrom, J. & Poudineh, R (2021).

complement the short-term energy storage technology that is currently being developed. As a result, it is important to consider new technology within the context of the system developments that are ongoing.

Figure 7: The cost trends for various sources of renewable power (excluding system integration costs)[50]



Source: IRENA, Renewable Power Generation Costs in 2020

2.3 Finance

Investment in new technology and the restructuring of the energy system inevitably raises the vital question of finance. As mentioned above, it is possible that state funding of economies across the world to encourage a post COVID-19 recovery could include significant spending on risk mitigation instruments to incentivise green energy, but ultimately a balance of private and public funding will be required to meet the investment requirements over the long term. With the IEA estimating that over the next decade $1-1.3 trillion will need to be invested in the power sector per annum (mainly in renewable energy and power networks), plus up to $1 trillion per annum in improving energy use in end-use sectors, the scale of financing needed in the energy transition is clearly large, while at the same time $0.6-0.8 trillion will still need to be spent on traditional fuels such as oil and gas to ensure a managed decline in traditional sources alongside changes in the existing system.[51]

The extent to which banks and other financial institutions will be prepared to take the dual risk of financing new technologies, while also responding to investor and societal pressure to withdraw from the funding of hydrocarbons, will be a key determinant of progress of the energy transition.[52] The formation of the Network for Greening the Financial System (NGFS)[53] demonstrates that Central Banks are taking steps to address this issue, but also highlights the key concerns that many financial institutions are facing. As noted above, it will also be vital to understand if governments and multilateral

[50] The graph shows the global LCOEs from newly commissioned, utility-scale renewable power generation technologies.
[51] IEA World Energy Outlook 2020, Launch Presentation, page 44 sourced from https://iea.blob.core.windows.net/assets/fd69e584-f43f-400b-9702-f5a6dc9c3156/WEO2020-Launch-Presentation.pdf
[52] For a discussion on this topic see Fattouh, B., Poudineh, R., & West R. (2019).
[53] For detail see https://www.ngfs.net/en

agencies will allow competitive markets to operate in the efficient selection of new technologies or whether they may feel compelled to "pick winners." The decisions taken on this issue will shape the risk profiles for investments and provide signals for those seeking to finance them.

2.4 Networks

The huge investment requirement in energy networks identified by the IEA highlights another vital area of the energy transition. The prevalence of hydrocarbons consumption across the world has seen the development of a network of pipelines, shipping fleets, and distribution outlets that has become a core asset base in the global energy system. Meanwhile, electricity grids have been established to optimise the delivery of power from a centralised supply system across a diverse range of industrial, commercial, and residential users. This infrastructure will need to be adapted or re-purposed if it is to remain relevant to a decarbonised energy sector which is seeing the emergence of new energy vectors that do not necessarily conform to the traditional centralised system.[54]

The most obvious risk is that older and less adaptable assets could become stranded. Arguments for repurposing networks have been made in a number of studies, on the grounds of preventing a significant loss of economic value, and potentially enabling an efficient transition.[55] The gas sector provides an example of this issue, where the proposed introduction of hydrogen raises questions around blending with natural gas in the current pipeline system, replacing natural gas with hydrogen while re-purposing current pipelines and associated infrastructure, or constructing a new, hydrogen system to operate in tandem with the current infrastructure as consumption of natural gas declines.[56]

In the electricity sector, although the "product" being transported is the same the grid may need to be expanded and adapted as electrification becomes a vital part of decarbonisation strategies and new intermittent and decentralised supply becomes more prevalent. Energy system integration[57] and using digitalisation to optimise the balancing of supply and demand, will be critical, and could also include development of physical and regulatory links with gas and other infrastructures to allow optimal use of storage and backup generation. Meanwhile, in the oil sector there are questions around distribution infrastructure, as various forms of transport start to switch to electricity and other less polluting fuels (for example LNG, ammonia or hydrogen in bunkering). As a result, the issue of whether existing oil infrastructure can be repurposed or whether it will ultimately become redundant has become highly relevant.

The resolution of these issues will be vital if suppliers and consumers of energy are to be convinced that the emerging energy system can be robust, and that the existing system will remain resilient as the transition towards a decarbonised system progresses over the next two to three decades. Regulators have a key role to play in establishing rules that can allow for appropriate levels of competition, but which can also provide confidence to all players in the value chain that investments made in the decarbonised system can generate adequate returns in their early years, when they could be undermined by cheaper sources of existing carbon-based energy. Arguably, more state and regulatory control and greater cooperation between key players across the value chain may have to take precedence over full competition in liberalised markets, at least while new forms of energy are becoming established (see sections 2.1 and 2.6).

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[54] Oxford Energy Forum, Issue No.124 (September 2020)

[55] For example, Qadrdan, M., Abeysekera, M. Wu, J., Jemkins, N. & Winter B. (2020) and Dodds, P. &McDowall W. (2013).

