Research Paper

Antony Froggatt, Paul Stevens and Siân Bradley
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Expert Perspectives on Norway's Energy Future

Contents

Abbreviations

CCS	carbon capture and storage
CCU	carbon capture and use
CCUS	carbon capture, use and storage
COP	Conference of the Parties
EIA	Energy Information Administration
EV	electric vehicle
GHG	greenhouse gas
$GtCO_2e$	gigatonnes of carbon dioxide equivalent
IEA	International Energy Agency
IPCC	International Panel on Climate Change
LUC	land-use change
mtoe	million tonnes of oil equivalent
NETs	negative emissions technologies
SAF	sustainable aviation fuels
SMR	steam methane reformer
SWF	sovereign wealth fund
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Summary

- The world is undergoing a transition away from fossil fuels towards renewable energy. However, the speed and depth of this transition is uncertain and controversial. This will have significant implications for Norway, one of the world's largest exporters of both energy and capital.
- With international efforts to limit increases in global temperature to 2°C, and as close as possible to 1.5°C, appearing increasingly off-track, there is an urgent need for a rapid move away from the unabated use of fossil fuels.
- An accelerated energy transition will have deep implications for future oil and gas demand. There is now a debate over when global demand will peak. However, what happens after demand has peaked is perhaps more critical – will there be an extended plateau, a gentle decline or a sudden collapse?
- The post-peak trend will impact oil exporters to varying degrees, in terms of reduced volumes and lower prices, as they compete for a shrinking market. There is also a debate over whether gas can act as a bridge between coal-powered electricity and renewables, or whether renewables directly replace coal.
- There is growing public and political pressure across most EU member states for more ambitious action on climate change. This particularly affects Norway as a supplier of energy to the EU, and as a member of the European Economic Area obliged to adopt at least similar binding domestic carbon reduction legislation.
- More challenging climate targets will accentuate many of the uncertainties of the energy transition, such as the rate of change and the costs of technologies including renewable energy and electric vehicles (EVs). While market developments will heavily influence the deployment rates of these technologies, policy interventions and investment in core infrastructure will be crucial to their scaling up.
- Meeting ambitious climate targets will require the decarbonization of heavy industry, which will rely on technologies that are yet to be tested at scale, such as green hydrogen or blue hydrogen with carbon capture and storage (CCS). The success or failure in commercializing these technologies will have a profound impact on the use of fossil fuels across sectors, particularly heavy and processing industries, and on existing transport and production infrastructure.
- Fossil fuel-producing companies have embraced the pivot to gas as part of the transition. However, the move to a net-zero-emissions economy will be disruptive, initially impacting the power and coal sectors, followed by heavy industry and the gas, transportation and heating sectors. The faster the transition, the more difficult it will be for energy exporters to adjust.
- Norway has one of the most decarbonized power sectors in Europe. Its renewable resources – primarily hydropower – are an important part of the Nordic power market, helping to balance supply and demand for domestic industry and across the region.

- The construction of additional power lines to Germany and the UK is likely to expand Norway's role as a key supplier of low-carbon electricity in Europe. Norway has the capacity to increase the system flexibility of the internal European electricity market, which is vital for strengthening renewable energy in the power sector.
- Power system flexibility may also come from an increase in the use of EVs, which will lead to lower battery production costs and the possibility of vehicle-to-grid balancing. These two innovations alone may devalue investments in interconnectors.
- The fall in electricity costs from renewable sources may negate the economic advantage of establishing heavy industry in certain areas and cause companies to relocate.
- Finally, Norway has a crucial role to play as an exporter of capital. With the largest sovereign wealth fund in the world, Norway's policies and investment decisions can have real impact at home and abroad, helping to support an orderly transition through its effective management of climate-related financial risk and investment in low-carbon sectors.

1. Preamble: Energy Transition in a Post-COVID-19 World

This paper on the Norwegian energy sector and the interviews upon which it is based were prepared and undertaken between the summer of 2019 and January 2020. Since its completion, two major events have occurred that could radically change the future global energy scene: the COVID-19 pandemic, which led to the lockdown of the world's economies, and recent disputes between OPEC+ countries that caused a temporary increase in production despite reduced demand. The result has been a collapse in crude oil prices and a significant decline in spending by international oil companies. In short, these events have dramatically changed the global outlook for energy, at least in the near future.

To understand the impact of these two factors, it is necessary to consider a number of major uncertainties affecting future energy markets and the way in which they might develop going forward. The main uncertainty is the extent to which the changes in consumer behaviour seen during the pandemic – voluntary and involuntary – are an anomaly and whether daily life will revert to something approximating business as usual, if the virus is managed through distancing measures and inoculation. Alternatively, these changes may represent a serious discontinuity that significantly alters societal behaviour and impacts future energy markets. Other related uncertainties include the length of the lockdown, whether a revival of the OPEC+ agreement emerges and, if it does, whether oil prices return to pre-crisis levels.

What are the implications for the current energy transition and the role of renewables and clean technologies?

