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The Energy Transition in Word & Deed:

Recovery, Decarbonisation, and Financial Risk

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Talk of the energy transition is not new. Yet heightened rhetoric across the policy world (the European Green Deal, net-zero pledges of the world's major economies; including China, the return of the U.S. to the Paris Climate Agreement), coupled with profound commercial developments, have generated great momentum in the growth story for renewables and associated decarbonisation pathways. This document provides an abridgement and commentary on the global energy transition. The aim is to synthesise major developments and the general contours of debate in the energy transition thus far. This includes: major policy announcements, changes in the fossil fuel industry, and the promise of renewables, all in light of internationally-established climate-related goals.

Introduction

This document provides an abridgement and commentary on the global energy transition. The topic is vast, dynamic, and only a non-exhaustive treatment possible. The aim is to synthesise major developments and the general contours of debate in the energy transition thus far. This includes: major policy announcements, changes in the fossil fuel industry, and the promise of renewables, all in the light of internationally-established climate-related goals. The paper attempts to differentiate itself through a more detailed examination of the coal, oil, and natural gas industries, juxtaposed with current climate-related targets. There is an emphasis on the structural, cyclical, and seasonal, particulars of the commodity markets in question, and how these particulars may figure in the ensuing debate of how the deployment of renewables and fossil fuels may fare. The document is supported by primary interviews conducted by the author, in tandem with a round-up of secondary commentary across industry participants and major stakeholders. The article is interspersed with recommended reading for more academic treatments of some of the issues at hand, as well as prompts for further reading.

The Major Contours of the Debate

Talk of the energy transition is not new. Yet heightened rhetoric across the policy world (the European Green Deal[1], net-zero pledges of the world's major economies including China, the return of the U.S. to the Paris Climate Agreement[2] amongst other developments[3]), coupled with profound commercial developments (the, albeit briefly, valuation of renewable energy giant NextEra Energy in terms of market capitalisation over Exxon Mobil in October 2020[4]), have helped to generate momentum in the growth story for renewables and associated decarbonisation pathways. That much is certain. So too is the fact that the swift changes public and market sentiments have not been lost upon the major oil and gas players of the world, some of whom (in an environment of changing government policy and capital investment decisions[5]) have pledged to "build back better" amidst contested predictions of the industry's wholesale demise. Total's CEO Patrick Pouyanné, for example, recently warned in February 2021 of a market bubble within the renewables sector, that the traditional business base of oil and gas majors will still be needed to generate the cash for green investments, and that the shift to renewables in general as part of the energy transition will not be cost-free[6].

In homage to the maxim that "every crisis presents an opportunity", as the world adjusted to the global pandemic a flurry of discourse has proliferated with anticipation of the profound, and in some commentaries permanent changes readily assumed to be nigh on the horizon, no less so than in the global energy industry[7]. Though definitions vary, broadly the "energy transition" refers to wide-scale processes to significantly alter patterns of global energy consumption, in light of established international climate goals. Given the sheer scale of what the term can be associated with, Blazquez et al. (2020) understandably state that "energy transitions are a multidimensional, complex, non-linear, non-deterministic, and uncertain phenomenon and, therefore, they are difficult to characterise". Features associated with the energy transition include: the gradual but now heightened attention on decarbonisation and the uptake of renewables (with recent track record of record implementation and lower production costs), a more resolved political drive towards international climate-related goals, and the subsequent pressure on the fossil fuel industry. As the word transition implies, there is a process at stake underlined by a greater uptake of renewable energy resources, commitments to decarbonisation to minimise degrees of global warming[8], but also the creation of a new growth market, characterised no less than the "motor of the recovery" post-pandemic (at least asserted as such for the European Union[9]). The European Green Deal emphasises wide-ranging structural changes in light of climate-related goals, a central tenant of which is that of a circular rather than linear economy which, in essence, emphasises sustainable consumption. The World Economic Forum posits that revolution might be a more apt term than transition. The EU's latest Climate Action Progress Report places

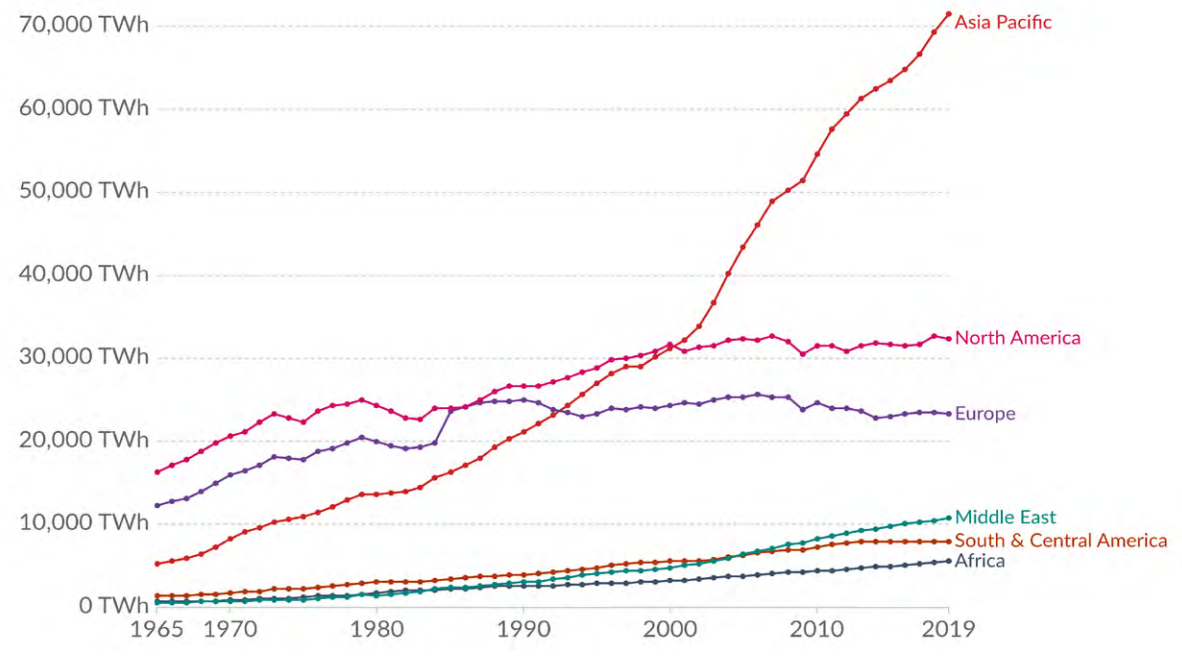
[1] Wood Mackenzie provides a concise summary of the energy transition here.
[2] The Paris Agreement is a landmark international treaty on climate change that entered into force in November 2016. The overall goal is to limit expected global warming to below 2 degrees Celsius (compared to pre-industrial levels) in this century - preferably to 1.5 degrees Celsius – by reducing greenhouse gas (GHG) emissions to around 40 gigatonnes by 2030. 2019 saw over 50 gigatonnes of GHG emissions. Stakeholders put forward nationally determined contributions (NDC's) reviewed every 5 years. The Paris Agreement is the contemporary culmination of numerous international efforts over the years to combat climate change. In November 2021, world leaders will gather in Glasgow for the successor meeting.
[3] When the U.S. returns to the Paris Agreement and adopts a net-zero GHG emissions target, 63% of the world's GHG emissions will be subject to net-zero goals either formally adopted, announced or under consideration, by 126 countries (United Nations Environment Programme – UNEP - 2020).
[4] A detailed round-up of major climate-related news and developments in both the policy and commercial worlds (including the oil and gas industry and the world of finance) in 2020, is here in Bloomberg Green (December 2020).
[5] According to The Economist (December 2020), energy was the worst-performing sector in the S&P 500 index of large U.S. firms in 2019, 2018, 2015, and 2014. $350 billion in stock market value has recently been lost, and the return on capital for five major Western firms – ExxonMobil, Royal Dutch Shell, Chevron, BP, and Total – sunk by an average of three quarters from 2008-2019.
[6] Wood Mackenzie suggests that full decarbonisation of the US power grid would cost $4.5 trillion.
[7] The global pandemic has been seen as a precursory global crisis to those which climate change will induce in the future.
[8] As per the IEA (December 2019), "no single indicator can fully capture the complexity of the global clean energy transition", though the most "comprehensive clean energy transition indicator is a country's or region's energy-related carbon emissions", given the fact that the energy sector accounts for nearly 90% of CO2 emissions globally.
[9] The think-tank Bruegel describes the situation as an industrial revolution against a deadline.

pride of place the fact GHG emissions fell between 2018 and 2019 by 3.7%, whilst GDP grew by 1.5% year-on-year, albeit weaker than recorded in 2018. "The European Union is proving it is possible to reduce emissions and grow your economy", Frans Timmermans, Executive Vice-President for the European Green Deal, has said.

At the global level, primary energy demand and GHG levels are still set to increase. Haberl et al. (2020) offer a systematic review of latent evidence on decoupling of economic growth from natural resource consumption and GHG growth, and a series of conclusions from the burgeoning literature on the topic. Firstly, there are absolute versus relative decoupling measures to consider. The former denotes GDP growth coinciding with absolute reductions in emissions and resource use, whilst the latter refers to emissions and resource use utilised increasingly less so than GDP. In other words, emissions and resource use still grow, but do so relatively slower than GDP growth. It is a logical necessity, the authors state, to decouple in absolute terms GDP "from the use of biophysical and/or emissions", to climate and sustainability goals[10]. Unsurprisingly, the authors find that though "energy and GDP are strongly related", but that a robust conclusion on the direction of causality between them cannot be drawn. The study suggests that relative decoupling between GDP growth and emissions/natural resource consumption, has been the more common achievement thus far. The observations made in the study fall short of the large-scale absolute decoupling necessary to achieve international climate targets. The authors then raise a more radical but pertinent question of whether GDP and structural dependence of continued economic growth is the best measure of economic policy and welfare. In any case, "Low economic growth is not a low-emissions strategy" the IEA recently asserted.

For the fossil fuel industry, three major lines of debate have been re-energised: the confidently predicted "end of coal[11]", the often-anticipated scenario of "peak oil[12]", and a heightened debate on the role of natural gas in the energy transition. Though exactly what the future holds is fundamentally uncertain, stakeholders have found it necessary to adjust to major long-term climate-related policy announcements, sentiments, and the nascent volatility in the oil and gas industry[13]. Lynch and Sandrea (2021) of the Energy Policy Research Foundation note that the case for a near-term peak in oil demand is more plausible that the case for a near-term peak in supply, but nevertheless the

Figure 1: **Primary Energy Demand by World Region** *(TWh)*



Source: Our World in Data

[10] The IPCC (2018) states that "climate change can only be mitigated and global temperature be stabilised when the total amount of CO2 emitted is limited and emissions eventually approach zero".

[11] A distinction is to be made between coking (metallurgical) coal used in steelmaking and thermal (energy producing) coal, the former said to be "less susceptible in the immediate term to a global energy pivot towards renewables".