[56] See Lefevre, C. (2019).

[57] O'Malley, Mark, Kroposki, Benjamin, Hannegan, Bryan, Madsen, Henrik, Andersson, Mattias, D'haeseleer, William, McGranaghan, Mark F., Dent, Chris, Strbac, Goran, Baskaran, Suresh, and Rinker, Michael. *Energy Systems Integration. Defining and Describing the Value Proposition*. United States: N. p., 2016. Web. doi:10.2172/1257674.

2.5 Impact on consumers (including energy justice and access issues)

The definition of the consumer is broad, ranging from large industrial companies and power plants to households and small businesses, and indeed the very concept is changing as buyers of energy can now become sellers via decentralised plants or demand-side management. However, in addition to the issue of reliability during the energy transition, consumers may also require further incentives to switch away from traditional fuels. Although the question of climate change is clearly vital, when consumers are asked to make specific changes to industrial processes or lifestyles, the questions of economics, convenience, and cost tend to come to the fore.[58] As a result, there are uncertainties around consumer reaction to new products, their willingness to change appliances, their desire to embrace demand-side management and their inclination, and ability, to potentially pay more in the short-term for a product which can contribute to long-term welfare.[59] Ultimately, of course, governments can force through change, but may be reluctant to do this in countries where political power is determined by voter choice.

Furthermore, many suppliers of energy will also be considering, alongside policymakers, what incentives consumers may best respond to, and whether new products and services will be needed to create differentiation in order to gain market share. Indeed, many new types of company could emerge to meet the requirements of a changing marketplace, with aggregators, service, and retail companies potentially set to take a more prominent role in a more circular economy. It will be interesting to see whether incumbent players can adapt to this element of the energy transition or whether companies more used to consumer-facing business models start to prosper.

However, these questions mainly concern consumers who already have access to reliable energy. Another key issue, though, is providing supply to those in energy poverty. In its World Energy Outlook 2020 the IEA highlighted that 2.6 billion people still do not have access to clean cooking appliances while 770 million have no source of electricity supply,[60] adding that the impact of the COVID-19 pandemic could mean that a further 100 million people could be unable to afford their electricity supply even though they are connected to the grid.[61] Furthermore, the energy transition itself could exacerbate inequalities around access to clean and affordable energy either by imposing costs on poor consumers who cannot afford to pay them or by offshoring pollution from developed to developing countries.[62] In addition to this access issue, more than 5 million excess deaths per year are caused by air pollution, with the vast majority of these being in poorer non-OECD countries. Indeed, energy justice will be a major theme of COP26, where one of the main points for discussion is the need for developed countries to meet (or increase) their funding commitments to support the energy transition in developing countries, with a target of $100 billion per annum by 2020 having been set in 2010 but not yet achieved.[63]

2.6 Business models

The two issues of climate and environmental policymaking and consumer response naturally lead on to the question of how companies that serve customers may need to realign their business models both to meet regulatory requirements and satisfy consumer preferences whilst optimising their position during the energy transition, or perhaps more radically, simply surviving it. Already it is clear that some companies are moving faster than others, but some key themes are emerging.

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[58] For a discussion on the need to take societal as well as economic factors into account when assessing investments for the energy transition see Poudineh, R. & Penyalver D. (2020).

[59] For analysis of consumer choice and incentives in the road transport sector see Sen, A. (2020).

[60] IEA World Energy Outlook 2020, p.91, IEA, Paris

[61] Ibid, pp.92-93

[62] Garsous and Kozluk (2017)

[63] UNFCCC paper on the “Roadmap to $100 Billion” at https://unfccc.int/sites/default/files/resource/climate-finance-roadmap-to-us100-billion.pdf

Firstly, the major IOCs, under pressure from investors and banks, are making strategic decisions about whether to stick to their core business or to diversify into becoming an "integrated energy services company". The split at present appears to be on geographical lines, with European companies such as BP, Shell, Total, and Equinor leading the way towards decarbonised energy, while companies in the US, the Middle East, and Asia to date remain primarily focused on their core business. However, the landscape is changing rapidly, as seen with the actions of shareholders at ExxonMobil and Chevron in mid-2021,[64] and winners and losers are not yet apparent. Meanwhile, although some National Oil Companies are investing in clean technologies, they might be constrained in their ability to diversify, especially if their hydrocarbon products or export revenues are vital to the domestic economy, and so may focus more on being both a low-cost producer and, importantly, also reducing the carbon intensity of their output and storing carbon.[65]