A key uncertainty explored in this research paper is the speed and shape of the transition, which we argue may occur faster than assumed by the 'energy establishment'. This will be determined by a combination of government policy to promote the use of renewables and energy efficiency, relative energy prices influenced by technology and innovation, and consumer expectations. COVID-19 may affect each in turn. It is likely that for at least the rest of 2020, government policy on climate change will take a back seat as leaders focus on overcoming the pandemic. Governments may also be reluctant to adopt policies associated with environmental protection if they impact economic activity. The weak enforcement of existing environmental regulations could also further delay the transition. Meanwhile, the expected pandemic-related recession may well worsen the commercial viability of carbon capture and storage (CCS) technology, which is central to many of the potential energy scenarios. Given that the energy transition will already be disruptive, any delay will require a more sudden shift in behaviours at a later date and cause greater turmoil, especially if stimulus packages in response to the pandemic are not compatible with climate goals.

As for relative energy prices, some believe the falling price of crude oil will slow the rise of renewables in the energy mix. This could be reinforced if gas prices, which are often contractually linked to oil prices, also decline – although this is not as relevant in Europe where the oil–gas price link is weaker. However, this view neglects two factors. First, governments may try and take advantage of the fall

in crude oil prices by increasing sales taxes on oil products. This would allow them to quickly and cheaply raise the revenues they will need in a post-pandemic world to help cover the spending costs associated with the lockdown and consequent recession. Governments could accelerate this approach if producers of oil products are slow to pass on the lower costs of crude to consumers. However, in Europe, increasing sales taxes may face serious opposition of the sort created by the 'gilet jaunes' in France. Even in Norway, the need for macroeconomic policy changes to address a growing budget deficit may require broader revenue raising options, such as more sales taxes on energy – which are already relatively high. This may also focus attention on changing the rules to drawdowns on the country's sovereign wealth fund (SWF), which is already under discussion in Norway.

Such changes to economic policy, both globally and within Norway, further emphasize the imperative of diversifying the economy away from the dependence on hydrocarbon exports. Any rising oil demand from lower prices would not necessarily lead to lower demand for renewables, as the two energy sources do not directly compete. Meanwhile, the demand for renewables is rising. The only exception to this relates to gas use, which does compete directly with renewables and whose price may reflect lower oil prices where the oil–gas price link survives.

What will the oil industry and oil markets look like?

One obvious consequence of recent events is that private oil companies have dramatically reduced their capex spending plans, especially in the upstream. Many smaller companies face bankruptcy, especially those in the shale oil and gas sectors in the US. This could lead to a spate of mergers and acquisitions involving upstream companies, reducing the number of private players in the market. Another consequence could be that the fall in capex and subsequent limitations on supply leads to a much tighter market if and when oil demand eventually begins to recover, pushing oil prices upwards. Given the Middle East's predominance in the oil sector, continued political instability there, which is likely to be aggravated as COVID-19 spreads, is expected to deliver a further oil price shock. This could benefit unaffected oil suppliers like Norway and reinforce the perception of them as reliable oil suppliers.

As to consumer expectations, much will depend upon whether the pandemic fundamentally alters people's behaviour and the resulting consequences. One possibility is that, due to less mobility, the current model of globalization will be discredited or decline naturally. Thus, security of supply could well become a much more important policy priority. From a European point of view this could make energy supply from Norway more attractive. It remains to be seen if the globalization model continues within different parameters, with less physical movement but greater connectivity, which might suggest that transport-fuel use declines and electricity use rises.

How will European gas and power markets evolve?

Even before the recent lockdowns, gas prices in Europe were lower than average for that time of year, due to a milder winter and LNG oversupply. By April 2020, prices were similar to those during the financial crisis in 2009. Lower gas prices will potentially benefit consumers, but have a significant impact on upstream companies and governments of producer countries already stretched by additional pandemic-related expenditures. The carbon price in Europe is also now at a two-year low.

There are likely to be two short-term trends in the power market. First, overall falling electricity demand, particularly from industry, will lead to lower power prices and reduce the profitability of the sector. Second, it is likely that in the EU there will be records broken for the percentage of power that is coming from renewables, as summer will mean higher solar production while power demand is limited by the lockdown. This will have a serious impact on the non-renewable energy producers that face the challenges of both lower market prices and smaller sales volumes. However, falling prices also means less capital available to invest in renewables and other aspects of power infrastructure.

One possible side effect of the pandemic is that governments and populations realize the importance of a coordinated global response in dealing with systemic threats; and that there are benefits to extending such cooperation to work on sustainable development. The postponement of the COP26 meeting to 2021 – while reducing the pressure on countries to develop ambitious carbon-mitigation plans – offers an opportunity for a more coordinated and sustainable response to the impact of COVID-19 on the energy sector and for longer term approaches to climate change.

2. Challenges and Opportunities for Norway

Norway's future as an energy producer, consumer, exporter and investor should be considered in the wider context of the global energy transition. A transformation of energy systems is under way in a growing number of countries around the world. A shift is occurring away from a model based on 'hydrocarbon molecules' to one based on 'electrons' and renewables. Climate change was the initial trigger for this global transition, with local environmental impacts – particularly urban air quality and its consequences for public health – accelerating the calls for changes in the way that energy is produced and consumed.

To date, the 'energy establishment'[1] has repeatedly underestimated the speed of the transition, as evidenced by the continual upwards revisions of their scenarios for renewable energy and electric vehicle (EV) penetration. Figure 1 shows that the International Energy Agency's (IEA) 2019 oil demand forecast for 2030 is 7.2 per cent less than the equivalent 2006 forecast to 2030. In contrast, forecasts for non-hydropower renewables, primarily wind and solar photovoltaic (PV), have risen by more than 200 per cent.