[12] Professor Gavin Bridge, University of Durham, defines peak oil as "an impending, permanent decline in the production of so-called 'conventional' oil as geophysical limits on its availability begin to bite". In January 2018, BP described the peak oil scenario as a "shift from an age of perceived scarcity to an age of abundance – and with it, a likely shift to a more competitive market environment".

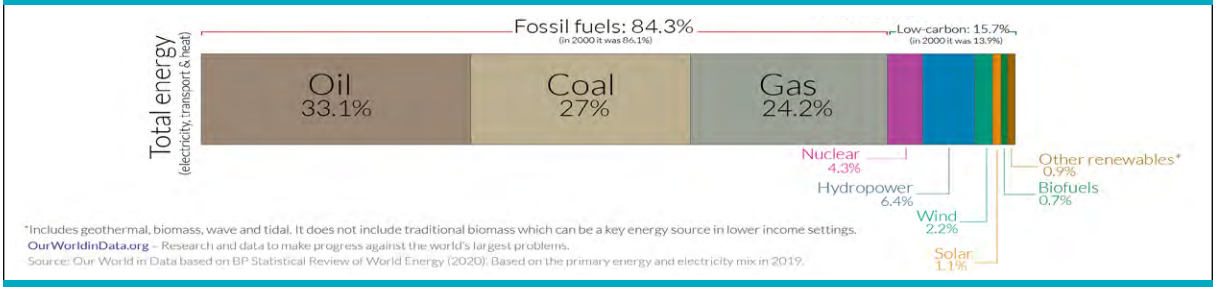
[13] Goldman Sachs estimates that renewable power will be the largest area of spending in the energy industry in 2021, surpassing upstream oil and gas for the first time in history.

crescendo of peak oil claims remains unwarranted. The shape, pace, and depth of an expected global recovery, and the thus-far preeminent role of fossil fuels for global primary energy demand, is now squarely set against the climate-related goals of the energy transition. Global primary energy demand is still set to increase in the decades to come. In BP's 2020 outlook, global primary energy demand still increases by around 10% in its Rapid and NetZero scenarios and around 25% in its BAU (business-as-usual) scenario. The consensus seems to be that is that primary energy demand (largely met with fossil fuels) eventually slows-down, plateaus, or decreases, earlier in the more developed and affluent countries of the world, where per capita energy use in particular declines, and where economic growth relies less on energy produced from fossil fuels. Major energy forecast publications now differentiate between numerous scenarios that incorporate current trends and stated policies, as well as changes expected as a result of stricter climate-target adherence. The IEA presents a Stated Policies Scenario (STEPS), a Delayed Recovery Scenario (DRS), a Sustainable Development Scenario (SDS), and finally a Net-Zero by 2050 outlook (NZE2050). STEPS sees global energy demand rebound to pre-crisis levels by 2023, and by 2025 in its DRS, although as with most outlooks, variation between developed and developing, OECD and non-OECD economies is envisaged. The IEA also asserts that primary energy demand in advanced economies has been on a downward trend since 2007, and will not return to 2019 levels in its STEPS scenario. Figures from Eurostat suggest that primary energy consumption (total energy demand) fur the EU peaked in 2006. Further, though major short-term uncertainties prevail regarding the duration and severity of the pandemic in terms of its economic implications, (together with uncertainties regarding the implementation of clean-energy scenarios), all of which compound forecasting efforts, institutions such as Bloomberg NEF have made nevertheless made bold assertions. Bloomberg NEF has asserted for example that 2019 may have been a year of peak energy emissions.

The historical record of CO_2 emissions from the global energy industry itself makes for sombre reading. As of December 2019, the energy sector is said to account for nearly 90% of CO_2 emissions globally (IEA 2019), and around 78% of all greenhouse gas emissions (GHG) (Our World in Data 2017), whilst around 84% of the world's energy needs still comes from fossil fuels (Figure 2). Though energy is certainly the dominant source of GHG emissions, "pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems [...]", as per the IPCC (2018). Between 1959-2019, CO_2 emissions from various uses of fossil fuels were estimated by the Global Carbon Project to be on average 81% of global emissions. CO_2 is the predominant form of GHG. In 2019, electricity/power production accounted for 44.3% of global CO_2 emissions, industry (22.4%), surface transport (20.6%), public buildings and commerce (4.2%), residential (5.6%), and the aviation sector (2.8%). Throughout this all, the three major fossil fuels of oil, coal, and natural gas have long since held predominant positions in fuelling the world's growing primary energy demand[14]. Net-zero emissions are necessary to reduce or stabilise atmosphere CO_2 concentrations and eventually incur temperature reductions. As per the IPPC, limiting global warming to 1.5 degrees Celsius implies reaching net-zero CO_2 emissions globally by 2050, with reductions in non- CO_2 emissions such as methane not to be forgotten, nor the fact that even if emissions decrease, concentrations of GHG do not necessarily decrease in tandem. On the contrary, concentrations of major GHGs continued to increase in both 2019 and 2020 (UNEP 2020). There are also warnings that global emissions have in fact not yet peaked, and in fact will continue to increase in the near-future, whilst Climate Action Tracker (November 2020), asserted that only Morocco and Gambia have made commitments in line with the 1.5-degree target.

Concerns regarding the long-term feasibility of current climate goals thus remain, despite the shorter-term effects of the global pandemic on global economic activity, which indicate a need to sustain and strengthen demands for effective change in earnest[15], as well as the adoption of consistent climate-related targets across the world. In December

Figure 2: Global Primary Energy Consumption by Source

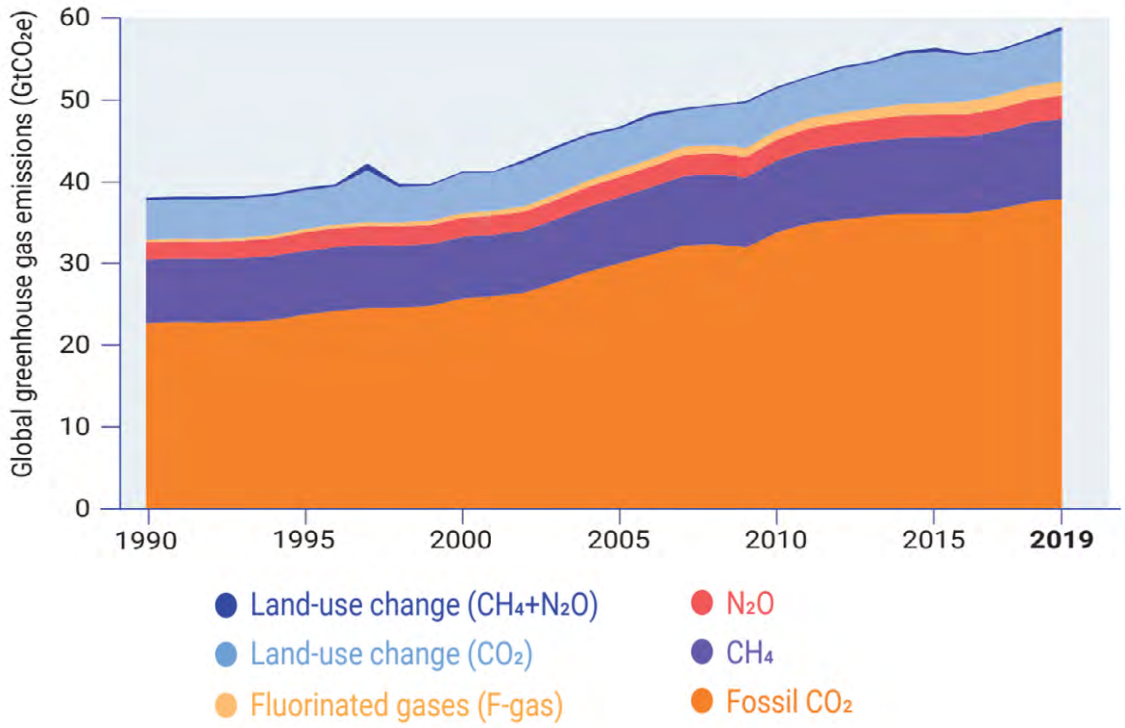


Source: Our World in Data

14 As per the Financial Times (October 2020), the share of fossil fuels in the global economy dropped by one percentage point between 2010- 2019, "despite plummeting clean-energy costs, rapid advances in battery technology and 25 years of high-level UN climate conferences. Four-fifths of the energy consumed last year still came from oil...".

15 "They're going to try and lock in as much expansion as they can at this moment, and so our job is to stop them in the markets, to stop them in the ground, and eventually to put in place the rules, the laws, and the international agreements to stop them everywhere", asserted Tzeporah Berman, international director of Canadian non-profit Stand, in this article for Gizmodo.

Figure 3: **Global GHG Emissions by Source**



Source: UNEP (2020)

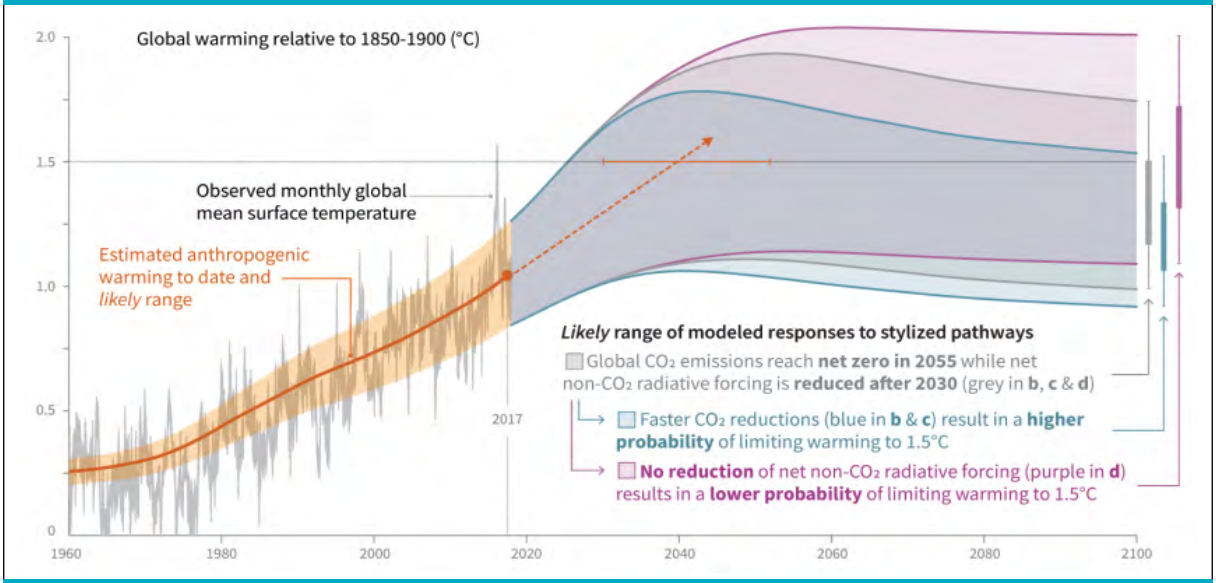
2020, the UNEP's emissions gap report asserted that the world was "absolutely not" on track to bridging the gap between estimated future global greenhouse gas emissions (if existing climate mitigation pledges are honoured), nor to bring global emission levels consistent with the temperature goals encapsulated within the Paris Agreement. A recent UN press release based assessing an initial United Nations Framework Convention on Climate Change (UNFCC) report on NDCs from member countries also painted a bleak picture:

"2021 is a make-or-break year to confront the global climate emergency. The science is clear, to limit global temperature rise to 1.5C, we must cut global emissions by 45% by 2030 from 2010 levels. Today's interim report from the UNFCCC is a red alert for our planet. It shows governments are nowhere close to the level of ambition needed to limit climate change to 1.5 degrees and meet the goals of the Paris Agreement".