A general supply-side trend as far as hydrocarbon output is concerned is for companies to put greater emphasis on gas, given its relatively lower emissions compared with oil and coal, but overall the trend is towards greater electrification and as a result any companies with aspirations to play a major role in the energy transition must prepare to be a significant player in the power sector. Whether this means producing renewable energy, offering transportation and storage services or supplying industrial, residential, and commercial consumers, the key question is where the highest value propositions can be found in a new, more integrated energy economy. However, this new operating model has significantly lower risks and returns than the traditional business that has dominated the upstream hydrocarbon industry to date and so the challenge for incumbent hydrocarbon companies that enter the renewable space will be to demonstrate where and what type of profits can be made in the new energy environment, what their competitive advantage is, and how they will manage the move away from hydrocarbon production.[66]

As such, it is also vital to understand how the electricity business model is changing. The impact of renewable energy has clearly been fundamental, both in terms of changing the generation model from one of high to low (and near-zero) short-term marginal cost but also in terms of decentralising the sources of generation and raising the question of the value of flexibility and back-up generation. However, the most interesting question may end up being which part of the value chain will benefit most from the transition, and whether the provision of services could become a much more important part of any energy company's offering. In Europe and the UK, for example, this is closely related to the manner in which different services might be stacked across different electricity markets, unlocking new value propositions. It is interesting to note that many suppliers now see consumers at the centre of their strategy,[67] focusing on the provision of services and the opportunity for end-users to play a much greater role. In addition, digitalisation and the opportunities it provides for a more efficient two-way information and energy flow between consumers and suppliers, is also emerging as a key new trend, paving the way for the role of aggregator or facilitator of energy services to become increasingly important. A good example of newer flexible business models is seen in Octopus Energy, which started off as an electricity retailer, before moving up the value chain towards generation.[68] The company also launched its own platform ('Kraken') for coordinating and integrating different consumer usage patterns with varying renewable demand.

Another issue around business models pertains to companies' own net-zero goals and the adoption of circular economy models (involving the decarbonisation of companies' supply chains) to achieve this. Corporate circular economy models have been developed and implemented within organizations since the 1970s, with the aim of improving short-to-medium term efficiency. The approach has evolved over

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[64] For detail see https://www.ft.com/content/da6dec6a-6c58-427f-a012-9c1efb71fddf
[65] For discussion see West, R. & Fattouh, B. (2019).
[66] Pickl, M (2019)
[67] As one example, see E.ON's consumer-centric strategy at https://www.eon.com/en/about-us/the-new-eon.html
[68] For detail on Octopus Energy see https://octopus.energy/about-us

time to include the aim of sustainability, and a move from 'linear' to 'circular' supply chains within organizations, allowing them to decouple financial growth from a dependence on finite resources. The circular economy concept is fundamentally based on keeping materials and products within a supply and demand loop for as long as possible, with leakages minimized or ideally eliminated through measures such as resource life extension, material re-use and recovery, and recycling. As such it can both reduce environmental impact and create new value propositions, offering a new business model that could be attractive to multiple stakeholders.[69] However, in order to gain credibility for these new models it will also be important to see increased transparency from businesses and countries alike. As Stern has pointed out,[70] broad acceptance of business models that involve reduction of leakage, use of carbon offsets and recycling of CO_2 require accurate measurement, verification, and reporting of emissions in the first place. Without this, any strategies that involve reducing these emissions (for example via the offer of carbon-neutral LNG) fall at the first hurdle, and so it will be vital to monitor the efforts of all actors in the energy sector to increase the availability of accurate data on these issues.

Overall, the rapidly changing environment highlights a number of issues for energy companies throughout the oil, gas, and electricity value chains as they think about their future business models. Firstly, how rapidly should they change? Is it better to cannibalise your core business now to create first-mover advantage but risk moving too soon, leaving excess profits for those moving more slowly, or to wait for others to take the first steps and stick to what you currently do well? Secondly, irrespective of the answer to the first question it would appear that companies need to be prepared to move fast if necessary and to have an open mindset ready for change. It seems reasonable to assume that policymakers may make rapid and potentially radical decisions at unexpected times and, depending on whether consumer habits either change or stay inert, companies will need to be able to respond quickly in order to prosper. Thirdly, companies may also need to ask themselves whether this more flexible approach is compatible with the operation of their existing core functions, or whether the "traditional" (power generation, trading, and upstream) and "modern" (renewables, decentralisation, and energy efficiency) parts of their business need to be separated.[71] A number of companies have adopted this approach already, but it remains uncertain whether this will become an industry norm or an anomaly. These issues are equally valid for companies in the upstream and supply parts of the energy business as for those involved in transmission or distribution of energy to consumers. The added complication for those companies further downstream is that they may not be leading the drive for change but will need to adapt to the availability of supply from new energy sources and customer demand for them.