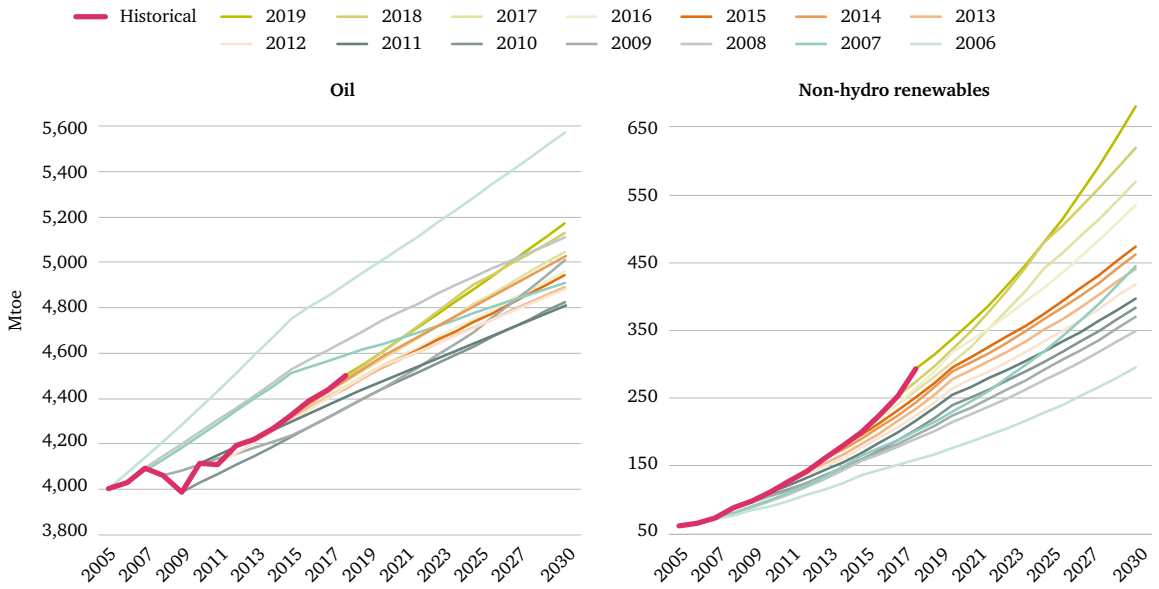
The impacts of the transition are not always immediately obvious and, despite climate change concerns, the consumption of fossil fuels globally continues to rise. In 2019, it is likely that global oil demand topped 100 million barrels per day (b/d) for the first time – up 25 per cent since the turn of the century. Growth in the consumption of the other major fossil fuels has been even greater, with both coal and gas increasing by 37 per cent since 2000; gas consumption in 2018 was at 3,850 billion cubic metres (m^3) and coal was at 3.7 billion tonnes of oil equivalent (mtoe), according to BP.[2] However, energy efficiency, changing consumption patterns and the increasing use of non-fossil fuels, primarily renewable energy, is slowing the rate of increase in demand for fossil fuels.

There are ongoing discussions about whether conditions exist for the continued use of fossil fuels, and their existing infrastructures and supply chains in a carbon-constrained world. The use of CCS and carbon capture and use (CCU) have long been proposed as means of decarbonizing while continuing to use fossil fuels and existing heavy industry practices. Despite decades-long political support for these technologies around the world, global deployment in the power sector has been slow to non-existent. According to the CCS Institute, in 2019, 25 million tonnes of carbon dioxide (CO_2) was permanently stored from a total of 19 facilities around the world with different functions including chemical, iron and steel, hydrogen and fertilizer production as well as natural gas processes and power generation.[3] There may be some expansion in 2020, including in Norway with the expected investment decision for a full-scale project with Norcem, Fortum and Equinor. Piloting and small-scale deployment is also under way to use biofuels and synthetic natural gas with existing energy

[1] This includes institutions such as the International Energy Agency (IEA), the OPEC secretariat, the US Energy Information Administration (EIA) and the major oil companies, at least in public.
[2] BP (2019), *Statistical Review of World Energy, 2019,* https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (accessed 18 May 2020).
[3] Global CCS Institute (2019), *Global Status of CCS 2019*, https://www.globalccsinstitute.com/wp-content/uploads/2019/12/GCC_GLOBAL_STATUS_REPORT_2019.pdf (accessed 22 Feb. 2020).

infrastructure as replacements for fossil fuels. This potentially would reduce the carbon footprint of the new sources of energy – although the environmental benefits of some of the replacement options are, in some cases, questionable.

Figure 1: Comparison of IEA WEO scenarios of oil and non-hydropower renewable production to 2030



Source: Chatham House analysis of Current Policy Scenarios (CPS), IEA, World Energy Outlooks 2006–19.

These debates and trends are seen by some as hiding the true extent and speed of the transition, which is already significantly changing investment patterns. In 2018, 57 per cent of global supply investments in the power sector were in renewable sources.[4] Solar PV and wind, which now account for most renewable energy investments, already produce electricity at a lower cost than fossil fuels in many countries. While the system integration costs of some renewable energy sources may be higher than those of conventional generation, falling storage costs and smarter balancing technologies are likely to mean that it is only a matter of time before these technological advances create an economic rather than an environmental imperative to go renewable. The longer-term investment community is engaging with the concept of declining fossil fuel demand, and many investors view the likelihood of stranded[5] oil and gas assets as credible.