The UNEP goes on to single out oil and gas as drivers of the growth in global emissions, with natural gas in particular addressed as the largest contributor to recorded fossil CO_2 emissions. GHG emissions grew consecutively between 2016-2019, reaching a record high of around 52.4 gigatonnes of CO_2 (59.1 gigatonnes including land-use change data) in 2019 (Figure 3). Many OECD countries have already reached peak GHG emissions, the UNEP asserts. The OECD (2020) itself states that emissions of member states peaked in 2007, have fallen by 9% between 2010 and 2020, and "now seem to be stabilising, [...]", though "GHG emissions are expected to rise again due to recent increase in energy use [...]". Interestingly, the OECD mentions that some countries have managed to reduce GHG emissions in absolute rather than relative terms whilst GDP has grown. Overall progress with regards to the level of emissions are nevertheless deemed insufficient. On a per-capita basis, OECD countries (which emit around 35% of global CO_2 emissions from energy), also emit more CO_2 than most other world regions. Emissions continue to rise in developing countries alongside energy consumption. The UNEP laments the vast discrepancy between recently-announced ambitious net-zero goals and the comparatively wanton current nationally development contributions. Under current NDC's, overall, there is an emissions gap centring around 15 gigatonnes by 2030 compared with the below 2-degree scenario. The UNEP has cited 41 gigatonnes by 2030 in its "least-cost pathway" to limit global warming to below 2-degrees by 2100 "with limited overshoot".

Targets are necessary, for they garner attention, influence market sentiment, and provide a benchmark for political accountability. It has also been suggested that a degree of constructive ambiguity is necessary to achieve initial agreement. Differences can also be observed between the various climate-related policy goals or scenarios adopted by relevant stakeholders. Levels of optimism vary between projections. The head of the IEA – Fatih Birol – states that he is "more optimistic than ever" given perhaps the momentum of the energy transition thus-far, yet warns that "nothing short of a total transformation of our energy infrastructure is required – a worldwide undertaking of unprec-

Figure 4: Cumulative CO^2 emissions & non- CO^2 Radiative Forcing & the Probability of Limiting Global Warming to 1.5 degrees Celsius



Source: IPCC (2018).

edented speed and scale[16]". Similarly, Ernest Moniz – Secretary for Energy of former U.S. President Barack Obama – has opined that "we have to go all out now, in this decade, with a major all-of-the-above innovation agenda". What follows now is first a closer inspection of the fossil fuels industry, with a deduction of structural, cyclical, and seasonal characteristics for oil, coal, and natural gas demand. Writing in September 2020, S&P Global Platts asserted that the impact of the pandemic on long-term global oil supply and demand is more "a decided step down, but not a step change". The pandemic has been a "significant, but not [a] transformative event". For S&P, the recent downturn in oil demand has not been enough to substantively bring forward a peak oil scenario for 2025, modelled prior to the pandemic. Though the pandemic is forecast to reduce energy sector CO_2 emissions by 27.5 gigatonnes between 2020-2050, and though a record fall in fossil fuel CO_2 emissions was recorded for 2020, more than 10 times this figure in gigatonnes is needed to meet a 2-degree global warming scenario through 2050[17]. 2020 saw around a 7 percent drop in CO_2 emissions compared to 2019, though by some estimates this would need to be sustained to reach net-zero emissions by 2035 and thereon better than even odds of limiting global warming to 1.5 degrees Celsius (Figure 4).

Finally, the role that oil and gas majors could play going forward is still up for debate. David Rabley, managing director at Accenture, has said that although demand for oil may fall long-term, oil fields not yet in production will still be needed to satisfy that lower demand. In December 2020, Rystad Energy asserted that given the current pace of the energy transition and the composition of global primary energy demand, "the world is on track to run out of sufficient oil supplies to meet its needs through 2050, despite lower future demand due to the Covid-19 pandemic and the accelerating energy transition". The behaviour of oil and gas companies will most certainly alter amidst the energy transition, with some entities becoming broad energy companies (with renewables and hydrocarbons), digging-in and focus on low-cost and cleaner oil and gas production (the last-man standing scenario), or pivoting entirely into clean energy. That the entire industry, its infrastructure, and capabilities, cannot be capitalised upon in some way seems farfetched. "Fossil fuels will only be doomed if something reliable, affordable, and scalable can replace it", says Phillip Lambert, chief executive of oil industry advisers, which raises the question of the practical comparative advantages between fossil fuels and renewables given latent technological and infrastructural capabilities. The cost-effective scale-up of renewables will inescapably vary by geography given factors such as distance to market or right from the start in terms of solar and wind intensity for example. Whether bottom-up, process orientated views of energy demand that juxtapose energy sources and consumers (energy-using capital stock), intensity and efficiency of use, or a more macroeconomic top-down approaches (price, population, GDP) – as well as the interplay between them – are consulted, clearly there are numerous moving pieces set against pledged climate targets that only begin to tell the complexity of the quest at hand, facets of which are introduced in the following section[18].

16 The IEA is expected to publish in May 2021 a comprehensive roadmap for the global energy sector to reach net-zero CO2 emissions by 2050. The IEA seems more pessimistic for a net-zero by 2050 scenario.

17 Bloomberg's New Energy Outlook 2020 asserts that CO2 emissions need to fall 10 times faster at 6% per year until 2050 to keep global warming below the 2-degree mark.

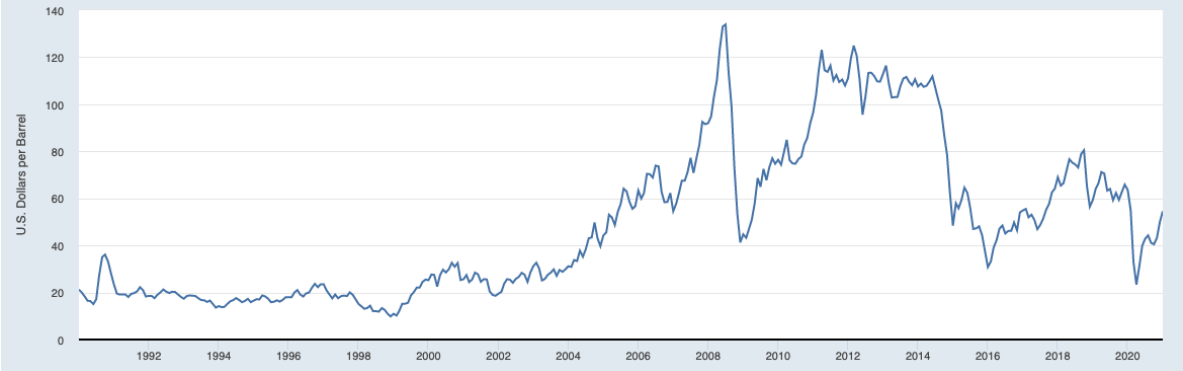
18 For a thorough treatment of the subject of energy economics, consult Zweifel, P., Praktiknjo, A. & Erdmann, G. (2017). *Energy Economics – Theory and Applications*, Springer Texts in Business and Economics, Springer.

Internal Change and External Pressure in the Oil & Gas Industry

The upturn in interest of the energy transition and the progress made so far has come concomitantly with a heightened scrutiny, and a relative downturn in the fossil fuels industry connected to the factors introduced above. Might the uptake of renewables and the various pathways to decarbonisation considered offer not only a lucrative growth market, but crucially a feasible, flexible, scalable, alternative to the world's contemporary consumption patterns? The answer no doubt will vary regionally, as so often questions of energy do. Structural, cyclical, and seasonal variations in demand combined with the nature of supply in terms of the actors involved, will also need to be considered – factors that will at the very least inform the manner in which the process of the energy transition will take place. What is often referred to as a contemporary global oil and gas glut (despite any seasonal price rallies and bouts of market tightness) – a situation of oversupply attributed to shale (or unconventional) oil and gas revolution, as well as number of significant conventional discoveries over the last decade (and a failure to induce significant boosts to global economic activity) – have all helped entrench "lower [prices] for longer" and "from scarcity to abundance" state of plays. In terms of the expansion of the shale oil and gas, it was, as a report for Equinor suggests, a time when "long periods of growing demand and high prices influenced the outlook and thinking at the time", where a consensus emerged that oil prices above $100 was a 'new normal'. As the market turned, many investments are now no longer robust. Hampered further in the shorter-term by the economic downturn in light of the global pandemic, contemporary suppressed oil prices (in contrast to the highs of 2014 when Brent crude – the international marker – traded at over $100 a barrel, with high watermarks of $145 in 2008, (followed soon after by an oil price plunge/down cycle between 2014-2016), formed the background for ample market (and now public and governmental)m pressure on the global oil and gas industry (Figure 5). In April 2020, an 18-year low of around $18 per barrel (p/b) was seen for Brent, whilst future prices for May 2020 instalments of a barrel of West Texas Intermediate (WTI) dropped to negative $37.63 – a first for the industry. Brent crude prices improved to around $50 p/b by the end of the year, with 2021 forecasts averaging at $55 p/b for ING, and an average of $49 for the EIA. Brent crude prices recently responded to decisions taken at the 05 January 2021 OPEC+ meeting, bolstering to around $53 p/b by news of only a minor production increase agreed for February this year[19]. That figure has since risen to $63 p/b as of mid-February.