A wider challenge relates to the fact that energy companies are less likely to be able to operate in a vacuum as the transition progresses. The energy system is likely to become more interconnected (for instance through the coupling of infrastructure and at the consumer end of the value chain)[72] and to become more closely related to other areas of policymaking (such as urban planning). This is for instance being seen in the integration between the mobility and electricity industries. As such, their business model will need to be both flexible enough to cope with radical change as well as to adapt to changing patterns of energy demand. Difficult choices around the timing and extent of investments will need to be made, with the implication that infrastructure companies could become the key to unlocking the energy transition.

2.7 Developments in Markets for Fossil Fuels and Markets for Electricity

As always, though, the consequences of policy, regulation, business activity, and consumer responses will be seen in the market, where the prices of energy supplies and the other externalities that impact

[69] See Sen et al. (2021).

[70] Stern, J. (2020)

[71] For example "German utility E.ON to split in two in major overhaul at https://www.cnbc.com/2014/11/30/german-utility-eon-to-split-in-two-in-major-overhaul.html

[72] An example would be through inter-modal shifts in patterns of consumption, for instance in transport.

them (such as carbon prices) will be established. A key issue will therefore be how the markets for various products will interact and what the impact of relative price movements will be on the energy transition. A second core question will then be if, and when, certain types of energy markets can be re-designed to cope with the energy transition and to catalyse certain outcomes.

Already the movements of hydrocarbon prices are having an impact. If prices for oil and coal fall in anticipation of lower demand over the long term, this could lead to a short-term rebound effect on demand, delaying the opportunity for lower-carbon and decarbonized fuels to build market share. A rising carbon price can act as a counterbalance, but this then raises the issue of whether the carbon impact will be priced in a similar way across all regions. The EU is clearly trying to encourage cooperation with its discussion of a carbon border adjustment mechanism, while China and various states in the US have introduced carbon markets. However, it remains the case that the price of hydrocarbons (including environment taxes), relative to each other and to the price of renewable energy sources, will be a critical issue.

Indeed, these issues raise the concern of whether liberalised markets can be expected to provide a suitable foundation for an era when the development of technology to encourage decarbonisation is of paramount importance. Significant state involvement has already been seen in the electricity sector, with various incentives provided for solar and wind energy, while wholesale electricity market design has also become a critical issue due to the price volatility caused by the introduction of intermittent renewables with high capital costs but a zero-marginal cost, into a market that was originally designed for fossil fuels with a different cost structure. This has already created problems for suppliers of dispatchable power. While capacity markets have temporarily resolved this issue, the 'ultimate' model of the decarbonised power sector is yet to be determined, and the role of auctions and long-term contracts will need to be observed as the transition progresses.[73]

Gas markets may well also need to be re-thought if new energy vectors such as hydrogen are to have a major impact. It seems very unlikely that, unless environmental externalities are fully priced in, hydrogen will be able to compete with natural gas on cost alone, at least in the short term, leaving it to regulators to provide the incentives required to catalyse development spending. Furthermore, other market initiatives may well be required to encourage activity to reduce carbon emissions. One obvious example is the potential for carbon offsets to be traded on markets such as the EU ETS, while the interaction of storage markets for power, natural gas, hydrogen, and carbon would seem to be another fertile area for market development.

Beyond this, the matter of regional market interaction will be vital if carbon leakage is to be avoided and economic imbalances are not to be created which could undermine the political will to combat climate change. Indeed, although markets could deliver efficient outcomes, they may not necessarily provide just outcomes. As discussed in Section 2.1, governments will therefore need to address issues of energy justice outside the market; a failure to do so may mean that the role of markets in the transition process will continue to be a subject of intense debate. Indeed, as noted above, their effectiveness in the energy transition may also be actively questioned if they fail to deliver the necessary reductions in emissions within targeted timeframes. The prospect of governments needing or deciding to pick winners to achieve environmental goals, or assigning greater weight to energy justice in their decision-making, must be considered as a serious option.