While there is broad agreement among countries and companies that this energy transition is under way, there is less agreement regarding its speed and scale.[6] As with previous energy transitions, once the initial trigger is pulled, other reinforcing factors come into play, changing the relative price and availability of energy sources. These factors range from incremental shifts such as energy efficiency and smarter demand, to more disruptive shifts such as the collapsing cost of renewable energy

[4] Ren21 (2019), *Renewable Global Status Report*, June 2019, https://www.ren21.net/reports/global-status-report/ (accessed 22 Feb. 2020).
[5] The term 'stranded assets' is a contentious one, and in this paper, refers to economically stranded oil and gas assets and associated infrastructure – i.e. assets that have received investment, but are no longer commercially viable as fossil fuel prices and demand decline. Policy support may of course alter assets' immediate vulnerability to stranding. This paper also refers to 'undeveloped' assets – i.e. proven or probable resources that never receive investment or come to market due to declining demand.
[6] World Economic Forum (2019), *The Speed of the Energy Transition, Gradual or Rapid Change?*, White Paper, http://www3.weforum.org/docs/WEF_the_speed_of_the_energy_transition.pdf (accessed 22 Feb. 2020).

and battery technology, and faster-than-anticipated EV uptake. Traditional factors are also still an important consideration, with the potential for oil price shocks due to geopolitical upheavals recently returning to the fore.

Government policies have a key role to play and over time will partly determine the quantity and sources of energy that are consumed. The IEA highlights the role of policies and measures in their *World Energy Outlook* (WEO) analysis, which shows a range of possible global energy consumption by 2040 depending on the extent of government intervention, particularly on climate change (see Figure 1). Under the different scenarios, compared to 2018 levels, fossil fuel consumption varies considerably: current policies lead to a 20 per cent increase; stated policies (where policy goals or targets have been set but the measures to achieve them have not been implemented) result in a 14 per cent increase; while in a scenario in which policies are put in place to meet international agreed climate targets fossil fuel consumption falls by 33 per cent.[7]

Global emissions continue to rise, as the United Nations Environment Programme (UNEP) notes: total greenhouse gas (GHG) emissions grew by 1.5 per cent each year from 2009 to 2018 without land-use change (LUC); and 1.3 per cent each year with LUC, to reach a record high of 51.8 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) in 2018 without LUC emissions and 55.3 $GtCO_2e$ in 2018 with LUC. UNEP highlighted that in 2018 there was an increase in the growth of emissions, and that 'there is no sign of a peak in any of the GHG emissions'.[8] Emissions directly from the energy sector in 2018 grew 1.7 per cent to reach a historic high of 33.1 $GtCO_2$. It was the highest rate of growth since 2013, and 70 per cent higher than the average annual increase since 2010. Coal-fired power plants were the single largest contributor to emissions growth in 2018 with annual total emissions surpassing 10 $GtCO_2$ (up 2.9 per cent year-on-year); non-energy coal use also produced significant emissions of 4.5 $GtCO_2$.[9]

Managing the consequences of climate change is in turn accelerating the need for a rapid move away from the use of fossil fuels. The publication of special reports by the International Panel on Climate Change (IPCC) – *Global Warming of 1.5°C* in 2018[10] and *Climate Change and Land* in 2019[11] – focused scientific, political and public concern over climate change, prompting calls for more ambitious national climate change mitigation targets. Some countries, such as France and the UK, introduced the target of reaching 'net-zero' carbon emissions (hereafter net-zero) by 2050. However, setting targets is only one element of a necessary and complex set of policies and measures that are needed to reduce emissions. International pressure on climate change mitigation plans is anticipated to continue during 2020 ahead of the next Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change (UNFCCC), expected to be in Glasgow in 2021.

[7] IEA (2019), *World Energy Outlook, https://www.iea.org/reports/world-energy-outlook-2019* (accessed 22 Feb. 2020).
[8] United Nations Environment Programme (UNEP) (2019), *Emissions Gap Report 2019*, https://www.unenvironment.org/resources/emissions-gap-report-2019 (accessed 22 Feb. 2020).
[9] IEA (2019), *Global Energy & CO_2 Status Report*, https://www.iea.org/reports/global-energy-co2-status-report-2019 (accessed 22 Feb. 2020).
[10] Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (eds.) (2018), *Global warming of 1.5°C*, Report, IPCC, https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/ (accessed 3 Apr. 2020).
[11] Shukla, P. R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D. C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., Malley, J. (eds.) (2019), *Climate Change and Land*, Report, IPCC, https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/ (accessed 3 Apr. 2020).

Reducing emissions from the coal sector is therefore fundamental to any global mitigation strategy. It is broadly recognized that this could be achieved by system-wide efficiency improvements, switching to lower-carbon alternatives, renewable electricity generation or the capturing of emissions.[12] More contested is the option of switching from coal to natural gas in power generation, which could rapidly reduce emissions, as gas generates less than half the emissions per kilowatt hour (kWh) of coal. However, without decarbonizing gas and/or using CCS, the use of natural gas is incompatible in the long term with climate targets and therefore risks creating stranded assets or locking-in emissions pathways.