Predicted upturns in the form a commodity super cycle have thus far either failed to materialise or have been deferred to various degrees into the future. For others, heyday benchmark crude oil prices over $100 are simply a thing of the past. How oil demand will shape-up in the post-pandemic economic recovery remains to be seen, though vaccine rollouts and announcements of vast government economic stimulus have generated optimism. Some analysts suggest that the lower for longer scenario will eventually be ebbed away in the near-term, despite the long-term fortunes espoused for the global oil industry. In this light, the EIA in January 2021 expected global demand for petroleum liquids to overtake supply in 2021, driving up the price of Brent crude oil to an average near $50 p/b through to 2022. More bullish predictions have been made by both Goldman Sachs and JPMorgan Chase that could see oil prices soar toward the $100 mark again. The general thesis is that near-term fiscal stimulus by governments seeking to counter the pandemic-induced economic downturn may coincide with a downturn in new production, especially in light of the public and market pressures faced by oil companies. However, as stipulated elsewhere in the paper as well, the role of OPEC+ (given downturns in the U.S. shale oil and gas industry and developments related to other

Figure 5: **Global Brent Crude Price** *(USD/barrel) January 2010 – January 2021*



Source: Federal Reserve Bank of St. Louis (2021).

19 Bloomberg (07/01/21) notes that crude oil has in fact recovered from its coronavirus-driven rout, benefiting from Saudi Arabia's unilateral output cuts, as well as an investment surge to "hedge reflation and coronavirus vaccines".

producers such as Iran), may mean that the organisation will shape the path of oil prices in the short term. OPEC+ has generally curbed oil output since 2017 in a bid to prop-up oil prices.

Optimism remains in the oil and gas industry, however bleak the discourse to the contrary. Options for producers include becoming broad energy companies (with renewables and hydrocarbons), digging-in and focus on low-cost and cleaner oil and gas production (the last-man standing scenario), or pivoting entirely into clean energy. Divisions seem prevalent between industry actors. BP has pledged "aggressive decarbonisation targets and to build a huge renewables business", with Shell, Total, and Equinor, making similar commitments as per the Financial Times (October 2020). At the time of writing, Shell has stated that 2019 was very likely the "high point" of its oil production, and Total seeks to rebrand as "Total Energies" in light of climate-related goals. ExxonMobil and Chevron have in contrast been thus far "slower on the turn"[20]. Of course this does not rule out major decarbonisation-related moves for them altogether, such as Exxon's eventual establishment of a low-carbon business focussing on Carbon Capture, Storage and Utilisation (CCUS) announced in February 2021. Briefly, CCUS captures CO_2 released by the combustion of fossil fuels in power generation and industrial processes at pre- and post-combustion stages. The captured carbon can be either stored (CCS) or utilised thereafter. Though CCUS is still expected to play a key role toward a net-zero energy future, despite the fact that the technology has not yet lived up to initial expectations[21], reservations persist. Enhanced oil recovery (EOR) techniques which CO_2 to improve oil production which may ultimately work at cross-purposes with the decarbonisation process overall.

Every use of technology will have its own unique set of applications and challenges, across a mixture of economic, scalar, and temporal considerations. Returning to strategic positioning, digging-in for the long-term seems to be Conoco's strategy. The company's CEO Ryan Lance told the Financial Times that "[...] a price recovery is coming", as his company announced plans to acquire Concho Resources; a move that would create the largest independent oil and gas producer in the world. Conoco was also the first US-based oil producer to pledge net zero carbon emissions by 2050. That a market shift was inevitable, that eventually there would be a peak in oil demand, but that even in a shrinking market there will be a need for fossil fuels, figures in Mr. Lance's public statements. The story is one of supply and demand fundamentals. As investment in the oil and gas industry continues to fall, with sustained cuts to upstream exploration and production activity, eventually a tighter market will emerge as supplies fall in the face of growing global demand, however tempered that growth in demand may be. The particulars of the U.S. shale oil and gas industry are also fundamental to market dynamics, explored below. In 2018, Harvard Business Review wrote of a new era of uncertainty and price volatility. Where global oil-producers worked at cross-purposes, that is, when OPEC+ and other producers agree to curtail production, yet U.S. shale oil and gas producers may ramp up production[22], then traditional boom and bust cycles may be replaced by "faster, shallower price rotations" responsive to changes in production. Price volatility is a dynamic that industry participants are already adjusting to. Chief Financial Officer of Eni Francesco Gattei told the Financial Times that "volatility is growing every year", as his company announced its aim to adapt to sustained lower oil prices[23]. Such volatility, compounded by financial pressure of major oil and gas companies, alongside changing consumer sentiments, may then further enable the pursuit of electrification and decarbonisation, as per Adnan Amin – former director general of the International Renewable Energy Agency, as a way to make countries "less dependent on the volatility of oil markets". Volatility is generally said to be good for commodity trading houses, where regional price divergences (themselves contingent upon multiple other factors such as temperatures and storage capacities often in combination) can be leveraged. In terms of spot LNG, which still represents a fraction of the global natural gas market, the recent Asian spot market rally (from a record low earlier in 2020) was favourable to traders. Still, longer-term convergences between regional prices, coupled with shorter time windows open for arbitrage between regions and issues of short-term liquidity, factor into what is an evolving trading environment, one that can also potentially incur a focus on smaller-scale or targeted local markets. It is such structural, cyclical, and seasonal characteristics of global oil and gas markets that renewables and the associated pathways to decarbonisation with them, will emerge alongside of.

Forecasts for Oil, Natural Gas, & Coal

In the IEA's STEPS (or a more business-as-usual scenario based on current policies), the pandemic delays projections in global primary energy consumption up to 2030 by around 2.5 years, in contrast with the projection for 2019. Importantly, a plateau rather than a peak is expected. Pre-crisis levels in oil consumption recurs by 2023 and a plateau in global oil demand in expected beyond 2030. In contrast, BP's business-as-usual scenario outlook implied that peak oil had already been reached in 2019. Thereafter, oil demand in this scenario reduces by less than 1% a

[20] Reuters reports that in BP, geologists, scientists, and engineers, of the oil exploration team have been cut to less than 100 from a peak of over 700 a few years ago, some transferred to low-carbon related streams. Spending on exploration had begun to wane after the 2014 oil price crash. This is the second time that BP has sought to reinvent itself in recent time, rebranding itself in 2001 as "Beyond Petroleum".

[21] Though the potential of CCUS is recognised, the technology has consistently accounted for less than 0.5% of clean energy/efficiency investments as per the IEA (September 2020).

[22] This dynamic is reiterated by The Wall Street Journal, which gives a good overview of hydraulic fracking in the U.S.

[23] S&P notes that "the pandemic created the second severe sector downturn in five years and the third in 12 years".

year through to 2050, unlike the more rapid declines in oil demand in the Rapid Transition and Net Zero projections. BP's outlook means that peak oil is no longer deferred into the more improbably green scenarios. In other forecasts, the peak oil scenario is generally repeated: BloombergNEF (2035), Total SA (2030), McKinsey (2033), Wood Mackenzie (2035), Rystad Energy (2028), Equinor (2027-2028), and OPEC (2040). Regional variations in consumption are fundamental to the outlook, with the IEA arguing that peak oil demand is already the reality in advanced economies, where oil demand falls by 5 mb/d between 2019-2030, although oil demand is expected to rise elsewhere in developing/emerging economies. There is something to elucidate further on what exactly "peak oil" entails. In January 2018, BP described the peak oil scenario as a "shift from an age of perceived scarcity to an age of abundance – and with it, a likely shift to a more competitive market environment". A more critical outlook might qualify the difference between peak oil as peak demand and peak oil as height of oil production, which is defined by geophysical, economic, and technological limits, together with a phase of irreversible decline[24]. Thus, there is a demand and supply-side approach to the notion of peak oil to consider. "The date at which oil demand is likely to peak is highly uncertain and not particularly interesting", the report continues, with an emphasis that an "age of abundance rather than scarcity" with a more competitive global market, is at stake. The recent news of falling investment in major oil and gas companies in particular that bolsters the view that exploration and production efforts will eventually wane, though in 2018 BP wrote that "there is little evidence or reason to believe that the peak in oil demand, whenever it happens, will trigger a sharp discontinuity in either oil demand or investment spending". The possibility that oil prices will increase in the future as capital investment declines is therefore apparent. Oil companies themselves must remain profitable. They may cut back on exploration and production and invest elsewhere under intense environment-related pressure. A supply gap may then emerge (given that global oil demand remains robust), prices may then duly rise which, without complementary developments in the uptake of RES (especially through regulatory intervention), may then signal the round of exploration and production activities. Thereon, the business cycle may repeat.

In tandem, there is no clear-cut or overall answer as to the exact effect of a longer period of lower fossil fuel prices upon the energy transition. As noted by the IEA, lower for longer oil prices may enable in places the removal of fossil fuel subsidies, lower prices may induce taxes on the consumption of fossil fuels, and there may also be a reinvestment of capital in greener alternatives. The latter may in-turn enhance the deployment of various renewable technologies such that, especially in the power and transport sectors, renewable sources and renewable-based end-uses (such as EVs), become cost-effective alternatives in the long-run, and especially across the lifecycle of the product. Global oil and associated liquid fuel demand is usually dominated by the transport (especially road) and petrochemical sectors, followed by industrial, built environment, and power uses (Figure 6). The removal of subsidies may go on to raise oil prices, especially in so far as they are applied in developing economies. However, there is much to be said on price and income elasticities for crude oil demand, where demand is often judged to be relatively price inelastic. Therefore, the displacement of oil becomes all the more difficult, given the lack of deployable renewable alternatives at scale. Price is of course a criti-

Figure 6:* Global Oil Demand by Sector & OPEC's Demand Projection *(mb/d).

	2019	2020	2025	2030	2035	2040	2045	Growth 2019–2045
Road	44.4	40.1	46.3	46.9	47.1	47.1	47.0	2.6
Aviation	6.7	3.5	7.1	7.7	8.4	8.9	9.4	2.8
Rail/waterways	1.9	1.8	1.9	2.0	2.1	2.1	2.0	0.2
Marine bunkers	4.2	4.0	4.4	4.6	4.7	4.7	4.6	0.5
Transportation	**57.2**	**49.4**	**59.7**	**61.2**	**62.2**	**62.8**	**63.2**	**6.0**
Petrochemicals	13.7	12.9	14.7	15.9	16.7	17.0	17.3	3.7
Other industry	12.8	12.7	13.0	13.5	13.5	13.3	13.1	0.3
Industry	**26.5**	**25.6**	**27.8**	**29.4**	**30.2**	**30.3**	**30.4**	**4.0**
Resid./Comm./Agric.	11.1	10.8	11.4	12.0	12.2	12.1	11.6	0.5
Electricity generation	4.9	4.9	4.8	4.6	4.3	4.1	3.9	–1.1
Other uses	**16.0**	**15.7**	**16.1**	**16.6**	**16.5**	**16.1**	**15.5**	**–0.5**
World	**99.7**	**90.7**	**103.7**	**107.2**	**108.9**	**109.3**	**109.1**	**9.4**

Source: OPEC (2020)

24 One cannot but help think of the famous phrase by the Saudi oil minister Ahmed Sheikh Yamani who recently passed-away at the time of writing: "The Stone Age came to an end, not for a lack of stones, and the Oil Age will come to an end not because we have a lack of oil".

cal factor, but one of many factors in a complex series of feedback mechanisms. Low oil or natural gas prices may hamper (to continue the example) the transition to EVs, an illustration of the fact that inter-fuel competition on a solely economic basis may still favour fossil fuels in certain contexts. Thus, the need for structural intervention (such as the various penalties on carbon emissions), or even shifts in strategy by companies themselves (such as at the time of writing: Jaguar, GM, and Ford, who have all recently announced that all new vehicles sold will be EVs in the not-to-distant future), and other policy interventions, may be needed to help reduce reliance on fossil fuels. Thus, as explored further on the section on renewables below, the debate between cost versus decarbonisation coupled with the need for stability and economic growth, will underline the debate on the possible effects of lower oil prices on the greater penetration of renewables in various energy mixes.