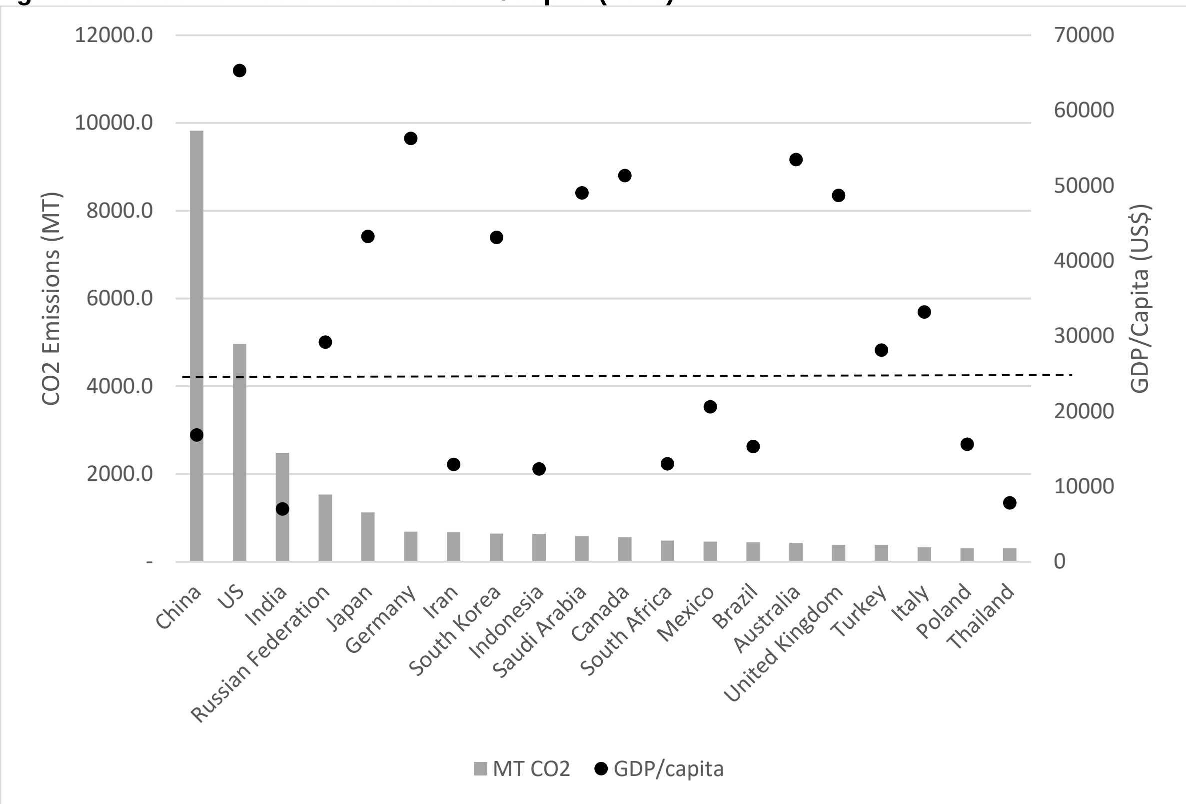
2.8 Regional developments

A further layer of complexity in the energy transition debate is evident in the fact that different countries and regions are starting from different positions both in terms of their economic development, current energy mix, and carbon emissions. Figure 8 compares total carbon emissions with GDP/capita for the

[73] For a discussion of electricity markets see Robinson. D. & Keay, M. (2020).

twenty largest emitters of CO_2 in the world. Of these, nine sit below the $25,000 per capita threshold often used as a broad definition for developing countries, while a tenth (Russia) is described by the UN as a country "in transition."[74] This would suggest that these countries are likely to prioritise development spending and that climate goals will only proceed rapidly if governments perceive them to be in line with other socio-economic objectives (e.g. addressing air pollution). If they are not, then government expenditure on the development and implementation of technologies to pursue climate-related targets could be constrained.

Figure 8: Carbon emissions versus GDP/Capita (2019)



Source: Data from BP Statistical Review of World Energy and World Bank

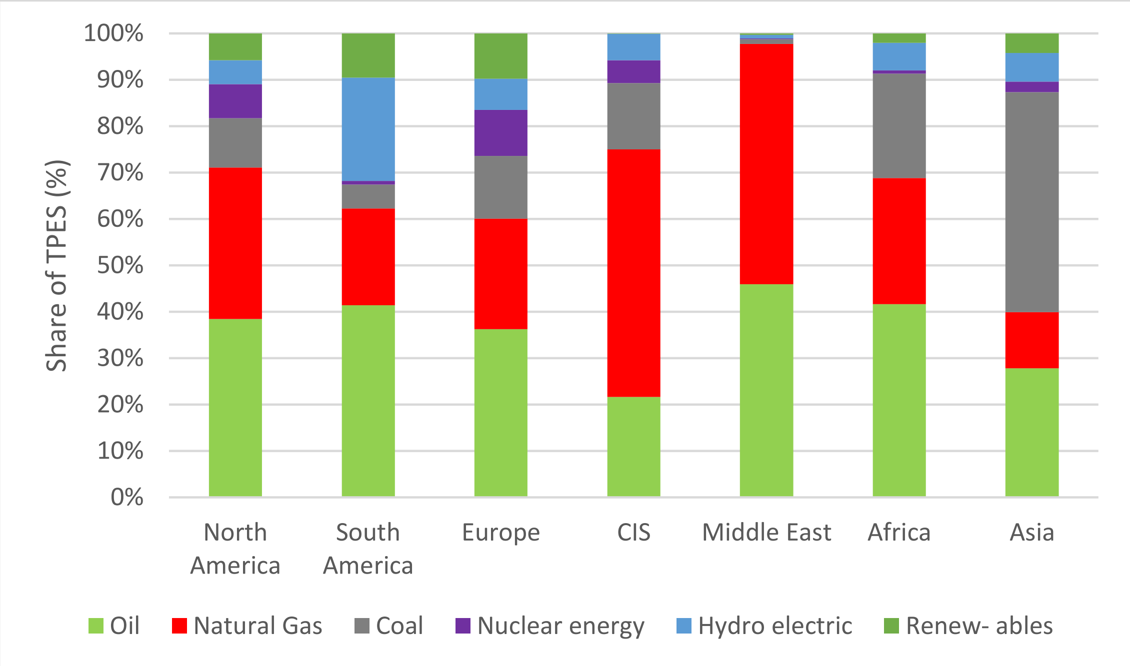
Secondly, energy mixes vary dramatically both within and across regions. This can be clearly seen around the use of coal and nuclear energy in Europe, where opinions vary widely over the future of both sources of energy. Across the globe, though, the starting point for any energy transition is clearly different, as shown in Figure 9. While regions such as North America and Europe have relatively balanced portfolios of energy supply (albeit still dominated by hydrocarbons) and so a shift to more renewable energy is a relatively natural progression, regions such as the CIS, the Middle East, and Asia start from a position of greater dominance by one or two fuels. In the case of the CIS that fuel is gas, and as this is the relatively cleaner hydrocarbon the incentive to change in the absence of internal or external pressure is reduced. Meanwhile in Asia, coal dominates, meaning that there are two possibilities: first, that the energy transition in its early stages may include a shift from coal to gas and second, that countries could alternatively leapfrog to renewables. Finally, the Middle East is