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There is increasing debate about when oil and gas demand will peak, yet in many ways this is the wrong question. What matters is what happens after the peak; will there be an extended plateau, a gentle decline or a sudden collapse? Where oil is concerned, it is already clear that OECD demand has peaked, and many believe the 'rest of the world' demand will peak before 2030. One of the primary arguments to counter this view (alongside scepticism about the pace of change in transport) is the idea that rising demand for oil as a petrochemical feedstock for plastics and fertilizers, for example, will offset falling demand in other sectors. In its *Future of Petrochemicals* report, the IEA found that petrochemicals currently account for about 14 per cent of oil demand and 8 per cent of natural gas, but could constitute one-third of oil demand growth to 2030 and half by 2050, as well as rising volumes of natural gas.[13] However, such projections may be overstating demand for plastics (of which 36 per cent is used in packaging) in established and emerging markets, given growing concern over single-use plastics and their impact on the environment, and the development of alternative materials and more circular value chains.[14] The manufacture of plastic, fibres and rubber consumes about 40 per cent of the fossil fuels used within the chemical sector.[15]

While changes in consumption levels are important, especially from a CO_2 perspective, the impact of 'peak demand' on oil producers is not so much about the immediate effect on sales volumes but the effect on current and future prices. Mainstream scenarios all suggest that falling demand will lead to lower prices over time, although there could still be volatility along the way in the event of a geopolitical upset or if a rapid decline in fossil fuel production leads to a relatively short-term supply crunch, for example, both of which would create a temporary price spike.

There is considerable debate around whether gas can provide a 'bridge' to a decarbonized energy system, given its infrastructure needs, price constraints and the lack of clarity over how it would then be phased out. On current trends, there is every possibility that global demand for oil and gas will not grow as anticipated to 2030 and will be significantly below current levels by 2050. Indeed, the

[12] UNEP (2019), *Emissions Gap Report 2019*.
[13] IEA (2018), *The Future of Petrochemicals*, Paris, https://www.iea.org/reports/the-future-of-petrochemicals (accessed 28 Nov. 2019).
[14] European Commission (2018), 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A European Strategy for Plastics in a Circular Economy', COM 2018/028 Final, Brussels: European Commission, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A28%3AFIN.
[15] IEA (2018), *The Future of Petrochemicals*, figure 2.3, primary products from the chemical sector include: nitrogen fertilizers (290mt/yr), plastics, fibres and rubber (420 mt/yr) and other products (250 mt/yr).

long-term goals of the Paris Agreement suggest that oil consumption in 2050 will need to be at least 50 per cent lower than today, and gas demand one-third lower. With rising climate and environmental pressures, the transition is increasingly likely to be driven by real economic and societal shifts.

Norway's role in the energy transition

As one of the world's largest exporters of energy and capital, Norway has a significant stake in the energy transition, as well as considerable influence over it. Factors such as the price of oil in a declining global market and the role of gas in a decarbonizing Europe will shape Norway's energy relations in the coming decades. So, too, will its overseas investments and its policy experience in transitions in transport and industry (including the oil and gas sector). Clear signalling from the major energy nations would reduce at least some of the uncertainties surrounding the energy transition. By defining its energy transition, including the role of its oil and gas exports and investments, Norway could demonstrate real leadership among oil and gas producers, and help to encourage meaningful engagement with the end-point of the energy transition, as well as its start. This could also help to guide an orderly transition in the energy, power and industrial sectors, which are critical given both their importance to the Norwegian economy and their exposure to decarbonization trends.

This research paper explores the opportunities and challenges for Norway, as seen by its international partners. Through a series of interviews with 15 experts, it explores a range of important questions for Norway's energy future in a European and global context, including:

- the speed and scale of transition globally and in those regions and countries that are heavily dependent on fossil fuels, especially those dependent on Norwegian oil and gas;
- Norway's position in a potentially declining and increasingly competitive fossil fuel market, and what this means for the competitiveness of its heavy industry;
- the role for existing fossil fuels and energy infrastructure in a decarbonizing world;
- the emergence of climate-related financial risks and their influence on Norway's decisions regarding future production and the management of its SWF;
- whether power systems become decentralized or retain a core of large-scale, centralized generation and, in turn, the role of interconnectors and Norway's hydropower; and
- the development of the European Energy Union and Norway's role within that, including its role in delivering net-zero targets enhancing energy security and developing new industrial strategies.

Chapter 3 brings together some of the key themes that emerge from the interviews, and builds on these, outlining the parameters of the debate and highlighting some of the key questions for Norway and for its European and international partners. The Annex contains 15 expert perspectives, covering these themes in greater detail and from different viewpoints. The paper concludes with a summary of the opportunities and challenges identified, and a series of high-level recommendations for key Norwegian stakeholders.