How exactly oil and gas prices will fare in the post-pandemic period will depend on the nature of the global economic recovery, market fundamentals of inter-fuel competition, and the specific commitments to greener energy policy, especially through fiscal means. The future of U.S. shale oil producers may also be key to this dynamic going forward, as OPEC+ nations may no longer have to work at cross-purposes such as competitors. The U.S. shale oil and gas revolution transformed the global energy landscape and bestowed upon the U.S. a swing producer designation, given that shale oil production is elastic in terms of production ramped up and down relatively quicker than traditional drilling[25]. But the industry has been described as a victim of its own success, where "culture of aggressive growth and unrealistic price assumptions permeated the entire industry", as companies rushed to gain a foothold in the emerging market. $400bn of outside capital was burned through by the sector between 2008-2018. The ability of U.S. oil producers to flood the global market with large volumes of cheap oil is in question. Cited in Bloomberg, Bill Thomas, Chief Executive Officer of EOG Resources Inc. – the largest independent shale producer by market value – concluded that "in the future, certainly we believe OPEC will be the swing producer – really, totally in control of oil prices". Going forward, weaker price frameworks can insulate demand from competitive threats, giving OPEC+ respite from U.S. shale oil producers. The role of U.S. shale producers is but one dynamic amongst many that will shape market dynamics to come. Structural patterns of supply and demand combined with cyclical and seasonal variations in both overall volume of economic activities, and price for all commodities in question constitute points of complexity against which various climate-related goals are juxtaposed. Efficiency improvements may be spurred for in the long-term. Expectations of greater fiscal discipline are also high in order to lure back investment capital, though promises of fiscal discipline erred before as oil prices rose.

Interview Excerpt:
Jamie Ingram – Middle East Economic Survey (MEES – 19/01/20).

"[...] near-term issues in the oil industry need to be addressed first, especially as some [including some of BP's scenarios] argue that oil demand might never return to pre-Covid levels".

"[...] much of the debate around peak oil demand is very Western-centric and often ignores that large parts of the globe see increasing access to cheap energy as a key strategic priority. Environmental concerns are much less of a priority there than in OECD countries".

"I fully expect in the coming years the emergence of a methodology for showing the greenhouse gas emissions of oil barrels. Currently the key metrics when selling oil are its gravity (API) and how sweet/sour it is. I expect that sooner rather than later oil that is produced with low carbon intensity will trade at a premium to oil, where production entails high emissions. Here, the big producers of the Middle East have an advantage. Their oil is cheap to produce because it is generally easy to produce. And as that means production requires less energy, their oil is also cleaner to produce. We are increasingly seeing the likes of Saudi Aramco and ADNOC flag up that they are best in class when it comes to the carbon intensity of their production. That should lend them a competitive advantage as the energy transition continues".

Talk of the energy transition has reified the battlelines over the future of natural gas. Confidence in the promise of the energy transition has translated into a tougher critique of natural gas' green credentials. Often dubbed a "transition fuel", the future of the "cleanest fossil fuel, discussions of natural gas seem locked in-between what is seen as two diametrically-opposed processes: the move to divest wholesale away from fossil fuels, juxtaposed with an equally wholesale onset of renewables. It is here that assertions of natural gas as a bridge fuel towards an overall greener energy system emerge. Natural gas has been described as a relatively more versatile natural resource that it put to use in a number of different sectors (with added regional variation), rather than being heavily weighted towards one sector such as power (electricity) generation as coal is. LNG in particular has enjoyed year-on-year growth since 2016. It was around that time that notions of a natural gas revolution were common, fuelled by the shale oil and gas revolutions in the USA complemented by a series of conventional oil and gas discoveries world-wide. The growth of LNG has also helped induce a more global, liquid, and competitive market for natural gas, albeit one that has seen a fair share

25 With LNG too, the U.S. has been categorised as a swing supplier, where contractual ability to scrap deliveries means that exports can be diverted to volatile (and more lucrative) markets elsewhere.

of volatility, with interplay between gas-consuming regions, bouts of convergence but also seasonality in pricing.

Proponents of natural gas have sought to emphasise the industry's green credentials. LNG cargoes designated "carbon neutral" emerged in 2019, whilst the world's first supply contract outlying production emissions was signed in 2020[26]. Natural gas' designation as a "transitional technology" in the European Council's recent GHG emissions target announcement for 2030 made the headlines. The propensity for coal-to-gas switching is also a significant feature of the overall process towards decarbonisation, especially for coal-reliant EU member states. In January this year, the European Investment Bank (EIB) had far more unequivocal words on the debate: "to put it mildly, gas is over". A far more aggressive commitment to decarbonisation hinged on current climate-goals would afford no privileged position to natural gas despite any favourable economic merits, nor seek to keep the industry afloat longer than necessary. In tandem, Bloomberg asserts that cheap gas may ultimately slow the energy transition in the U.S., but not deter it. Definitive conclusions on the future of a $600 billion global natural gas industry, and where gas accounts for around a quarter of global primary energy demand, may be far too quick to the draw, and obscure the geographically-varied significance of the fuel, where issues of: inter-fuel economic competition across the power, residential, industrial, and transport sectors, existing infrastructural constraints, technological innovation, and degrees of government policy commitment to climate goals all coalesce. Contrary to oil, natural gas has seen relatively little net downturn from the global pandemic. Global LNG imports (which make up around 10% of global gas demand) in 2020 were roughly equal in volume to that of 2019. Global natural gas is still expected to grow 2.8% in 2021, with again emerging markets driving growth. In Bloomberg's (2020) outlook, natural gas grows continuously overall through to 2050, though there will be a sustained decline in gas as used in power generation.

A less charitable view of natural gas' green credentials highlights the serious prevalence of natural gas flaring and methane emissions. As highlighted by the Oxford Institute of Energy Studies (OIES) in November 2020, the natural gas and LNG community will have to engage with the problem of flaring (mainly CO_2) and any accidental or fugitive emissions including methane, the latter of which is a more potent GHG than CO_2 (with a global warming potential 84-87 times that of $CO)_2$. Natural gas flaring reached its highest level in the last 10 years; an eventuality related to low natural gas prices that disincentivises the capture of natural gas during oil extraction (associated gas).

In contrast, coal is by far the single largest source of global energy-related carbon emissions (Figure 7). Therefore, it is a prime target for decarbonisation. In 2019, coal was still the largest source of power generation. Yet it is precisely here in the power generation sector that renewables and nuclear made their greatest gains in recent time[27]. That the global coal industry (but in particular that of the more developed economies of the world), is now said to be in terminal decline is underpinned by these two major dispositions, bolstered in recent time by high-profile announcements such as that of U.N. Secretary General Antonio Guterres, who in July 2020 asserted that: "Coal has no place in COVID-19 recovery plans". In January 2021, EU ministers called for a worldwide phase-out of unabated[28] coal-fired power generation and the "immediate end to all financing of new coal infrastructure in third countries". In terms of future scenarios, the IEA (2020) asserts that "global coal use never gets back to previous levels", and by 2040, coal's share in the global energy mix is to fall below 20% for the first time in modern history. Clearly the consensus is that the consumption of coal – the dirtiest fossil fuel – will need to be reduced in light of emission goals.

Interview Excerpt: James Huckstepp, S&P Global Platts (29/01/21)

"The biggest single advantage with natural gas is that you do have long-term storage, that the power industry still does not have a solution to. Even once we have 50% electric vehicles and you have lithium-ion batteries all over the grid and grid storage with the pricing continuing to drop, that is still going to be short-term storage focussed on peak shaving and frequency response. It is not going to be seasonal. In terms of energy demand, that also is not going to stop being seasonal".

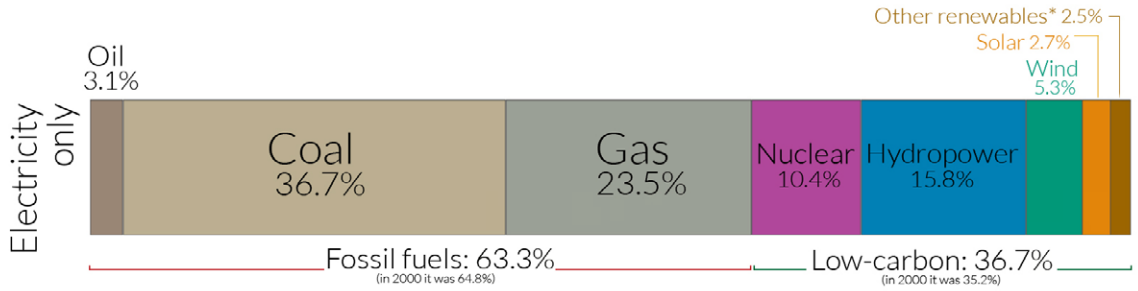
"Seasonal electricity storage does not exist; it will likely never exist. Therefore, you do need something else, some sort of liquid or gas fuel to realistically bridge that gap between the winter and the summer in Europe. Globally it is the same. Gas storage is being built up in Asia but generally LNG markets are becoming more and more seasonal, and you have seen that with Asian LNG prices recently with a bit of a cold spell".

"Gas is not the only potential solution there. The other one is hydrogen. "If cost comes down and regulation opens up we should see a significant volume of hydrogen making use of current gas (methane) infrastructure within the next decade".

26 "Carbon-neutral" LNG (emissions offset elsewhere) can now be sold at a premium.
27 Nuclear power hardly shares the spotlight cast by talk of the energy transition, a propensity often associated with the known dangers of the technology.
28 Unabated here refers to coal-fired power plants that do not inhibit the release of GHG emissions.