[74] There is no specific definition of developing countries. Of the 20 countries in Figure 7, 11 are defined by the UN as developing countries, but these include South Korea which has a GDP per capita much higher than some of the supposedly developed countries.

unsurprisingly dominated by oil and gas, and although the potential for renewables (especially solar) is high, it will be difficult to move away from fuels which are cheap and underpin both the domestic economies and export revenues, without substantial fiscal reform.[75]

Security of supply is also a critical issue from a country and regional perspective, from which two overall hypotheses emerge. Firstly, one might expect regions which import large shares of their energy requirement to be keen on the development of renewable energy as an indigenous source of fuel, although this could create different supply chain challenges for the new materials required for the energy transition. Secondly, one might expect a reluctance to move rapidly away from indigenous energy sources that are abundant, relatively cheap, and which provide employment and domestic wealth. This is a clear issue for countries such as China,[76] India, and Indonesia as they contemplate a need to move away from coal, and for Middle Eastern oil producers as they anticipate a potential decline in domestic and export demand for product which underpins their economies.[77]

Figure 9: Share of Fuels in Energy Mix (2019)



Source: Data from BP Statistical Review of World Energy 2020

Overall, then, it is necessary to consider the differing regional dynamics that will create a multitude of incentives to action with regards to changes in the energy mix required to meet climate goals. Evidence of potential conflict is already seen in arguments about how investments in cleaner energy should be paid for, with developing countries arguing that although they may be a growing source of emissions now, the problem has been created by, and the solution should be financed by, the developed countries who are historically responsible for climate change, having emitted CO_2 and other pollutants since the industrial revolution in the 19th century.

Furthermore, the concept of a just transition also incorporates the need to anticipate the problems that the decarbonisation of the energy system is likely to have on countries which rely on the supply of

[75] For an analysis of the MENA region see Poudineh, R. & Fattouh B. (2020).
[76] See OIES China Programme at https://www.oxfordenergy.org/china-energy-research-programme/ and in particular Meidan, M. (2020).
[77] As an example, see Fattouh, B. (2021) on Saudi oil policy.

hydrocarbons for a large share of their revenues. Although diversification would seem to be an obvious answer, it may be unrealistic to expect rapid transformation or even overall support for the transition process unless there is acceptance that some technologies, such as CCUS and Direct Air Capture, which can form part of a circular carbon economy, can play a role even though they could prolong the use of hydrocarbons in the energy system. While some are sceptical about these technologies for this very reason, others argue that they will be vital for the energy transition both because the use of oil and gas will inevitably continue for some time, and also because they can encourage oil and gas producers to make a positive contribution to the transition rather than adopting a non-cooperative stance.[78] As such, the differing energy mixes, economic development, and import/export positions of countries across the world will continue to dominate the debate around the energy transition.

2.9 Sectoral developments

A further layer of complexity in understanding the opportunities and risks in the energy transition can be seen through the lens of the various energy consuming sectors in the economy (with each of these in turn also reflecting the regional dynamics discussed above). The main focus to date has been the power sector, where the introduction of renewable energy to displace hydrocarbons has been the most obvious, and early, route to decarbonisation as it provides significant emissions reductions.[79] However, although this progression has further to run in all regions, the need to start focusing on other more difficult sectors is now becoming obvious.