3. Norway's Energy Future

European climate leadership

The EU has consistently played a global leadership role over climate change, putting in place binding GHG reduction targets on its member states, promoting renewable energy and energy efficiency, and encouraging low-carbon investment and expenditure (through its structural programmes). At the end of 2019, the heads of state endorsed the objective of making the EU climate neutral by 2050 in line with the Paris Agreement. In March 2020, the European Commission presented a proposal to enshrine in legislation the EU's political commitment to be climate neutral by 2050.[16]

The discussion of carbon neutrality builds on a long track record of climate targets. In 2014, the European Council agreed targets to reduce GHG emissions by at least 40 per cent by 2030 and, by 2050, to decrease emissions by 80–95 per cent below 1990 levels. As the energy system is responsible for close to 80 per cent of total GHG emissions in the EU, such aims will have a significant impact. In 2008, EU-wide targets were adopted to deliver a 20 per cent reduction in GHG emissions, a 20 per cent improvement in energy efficiency and to enable renewable sources to supply 20 per cent of energy. Subsequently, the EU stated that by 2030 renewable energy would account for at least 27 per cent of total energy production and that there must be a 27 per cent improvement in energy efficiency.[17] In July 2018, the energy efficiency and renewable targets were revised in an agreement between the European Commission and Council, to at least 32.5 per cent and 32 per cent, respectively.[18]

> The political will has caught on faster than many people expected and momentum behind targets for net-zero emissions will increase, but I don't know about the 2050 timeframe. I don't think the targets will kill fossil fuels but the industry will have to find ways to adapt; to become less carbon-intensive and find ways to offset and capture the carbon produced.[19]
>
> Philip Cunningham

The EU as a whole is exceeding its GHG reduction targets. In 2017, emissions were at 22 per cent below 1990 levels, compared to a 2020 target of 20 per cent reductions.[20] However, there has not been uniform success across the EU. In 2016, 22 member states met their annual Effort Sharing targets.[21] In Belgium, Finland, Germany, Ireland, Malta and Poland, Effort Sharing emissions were higher than the national Effort Sharing targets. Malta has missed its target every year since 2013, while 2016 was the first time that Belgium, Finland, Germany, Ireland and Poland missed their Effort Sharing targets.

[16] European Commission (2020), 'Committing to climate-neutrality by 2050: Commission proposes European Climate Law and consults on the European Climate Pact', press releasehttps://ec.europa.eu/commission/presscorner/detail/en/ip_20_335 (accessed 22 Apr. 2020).
[17] European Council (2014), 'European Council (23 and 24 October 2014) – Conclusions', http://data.consilium.europa.eu/doc/document/ST-169-2014-INIT/en/pdf (accessed 1 Oct. 2019).
[18] European Commission (2018), *In-depth Analysis in Support of the Commission Communication,* COM/2018/773, 28 November 2018, https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en.pdf (accessed 1 Oct. 2019).
[19] Quotations in the paper are all taken from the expert perspectives in the Annex.
[20] European Environment Agency (EEA) (2018), 'Total greenhouse gas emission trends and projections', December 2018, https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-2 (accessed 22 Feb. 2020).
[21] The individual country requirements, outside of the sectors covered by the Emissions Trading System, to reduce their GHG emissions.

While the EU has raised the collective targets, current policies and industrial and consumer trends are insufficient to meet 2030 targets. Further legislative measures are needed: under present draft national plans, instead of at least 32 per cent, the share of renewable energy is only likely to reach between 30.4 per cent and 31.9 per cent in 2030 at the EU level.[22] Growing public concerns over climate change are leading to greater individual action and pressure on policymakers and businesses to introduce new policies and practices. A survey undertaken for the European Commission and published in September 2019 indicates that 93 per cent of respondents think that climate change is a serious problem, with 60 per cent of respondents thinking it is one of the most serious problems facing the world. Almost all respondents (92 per cent, up three percentage points since 2017) think it is important that their national government sets ambitious targets to increase the amount of renewable energy used, such as wind or solar power, by 2030.[23]

While the views of citizens in the EU are clear, a global opinion poll undertaken by YouGov and released in September 2019 somewhat surprisingly had Norway at the bottom of a 28-country survey of the percentage of citizens who agreed with the statement that the 'climate is changing and human activity is mainly responsible' (35 per cent). It also came second to the US in terms of having the highest percentage of citizens who thought that the 'climate is changing but human activity is not responsible at all' (8 per cent).[24] While there is a danger of reading too much into individual polls, the dependency of the Norwegian economy on fossil fuels is likely to affect public opinion about the need for a rapid energy transition driven by climate change.

It is also important to note that there is a wide range of public and political views within the EU about the need to act on climate change. *The European Green Deal*, published in a communication by the European Commission in December 2019, is said to 'reset the Commission's commitment to tackling climate and environmental-related challenges that is this generation's defining task'. The European Green Deal is expected to 'transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases (GHG) in 2050 and where economic growth is decoupled from resource use'. Key elements of the Green Deal include:[25]

- The adoption of a 'Climate Law' to ensure climate neutrality of the EU by 2050 and to legislatively enshrine the objective and its associated policy measures. The Commission will present an impact assessment plan to increase the EU's GHG emission reductions target for 2030 to at least 50 per cent, moving towards 55 per cent.
- A proposal for a carbon border adjustment mechanism for selected sectors, to reduce the risk of carbon leakage.
- The development of a power sector based largely on renewable sources, complemented by the rapid phasing out of coal and by decarbonizing gas. Increased cross-border and regional