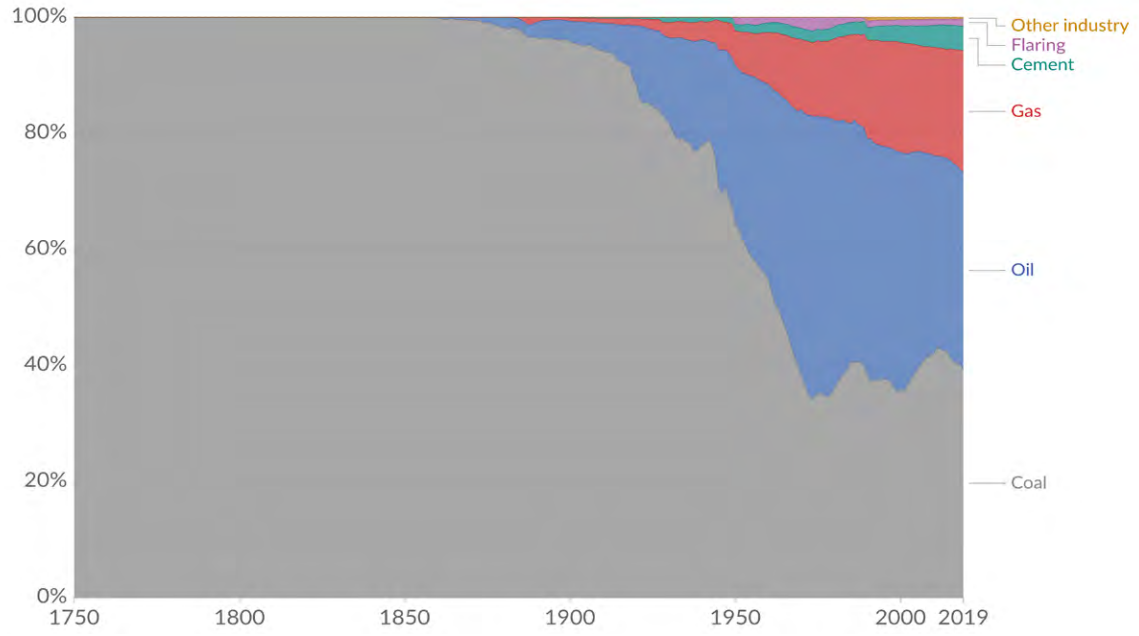
A regional outlook suggests that coal markets in Asia where coal consumption is vastly more abundant than say in Europe, will be key. In 2020, renewables (38%) generated more electricity than fossil fuels (37%) in the EU for the first time, a feat recorded in the UK in 2019 (see also Figure 6). Offsetting coal consumption at pace and scale in Asia – namely China and also Indonesia and India – will be quite difficult, given large-scale domestic availability and the economic significance of the sector. Coal imports may reduce, yet more domestic coal may be in turn consumed given the energy demand growth scenarios often ascribed to these regions of the world. There is also something to be said of market structures. In Europe, coal to gas switching has been more straightforward given cheaper natural gas prices, hence an enabling price elasticity. However, if say in Asian LNG import markets oil-indexed pricing mechanisms remains dominant, then prospects for market competition between coal and natural gas will be limited. The final nail in the coffin of coal is palpable but premature for now, again as regional discrepancies in fossil fuel use come to the fore. Coal plays a major role in electricity generation in China, generating around 60% of the country's power. China, often cited as the "world's factory" with an economy set to surpass that of the US by 2028, assumes a significant role for the world's energy dynamics as a major explainer of global trends[29]. Coal is clearly the "bad fossil fuel" at the combustion stage (Figure 8). However, well-to-tank emissions to decarbonise existing sources of carbon emissions through CCS might may also need to be considered. This way, lifecycle of emissions of coal could dwarf that of natural gas where in the later methane emissions remain a key problem. Edenhofer et al. (2018) warn that if "all coal-fired power plants currently announced, planned or under construction are realized, coal emissions will exceed the total emissions allowed by the entire power sector by 2040". A worldwide tracker of coal-fired units is provided here by Global Energy Monitor, including announced coal-powered plants.

Figure 7: Global Electricity/Power Generation by Source



Source: Our World in Data (2021) – Using BP Statistical Review of World Energy 2019 data.

Figure 8: Global CO2 Emissions by Fuel Type across Time *(tonnes/y).*



Source: Ibid. (2021).

29 China surprised the world with an ambitious long-term goal of carbon neutrality by 2060.

Interview Excerpt:

Jake Horslen, Editor Argus Media *Coal Daily International* – 23/02/21.

"The lack of investment in new coal-fired capacity in many developed countries (US, EU, Korea, Japan) means that total capacity and coal use will drop this decade either quickly, like in the EU, or more gradually, like in Japan/Korea. Only in developing economies where electricity demand is still growing strongly is there much potential for further growth, and even there it could be limited if the pace of renewable capacity growth accelerates. The long-term trend is certainly going to be down, but the gradient will depend on how effectively policy reduces coal use in developed economies and on the extent of overall power demand growth and renewable capacity development in developing economies. The rise of renewables can make generation mixes more volatile and boost the need for flexible generation that can respond to peaks in demand or periods of low wind/solar, however gas more than coal is probably better suited to filling this role as gas-plant technology is typically more flexible than coal. There are not many "saving graces" to arrest the downward trend in coal demand".

Interview Excerpt:

Natural Gas Industry Observer (19/01/21)

"The energy question is a crucial question for the natural gas industry and of course depending which region is in question, there is increasing awareness that in the future that gas (mainly fossil gas), there is an increasing need to diversify. At the same time, when you look at the more medium-term market reality, there is of course still potential for a lot of natural gas to grow".

"It is a question of regions and different [market] realities. If we look at how the discussion has evolved in Europe and probably in certain states in the U.S., gas in a very short time became the new coal and this is true in NW Europe, in places like the Netherlands and the UK. You have coal being phased out and the rhetoric now shifts to natural gas. When we move to other parts of the globe like China and India, the discussion is different, framed by the fact that in your power mix you will have 60-70% of coal or lignite. You acknowledge that coal to gas switching is part of the medium-term energy transition. If you look at Central/Eastern Europe, there has been some coal to gas switching. The champion of coal to gas this year was Turkey. [...] This is just to say that how natural gas is perceived...is it something like coal to get rid of or a bridge to cleaner energy future depends on the region we are talking about, mostly Asia versus Europe and North American".

"If the gas industry wants to be a part of the future, there is a need to diversify and to develop these pathways towards low-carbon gases. One way would be CCUS the very much hyped hydrogen future, and then bio-methane, you can think also about synthetic of methane – most probably there would be a combination of gases. You will have to think about how they interact with each other but for now the main question is really at the technical level: how to enable that system at the infrastructural level and what regulatory framework would be best suited to start to develop that. In terms of both production and network integration, to switch consumers is a first but can be a very complex process".

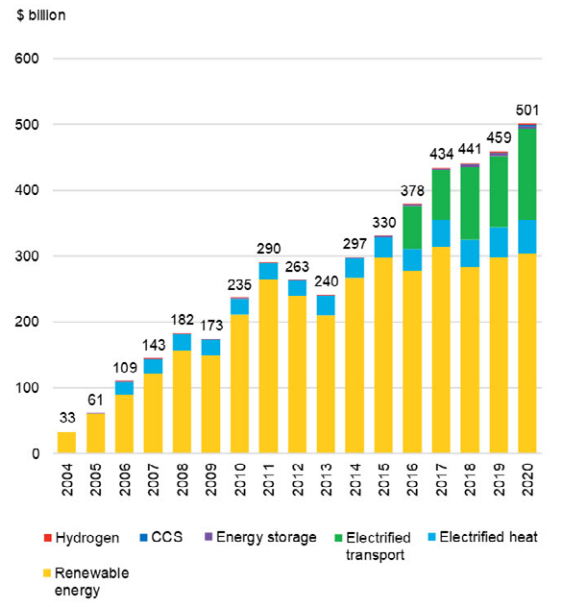
"There is always a combination of factors. The situation of a company in question, the customer base, how much they can diversify; some of the companies may not have liberty to diversify from the consumer base because the pipelines have been built and there is an onus to push as much gas as you can. It is very difficult to tell because each and every company is different (different strategies, consumer and resources bases) there is no one-size-fits-all response".

"In terms of volume of consumed gas, there will be at some point, the share of natural gas in that energy pie will start to decline vis-à-vis renewables. [...] Then what is also interesting is the perception of gas versus renewables but there is a question of how gas supports the integration of renewables into the electricity systems. The volatility of electricity supply is increasing because it is increasingly dependent on variable renewables and you ultimately need some flexible back-up to that. There is a lot of talk about batteries, but you would still need some time for renewables to provide the same flexibility as gas. Another factor is that if we look at the seasonality of energy demand, it is hard to imagine how seasonality can be met without molecules. You can electrify as much as you can but what technology will enable large-scale seasonal energy storage? This is crucial particularly in the Northern hemisphere. Energy efficiency may improve but it would hard to imagine the seasonal swing in energy consumption will be flattened. Regional gas markets are becoming more global in the sense that they are interacting a lot more. [...] An interesting question is what will happen with seasonality of EU gas prices which are a major concern for storage system operators".

The Promise of Renewables & Carbon Fiscal Regimes

The promise of renewables is vast topic. With a focus on the power sector, introduced here are of the major trends as of late in the renewables world, touching upon also various carbon governance regimes, and the potential of hydrogen. Briefly, 70% of new global capacity in 2020 may have been from RES. However, around 80% of the world's primary energy demand is commanded by fossil fuels. Wind and solar make up only 8% of generated electricity. Fossil fuels, such as natural gas and LNG will continue to produce the majority of power through to 2050[30]. Green technologies, often still emerging, are complex and uncertain, and the process to deploy low-carbon technologies at scale is still underway. Much depends on technological innovation spurred on by financial investment, coupled with larger patterns of supply and demand of the various different energy sources or commodities in question. As seen in Figure 9 below, investment in various technologies associated with the energy transition have increased significantly over the last few years. Often cited as part of the discussion on renewable uptake versus cost[31] is unmistakable way in which lower solar costs then influence installation as part of a virtuous circle (Figure 10). Installed capacity though a positive development, clearly needs to be utilised. Trends in sales of EV for example should not be considered in a vacuum, devoid of related market trends that may be inconvenient for the narrative. EV sales in the US are reported to still be around a tenth of SUV sales.