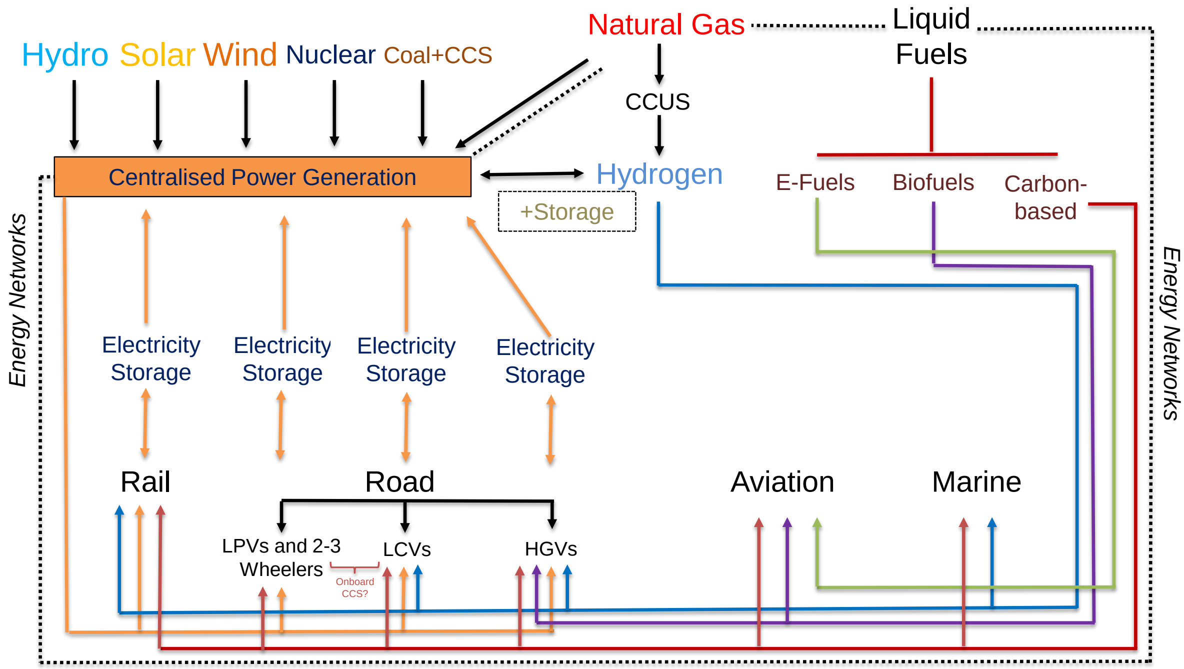
The largest, and most complex, sector is heat, which covers both heat for industrial processes as well as heating for buildings (including residential) plus cooking. Within the industrial context, one of the key issues (many of which have been covered by Honore (2018))[80] surrounds the levels of heat required and the ability of various fuels to reach higher temperatures. Gas, coal, and electricity all play a role, and in future hydrogen can also be added to the mix, depending on the exact process that is taking place. Furthermore, some hydrocarbons are used as inputs for petrochemicals and refining and will be hard to replace, with the production of plastics being one area where continued long-term use of oil is anticipated. The adoption of circular economy approaches, discussed earlier, could potentially mitigate emissions in these 'hard-to-abate' sectors, but policy frameworks would need to ensure that there would be a net economic as well as environmental benefit overall.[81] Meanwhile, in terms of the heating of buildings and cooking, a switch from gas to electricity is certainly anticipated in many countries, but faces challenges surrounding existing infrastructure, the suitability of housing stock and the willingness of consumers to make necessary changes. Again, hydrogen can play a role in some areas, and distributed renewable energy solutions can also contribute in countries with underdeveloped infrastructure, but overall these sectors provide difficult questions in terms of the optimal route to decarbonisation.[82]

Finally, the transport sector offers a diversity of challenges across its multiple sectors, stretching from rail and road to aviation and marine. Figure 10 below shows the options currently being assessed in each area and highlights that while electricity is expected to become a much more prevalent form of energy for transport, various forms of liquid fuel will continue to be consumed, and use of gaseous fuels (especially hydrogen) could provide an additional alternative over time.[83] Of course, the benefits of electrification of transport depend on the source of the power being used, and cost remains an issue while battery technology continues to be developed, but there is clearly hope that in the road sector the

[78] Fattouh, B. et al (2021)
[79] Fattouh, B., Poudineh, R. & West, R. (2018)
[80] Honore A. (2018)
[81] See Sen et al. (2021).
[82] As another example see Keay, M. (2020).
[83] See paper from OIES Transport Day in 2018 at https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/01/Disruptive-Change-in-the-Transport-Sector-8-Takeaways.pdf

vehicle fleet can become an enabler of energy system integration and can therefore create system efficiencies as well as new sources of demand.