[22] European Commission (2019), 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, United in delivering the Energy Union and Climate Action – Setting the foundations for a successful clean energy transition', COM/2019/285 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1565713062913&uri=CELEX:52019DC0285 (accessed 1 Oct. 2019).
[23] European Commission (2019), 'Climate Change, Special Eurobarometer 490', September 2019. https://data.europa.eu/euodp/en/data/dataset/S2212_91_3_490_ENG (accessed 23 Mar. 2019).
[24] YouGov (2019), 'International poll: most expect to feel impact of climate change, many think it will make us extinct', 15 September 2019, https://yougov.co.uk/topics/science/articles-reports/2019/09/14/international-poll-most-expect-feel-impact-climate (accessed 3 Oct. 2019).
[25] European Commission (2019), *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal*, COM (2019) 640 final, 11 December 2019, https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf (accessed 22 Feb. 2020).

cooperation will help to achieve the benefits of the clean energy transition at lower cost. This will be aided by a €100 billion Just Transition Mechanism to support those regions most affected by the transition to a green economy.

- The transition to climate neutrality also requires enhanced energy and resource efficiency, including developing smart infrastructure and moving towards a clean, circular economy. This should foster the deployment of innovative technologies and infrastructure such as smart grids, hydrogen networks, CCUS or energy storage that enable sector integration, and the decarbonization and modernization of energy-intensive industries such as steel, chemicals and cement, which are indispensable to Europe's economy, as they supply several key value chains.
- The Commission has estimated that achieving the current 2030 climate and energy targets will require €260 billion of additional annual investment. The Commission has proposed a 25 per cent target for climate mainstreaming across all EU programmes. The EU budget will also contribute to achieving climate objectives on the revenue side.

Norway and the future of oil and gas

Oil supply and demand in Europe and internationally in 2030 and 2050

With the world striving to meet decarbonization targets in line with the Paris Agreement, the global oil market will shrink considerably.[26] One obvious implication of this is that there will be increasing competition between existing oil suppliers to secure their share of remaining supply, and to prevent their assets from becoming stranded or left undeveloped.[27] For oil producers this will be a global race, which will almost certainly lead to price competition between producers and falling crude oil prices.

Unlike in previous eras, these lower prices are unlikely to be offset by rising oil demand for two reasons. First, as crude oil prices fall, consumer governments in the major markets will almost certainly pick up any slack created by falling crude oil prices by increasing sales taxes on oil products. For example, in 2014, before the crude oil price collapsed, 47 per cent of final oil product prices in the G7 countries were sales taxes; by 2018 this figure was 50 per cent. This trend is likely to be especially strong in Europe where there is a long-standing practice of taxing oil products. The second reason is the availability and affordability of alternative technologies, especially EVs.

The carbon intensity of different oils may also affect their competitiveness over time. A possible advantage for Norway is that the bulk of its reserves are dominated by light oil, which has a relatively low-carbon footprint although new reserves such as the giant Johan Sverdrup field are comprised of heavier oil and so will change the relative composition of Norway's oil production over time.[28] The bulk of conventional global oil reserves by contrast tend to be heavier and have a higher carbon

[26] IEA (2019), *World Energy Outlook*, 'Sustainable Development Scenario', p. 673.
[27] While there may be peaks and troughs of investment in response to changing market prices, the overall direction of the market is clear in a rapidly decarbonizing world.
[28] In 2018, according to ENI, 74.4 per cent of Norway's total oil production was 'light and sweet'; see ENI (2019), *World Oil Review 2019*, p. 51, https://www.eni.com/assets/documents/documents-en/WORLD-OIL-REVIEW-2019-Volume-1.pdf (accessed 24 Mar. 2020). However, this composition changed when the Johan Sverdrup field came online in 2019, see Coleman, N. (2019), 'Norway's Johan Sverdrup giant breathes life into declining North Sea', S&P Global Platts, 7 October 2019, https://www.spglobal.com/platts/en/market-insights/latest-news/oil/100719-norways-johan-sverdrup-giant-breathes-life-into-declining-north-sea (accessed 4 Mar. 2020).

footprint. The practical benefit for Norway of this is uncertain. Unconventional tight oil reserves also tend to be light. Large medium sour reserves are located in the Middle East and tend to have low technical costs of production, in the absence of a carbon price.

Global competition

The expert interviews in the Annex reflect the varying degrees of uncertainty affecting future oil demand. Some suggest that there will be declining but still significant demand for oil in 2050, while others expect demand to drop by 2030 and little to no demand by 2050. The speed and scale of transition in the transport sector will be key. Estimates of sharply declining demand are underpinned by the expectation that EVs will reach price parity with internal combustion engine (ICE) vehicles within the next five years, and that electrification, hydrogen and oil-to-gas switching may ripple out through light, medium and heavy goods vehicles. The latter would reinforce the view set out in the interviews that the transition may happen faster than many in the energy establishment currently expect. A faster decline in oil demand would intensify competition between national oil companies with access to low-cost reserves and large international oil companies with relatively high-cost reserves, which may come under financial pressure sooner than anticipated.