Figure 9: **Global Energy Transition Investment 2004-2020** *($ billion).*

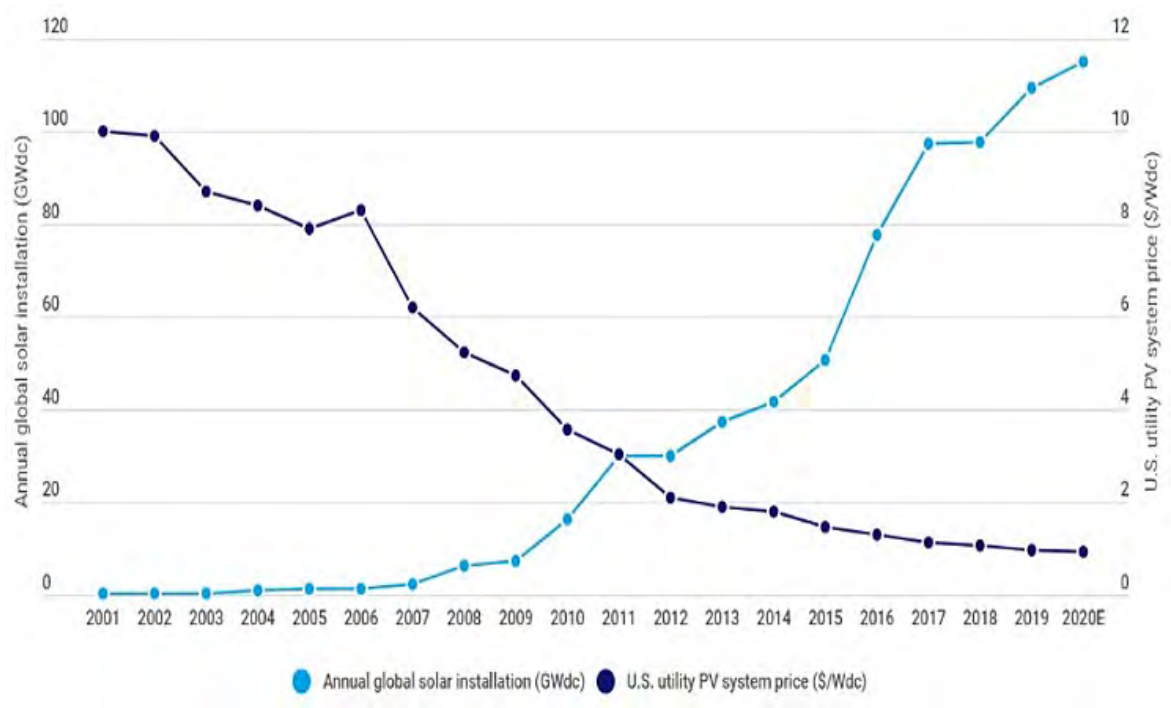


Source: BNEF – Bloomberg New Energy Finance (January 2021).

Aspiration on the proportion of renewable penetration in a country or regions energy mix for the future must also be commensurated by both the issue of energy demand first and foremost, and then issues of cost-competitiveness vis-à-vis renewables. What matters further are the comparative advantages of renewable resource deployment as opposed to an energy system that has over decades emerged and adapted to fossil fuel consumption. There are many different pathways for renewable resources to make inroads and perhaps in some domains significantly displace fossil fuels. But there is also competition between renewable resources, especially in terms of economic feasibility of deployment, to consider. For example, hydrogen, and in particularly green hydrogen (discussed in more detail momentarily), may not be able to compete on price with the direct use of clean/renewable electricity and battery technology. But hydrogen may be still be uniquely positioned to as an unlimited source of flexible capacity as backup, and a form of strategic energy storage at times when an electricity system built on wind and solar may require assistance to meet power demand[32]. The point on power demand is particularly pertinent. Renewables and hydrogen will not solve the need for dispatchable electricity[33], hence there may now need to be a reconsideration of nuclear power. The path to decarbonisation is often seen through electrification (though there may indeed be limits to electrification), growth in low carbon generation with use of renewables, nuclear, CCUS and other technologies. The Intergovernmental Panel on Climate Change (IPCC) states that to cap the rise of global temperatures by 1.5 degrees Celsius, the "virtually full" decarbonisation of the global power sector is needed by 2050. Cited in The Guardian, Melissa Lott, senior research scholar at the Centre on Global Energy Policy at Columbia University, argues also that "when you look at overall pathways to net zero for the whole economy, it's the power sector – zero carbon electricity – that is the backbone of all that". Wood Mackenzie also writes that the "full decarbonisation of power must be regarded as a prerequisite of any meaningful progress towards deep decarbonisation of the overall energy system". Cross-sector electrification, and not just the decarbonisation of the power sector, is also slated to be a key factor for the energy transition[34]. But why the focus on electrification and the power sector at all?

30 Figures drawn from the S&P London Energy Forum 2021.
31 Investment firm Lizard publishes periodic reports on the average cost of power generation from a variety of sources.
32 There is also a potential for hydrogen to be used in conjunction with CCUS technologies, where hydrogen is used in the pre-combustion stage in the process to remove CO2 from the fuel itself.
33 S&P Global Platts London Energy Forum 2021.
34 Or in the words of the World Economic Forum (April 2019), "electrification can supercharge the energy transition".

Figure 10: PV Cost Versus Uptake



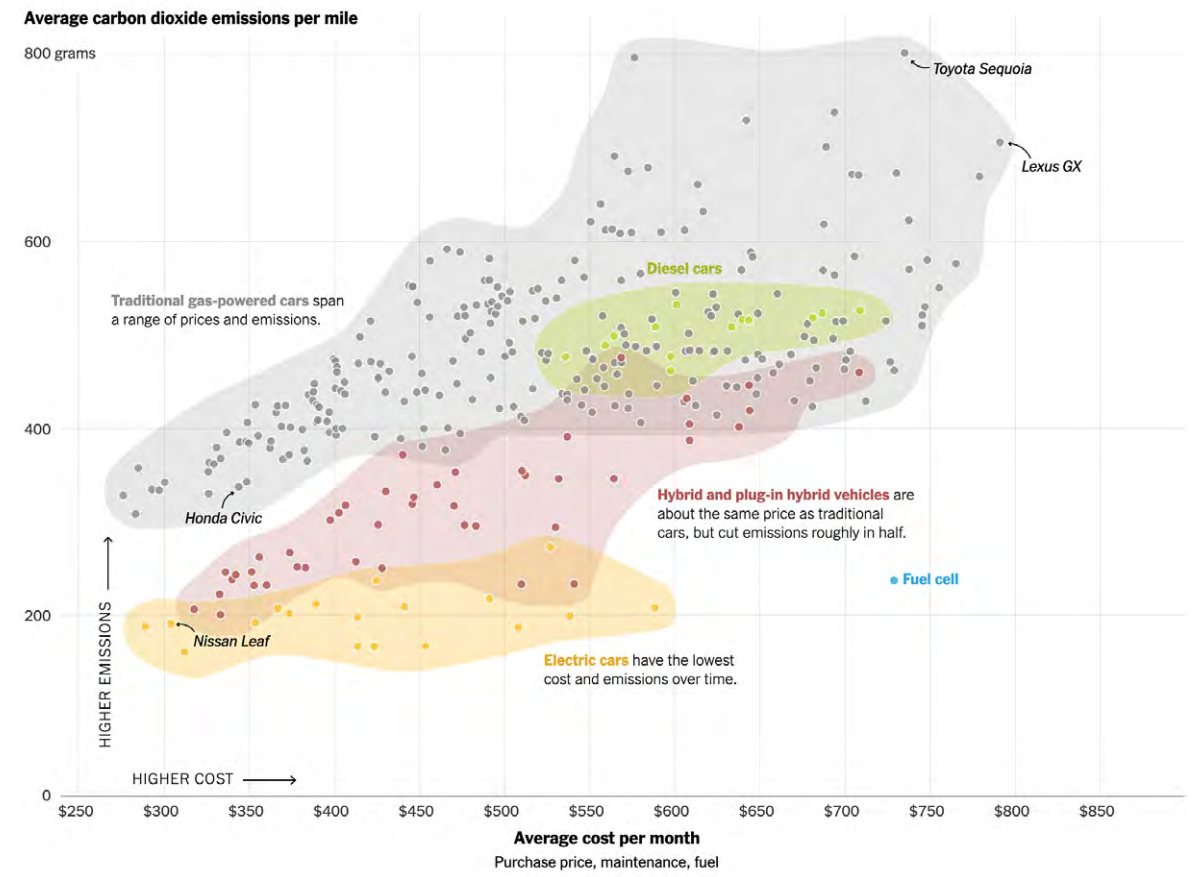
Source: Wood Mackenzie (2021).

The power sector is of course only one component of energy demand, though renewables and nuclear already account for larger portions of electricity demand compared to overall energy demand. The ever-increasing uptake of renewable energy resources is now mainstay of media reporting on the energy transition[35]. In 2019, 11% of global primary energy was sourced from renewable technologies, including wind, solar, hydropower, and other renewables. Around a third of global electricity demand comes from renewables. Hydropower in particular has played a much significant though often less acknowledged role. Though figures vary somewhat, though it would be safe to say that electricity currently accounts for around 20% of what is known as global final energy, which refers to what end users actually consume rather than total demand. Electricity/power production also accounted for 44.3% of global CO_2 emissions in 2019. Electrification, however, is set to increase, providing yet more opportunity for renewable resources to make their mark, particularly in the heating and transport sectors. Electrification is associated with increased efficiency and reduced GHG emissions, especially when paired with a renewable or clean energy fuel source. Figure 11 below visualises a U.S. study on how electric vehicles (an unmissable subject of the energy transition given the significance of the transport sector) are in the long run cheaper than their competitors, given the lifetime maintenance and upkeep of such vehicles.

These characteristics combined can help explain why the drive to decarbonise the electricity sector is popular, as well as related demands to electrify end-uses in other sectors. Though coal and natural gas are still primarily used in power generation on a global scale, regional differences again ensue. There may be difficulties in the endeavour to match renewable energy supply with electricity demand. Residual loads, that is the demand that remains after solar and wind energy is subtracted, has to be served with dispatchable generation sources. The combination of solar and wind may exceed the overall demand for power. At some hours, however, solar and wind may simply not be available, hence why the emphasis on energy storage technology. The demand for dispatchable energy possible in the form of fossil fuels may then need to be flexible to help meet periods of high demand, which may also then result in higher peak prices. Low-cost renewables may account for a power grid's overall needs, but plants using fossil fuel may still set marginal costs. There are also transmission and distribution costs to consider, amongst other factors such as the interplay between wholesale electricity prices, levelised cost of electricity (LCOE), best assessed on a case-by-case basis. Grid stability concerns often come with discussions of renewable energy sources (RES), a full treatment of which is beyond the scope of this paper. However, it is also the case that in extreme weather events conventional supplies such as natural gas for power generation may also be affected by extreme cold weather events.

35 Referred to earlier was the fact that renewables at 38% edged out non-renewables (37%) of Europe's power demand in 2020.

Figure 11: Average CO2 Emissions *(grams/mile)* of Car Type



Source: New York Times (January 2021) / MIT Trancik Lab.

Beyond the mere awareness of the role of carbon in anthropogenically-induced climate change, carbon consciousness has increasingly become normalised and commercialised, from niche concern to corporate strategy, to being supported by government policy and central banks. A number of regulatory instruments now exist such as carbon taxes and emissions trading schemes (ETS), the latter of which are bought to offset carbon emissions throughout the commodity cycle and used to support reforestation programmes and renewable energy schemes. As of 2019, around one-fifth of global GHG emissions are covered by around 46 national carbon pricing systems operating today or planned, with a global average carbon price of $2/t CO_2. There has also been recent interest in the EU for carbon border taxes or carbon border adjustments, as stipulated in its flagship Green Deal initiatives announced in December 2019. As per the World Bank (2020), there are 30 carbon taxes and 31 emissions trading schemes (ETS) currently in place across the world that cover 22 percent of global carbon emissions. Carbon taxes do not necessarily limit emissions. As summarised by Green (2020), stakeholders regulated by carbon taxes deal with an added surcharge. For ETS', stakeholders are allocated allowances that represent caps on total allowed emissions, as opposed to carbon taxes. However, they are free to trade allowances amongst themselves, buying more to cover emissions, selling allowances, or banking them for future use.