Figure 10: A potential future energy system for the transport sector



Source: OIES

2.10 Consequences for geopolitics and energy security

All the dynamics of the energy transition described above also raise the question about what the global energy map will look like in thirty years and who might be winners and losers from the changes that are already underway. For more than fifty years, oil and gas have been at the heart of the geopolitics of energy, with questions of trade flows, energy security and economic power at the fore, but if climate targets are to be met then it would seem that significant changes to the energy landscape are inevitable. The outlooks for oil and coal in particular appear bleak, although as we have discussed in the introduction, they are unlikely to immediately recede from the global energy mix, while the prospects for gas are rather more nuanced. Nevertheless, a simplistic conclusion to reach is that exporters of traditional forms of hydrocarbon energy are likely to struggle in the energy transition while energy importers who adapt to renewable energy more rapidly could be winners.

However, as discussed in a recent edition of the Oxford Energy Forum,[84] the development of the global energy picture is likely to be rather more subtle than this. While there will certainly be challenges for incumbent producers as demand for their products is threatened, there will be opportunities too for those who can become or remain low-cost suppliers of products with a lower carbon intensity. In addition, just as energy companies are adapting to the transition, so many oil and gas producing countries are preparing to change, with the opportunities for solar energy, CCUS, and hydrogen in the Middle East being obvious examples. Indeed, the battle to become a leader in renewable and low-carbon technology and in the development of renewable energy heartlands could become the new theme of energy geopolitics over the next two to three decades, while the control of supply chains involving decarbonised and renewable energy is also likely to emerge as an important topic as countries

[84] Oxford Energy Forum Issue No.125, (January 2021)

and companies balance the potential risk of switching from one form of dependency (on oil and gas) for another (on low carbon fuels). One example is the increasing efforts being made to secure the raw materials, rare earths, refining and manufacturing capacity needed to produce batteries, electrolysers, and other equipment vital for the energy transition on a large scale, with China currently at the forefront but with other countries now realising that this is a contest which they cannot afford to lose.

Given the technological requirements of the energy transition it seems likely that the foundations for the new geopolitics of energy will be centred on the ability to develop and produce the equipment that will be at the heart of the decarbonisation of the global energy economy. The Chinese authorities appear to be very focused on the goal of becoming a leading player,[85] and although the US has been slow to react, its potential to exploit its financial and entrepreneurial resources is also high. Meanwhile countries such as Russia, where the impact of climate change as a major issue has been downplayed, would seem to be lagging behind with potentially disastrous consequences for its geopolitical influence. However, despite the potential conflict which could occur, an alternative pathway could emerge that might lead to greater cooperation in the face of what is a global challenge. Although it may be an optimistic suggestion, it may also be possible to conceive of a world in which the global pandemic could catalyse a more collaborative effort to solve another existential challenge facing the world's population.

Conclusion

The ultimate objective of the energy transition is clear – the decarbonisation of the global energy system in order to achieve net zero emissions and a global temperature rise of no more than 1.5^{o} C by the end of the century. The ultimate replacement of hydrocarbons by renewable power and other forms of decarbonised energy will be fundamental to this process.

Nevertheless, it is important to recognise that the transition is, as its derivation suggests, a process of moving from one state to another, and if it is to be successful must involve the managed decline of the existing energy system as well as its transformation towards a future state. Policymakers have set countries on this essential road, and technology is the key to accelerating the process, but many complex questions remain to be resolved if the world is to avoid the transition becoming a disorderly mess.

At one level these concern issues such as regional differences in terms of economic factors and the energy mix, the reaction to energy transition from heterogenous groups of consumers with varied preferences, and the geo-political consequences of re-drawing the energy map. At another level the pace of technological change, the re-purposing, refurbishment or replacement of infrastructure, the impact of market forces and the need for companies to radically adapt their business models in order to align with both government policy targets and regulations, and consumer preferences, all add extra layers of complexity, which are further compounded by the need to consider these questions across different countries and multiple sectors of the economy.

Given these issues, and the uncertainty over the achievable pace of change, the incumbents in the current energy system face a multi-layered challenge to determine the risks to their current business, to formulate a strategy to thrive in a re-shaped energy sector and global economy and to assess the optimal speed at which to implement their plans for change. It is arguable that the solutions which incorporate future use of abated hydrocarbons, as well as their removal, may need to be considered to encourage cooperation from across the spectrum of energy suppliers and consumers.

Arriving at a successful outcome will involve an assessment of all the questions raised in this short paper to arrive at a full understanding of how the current energy value chain may be restructured over the next two to three decades. This will involve analysis of new technologies, government policies,

[85] For a discussion of China and the geopolitics of energy see Meidan, M. (2020).

regulatory frameworks, consumer preferences, the interaction between different energy vectors, an understanding of varying regional and sectoral perspectives, risks and uncertainties, a willingness to develop new business models, and an appreciation of the potential geo-political consequences of the energy transition.

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