Green (2021) asks the pertinent question of whether carbon pricing reduces emissions, and conducts a meta-review of ex-post evaluations. At the heart of these studies are regression analyses used to infer the form of a supposed causal relationship. The author notes that ex-post reviews are seldom[36]. Green finds that though carbon taxes perform better than emission trading schemes (ETS)[37], aggregate reductions from carbon pricing on emissions are themselves generally limited to single figures per annum (with variation across sectors). This stands in sharp contrast with the IPCC's advocation that emissions must fall by 45% below 2010 levels by 2030 in order to limit global warming to 1.5 degrees Celsius. Rosenbloom et al. (2020) give an insightful assessment of the limitations of carbon pricing, arguing that carbon pricing "should not be the

36 As a point of digression, forecasts of the share of various fuels in the global energy mix across time would also benefit from ex-post reviews to see how actual recorded demand shaped up against predictions beforehand.

37 As of 12 January 2020, Europe's ETS system charged 35.42 euros per ton of CO_2.

primary policy strategy to combat climate change". There is also currently no global price for carbon which, though advocates have said would be significant for the purposes of the energy transition, remains a distant prospect. This is said to have led to interest in more regional cross-border schemes initially emerging in Europe. In the largest carbon market in the world – the EU carbon market - Frans Timmermans, Vice-President of the European Commission for the European Green Deal, has recently stated that ETS is a resilient system that is strengthening, that it is "one of the best instruments we have to influence the behaviour of industry and the necessary reduction in the use of carbon". Studies of the impact of carbon taxes vary in methodology, with differences in use of synthetic control variables associated with varied estimates for emission reduction. To explore further for policymakers in particular is the claim that carbon taxing as a policy tackles the flow of emissions rather than the overall stock or concentration of GHG in the atmosphere, that fuel-switching and efficiency improvements are the most common result of carbon taxes which are more marginal in effect, and fall short of social-level transformations thought of for decarbonisation.

The scale and scope of announced and recorded changes thus far have helped to allay (at least temporarily) suspicions of "greenwashing". In June 2020, Goldman Sachs estimated an "investment opportunity" of $16tn by 2030 to decarbonise the energy industry in a scenario consistent with the 2-degree global warming target, through an accelerated uptake of renewables and forms of carbon sequestration. Relatedly, in the early stages of the energy transition, it may not come as a surprise that the valuation of renewable energy companies will hinge on expected future earnings and not present cash flow, which can be in the negative. Major oil and gas companies will have obligations to pay shareholder dividends in the near term, which may come into tension with the capital that needs to be invested in low-carbon businesses for the long-term. Coupled with negative sentiments on the growth of the oil and gas industry, as well as the problem of valuation disconnection – where Big Oil's legacy business may incur negatively on the valuation of the renewable segments of their portfolio, compared to stand-alone renewable companies – challenges may thereupon emerge for global oil and gas companies. In any case, the outlook for RES continues to be positive. In 2021, RES are expected to become the largest sector for spending in the energy industry, surpassing upstream oil and gas for the first time in history. Plateaus in investment do not necessary reflect a negative scenario for the future of renewables, but in fact may mean that initial costs themselves have fallen. In the USA, the cost of generating electricity from solar energy is said to be up to 90% lower than costs ten years ago. Thus, renewable energy projects need not be supported by large government subsidies as before, yet in developing countries of the world where fossil fuel demand is expected to remain strong, government subsidies for fossil fuels may hinder movement towards a cleaner energy transition. There is quite a

Interview Excerpt: Element Energy (United Kingdom – 22/01/21).

"There has been some criticism in the EU recently of how close the natural gas and hydrogen lobbies are getting. There might be critiques of whether blue hydrogen advocates are helping continue the dominance of gas for another couple of decades".

"A lot of climate activists really want the fossil fuel industry to die [...]. The fossil fuel industry can bring quite a lot to the table; they have the expertise, they have the finance and they have the infrastructure which can be converted to hydrogen or used for offshore operations in the future. [...] They can be seen as an asset that can be used".

"If you think about the strategy for deployment, deciding the best path for the energy transition for whatever sector, there is always going to be a cost consideration. With PV, as you scale up, the costs come down due to both scale and innovation. There are lots of promising technologies and everyone will pretty much say that we have the technology we need to decarbonise almost entirely, with the exception of a few areas like aviation. If it was produced on a large enough scale, the cost will reduce for the average consumer to buy an electric vehicle, or hydrogen bus if you are a public transport provider. There are difficulties over grid connection and stability, which need to be addressed, but solutions exist".

"Flexibility is the big issue with electrification of heat and transport, as well as grid capacity. Batteries come with the problem of embedded carbon and the resources used. That is discussed more around the EV rhetoric than the power rhetoric. Hydrogen and natural gas can use existing infrastructure and consumer technologies, such as gas pipelines and boilers. Hydrogen is interesting because it works across sectors, transport, industry, heating, power generation. There has to be a big decision made as to what the role of hydrogen will be, and the preference will likely differ between countries. We are in a kind of wait-and-see era to see if full electrification or the hydrogen route will become a reality. We're also waiting on a few developments such as: battery costs, lifecycle emissions and recycling; hydrogen safety, production cost at scale, the modification of infrastructure at scale. That is the sort of evidence that will influence the big decisions from private and public sector".

"In the UK, the IPCC is influential, and the carbon budget is what everyone is working towards. The impact of the Paris Accords are generally important and symbolic in the sense that everyone is working towards net-zero more than ever before. We have councils declaring climate emergencies and then commissioning consultancies to work out what it means for them and their local policies. You have a political action point that filters down into working out practically how to implement it. It takes heavy lifting at the start to get the ball moving in whatever part of the energy transition you look at but eventually the momentum builds up and we drive change at scale".

large literature in existence on subsidisation of fossil fuels and renewables. Briefly, the Grantham Research Institute at the LSE noted in 2018 that fossil fuels and nuclear power have received more financial support than renewables to date. Subsides on renewables may be used to address price disparities vis-à-vis fossil fuels especially when environmental costs related to the later are not adequately addressed. More so, given current trajectories of cost-competitiveness, subsidisation of renewables may no longer be necessary in the near-future.

Finally, the future of hydrogen must be considered in greater detail. Hydrogen is a clean-burning gas currently made almost entirely from fossil fuels, largely through what is know as the Steam Methane Reforming (SMR) approach. 6% of global natural gas and 2% of global coal is currently used for production (IEA 2019). Hydrogen has been used as feedstock for decades, yet hydrogen now finds itself associated with numerous energy end-use sectors, from transport to heating and energy storage, sectors where it is currently almost completely absent. As per the IEA, less than 0.1% of hydrogen is currently produced through electrolysis. The latter when combined with electricity produced from renewable resources is known as green hydrogen, whilst the former using natural gas but where CCUS systems are used is known as blue hydrogen. There are many other 'colours' of hydrogen that denote different production methods. For instance, grey hydrogen is produced from coal and yellow hydrogen from nuclear. Hydrogen can be obtained through multiple processes, but blue hydrogen through the electrolysis of water may with the decline in cost of renewable power generation, presents a potential pathway to obtaining renewable hydrogen in a hybrid system. As with the energy transition in general, talk of hydrogen is not exactly new but has again proliferated immensely. A global or more regional market for hydrogen is still in its infancy and yet to be fully established. It operates less as a global commodity market than a clustered and localised intra-industrial market. Expectations for clean hydrogen extremely high. Cited in Montel News, Allard Castelein – chief executive of the Port of Rotterdam Authority – asserted that "we expect hydrogen to take on the position oil has today, as an energy carrier as well as feedstock for the industry". With the market for hydrogen still emerging, S&P Global Platts in 2019 began the world's first hydrogen price assessment using production costs and capital expenditure. A less charitable view of the work that has gone into the promotion of hydrogen suggests, amongst other critical assertions, that a "hydrogen lobby" exists that may enable the further growth of the natural gas industry, rather than the gradual phase out of fossil fuels sought by the most vocal environmentalists. This is not only due to the fact that the production of hydrogen is at presently based largely upon the use of fossil fuels and in particular hydrogen, but also due to the potential for hydrogen to be leveraged by natural-gas industry itself through use of its existing pipeline infrastructure and through the possibility of 'blending' hydrogen with natural gas. A recent event at the University of Columbia's Centre on Global Energy Policy outlines further some of the key promises challenges posited between the possible interplay between hydrogen and natural gas.

Conclusion

Decarbonisation drives the narrative of the energy transition. The global pandemic has temporarily dented but has not wholly reversed emissions-related trends and global economic growth and primary energy demand, which is now gradually recovering. Important signals have begun to be registered in the story of the energy transition. Heightened momentum has been reflected in record investments in RES, the proliferation of wide-ranging GHG related announcements at the governmental level, and degrees of business-model change in global oil and gas companies. Though uncertainty remains as to whether current climate goal are achievable in practice, the resonance of the IPCC's target recommendations in policy-making, public discourse and sentiment, as well in the continued rollout of RES, has been prolific. A number of milestone achievements have recently been recorded. GDP growth in Europe for example has grown whilst GHG emissions have reduced; an initial predilection that opens up a wider discussion of decoupling in relative and absolute terms the decoupling of GDP growth from primary natural resource use and related emissions. The shift towards a sustainable future may in the end raise questions on whether continuous GDP growth and consumption is tenable. Much has also been made of the fate of the global fossil fuel industry, the terminal fate of coal in particular, oil, and then natural gas subject to varied levels of confidence. The use of fossil fuels will continue to form significant portions of global primary energy demand by fuel source, yet renewable penetration particularly as it concerns the offsetting of fossil fuel use in various sectors but especially that of power, is highly likely to show regional variation across time. The difficulty in speaking of the energy transition is that pathways for the efficient development of the market and optimal use of all resources is a grand balancing act of variables that are themselves subject to change. The stigma and fear over CCUS and nuclear power for example, may also need to be addressed as part of optimisation measures that leverage all pathways in various admixtures. There are many facets of the energy transition left unaddressed here, including: the role of minerals production as the production and deployment of green technologies ramp up, a full elucidation of all technologies associated with the energy transition, and a deeper dive on the way in which the economics of these debates unfold. More so is the possible ways that geopolitics of the future may in some way be affected by a transformed global energy system. In the end, the energy transition also needs to be a just transition, and there are also suggestions that more should be done to treat climate change as an immediate emergency to rile a quicker transition or for want of a better phrase, a revolution against a deadline.