> There is still a need for oil. Even in the most ambitious scenarios of displacement by EVs, you still have a significant amount of oil being produced in 2040 or 2050. From a range of calculations from different analytical groups – the IEA or the EIA or independent groups and oil company scenarios – the lowest demand for oil appears to be 50 or 60 million b/d, instead of 100 million b/d: roughly half the consumption in 2019. Finding 50 million barrels of oil to produce per day still requires a lot of investment.
>
> Adam Sieminski

> Oil will have a steeper decline than many of the companies are anticipating, and my commission posits it down by 70 per cent or 80 per cent by 2050.
>
> Adair Turner

As countries commit to net-zero, even the hard-to-reach sectors of their economies will need to decarbonize. In the marine and aviation sectors, electrification and decarbonization are either under consideration or are already occurring. In Norway, it is expected that there will be 70 battery-powered ferries by 2022, with development of hydrogen/electric ships also under way.[29] The aviation sector is particularly difficult to decarbonize, but it is developing different supply options and improving energy efficiency, including biofuels, hydrogen and electrification for shorter distances.

> Sustainable aviation fuels is a really exciting area, and one that does have significant opportunity for nations that either want to repurpose an oil and gas industry, or want to leap a generation and create a new industry that doesn't exist today.
>
> Paul Stein

The debate around EVs provides a good illustration of the uncertainty regarding the speed and scale of transition. EVs tick many boxes, including improvements in urban air quality and falling emissions,[30] reduced security of supply concerns and potentially provide a source of decentralized battery storage. Rates of EV penetration will be heavily influenced by government policies, including investment in charging points and other core infrastructure, the introduction of end-date bans on

[29] Tekna (2019), 'Electric ferries – a success for the climate and for Norwegian battery production', 4 February 2019, https://www.tekna.no/en/news/newsletter-february-2019/electric-ferries/ (accessed 24 Jan. 2020).
[30] Assuming the power is generated by renewable technology.

ICE vehicle sales at national and city levels,[31] and the relative price of oil-based transport fuels. On current trends, EV uptake may be rapid in Europe – especially in Norway – and even faster in China, where the development of a world-class EV manufacturing base is a strategic priority.

> It's hard to predict when the ICE will be phased out in Europe and elsewhere. The critical years will be 2022 to 2025.
>
> Mark Campanale

Bullish oil market analysts believe that these trends will have limited impact on oil demand. They highlight the fact that passenger vehicles only account for around 20 per cent of oil consumption and that growth elsewhere in the transport sector, and non-energy uses of oil, will compensate for any fall in oil demand. This assumes that shifts in the passenger vehicle sub-sector will be slow, with EVs reaching price parity in the mid-2030s rather than the mid-2020s. It is also based on the assumption that transition in other sub-sectors will be even slower, given the expense and technical challenge of either electrifying medium and heavy-goods vehicles, or converting them to hydrogen or biofuel.[32] Such analysis also fails to acknowledge modal shifts that are already happening, including urbanization and the growth of ride-sharing and electric two-wheelers, especially in emerging economies such as China and India.

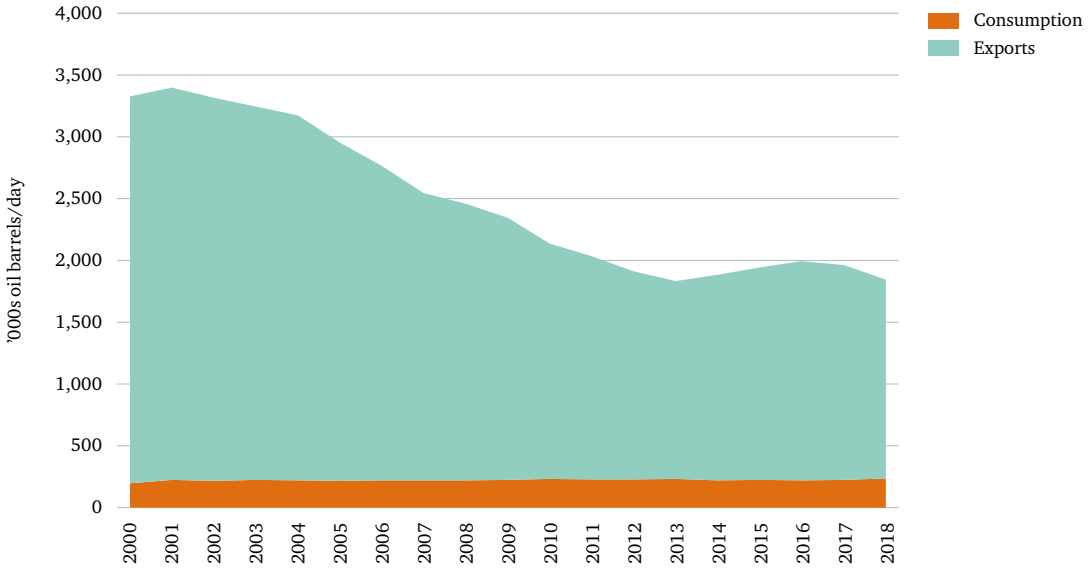
> The transition away from the ICE is happening much more rapidly in Norway than was imagined a couple of years ago, driven forward by technology. However, only about 50 per cent of the barrel is used in petrol or kerosene or diesel engines. As long as the underlying demand for the other 50 per cent continues to grow, oil projects will not be shut down, although its growth may be flattened by the reduction in demand from transportation in time.
>
> Philip Cunningham

Implications for Norway

These trends have important implications for Norway. The pattern for Norwegian oil exports since 2000 is shown in Figure 2, with the decline in production since the start of the century simply reflecting the natural depletion of Norway's fields. The prospects for future production, and therefore Norway's export potential, will to some extent continue to depend upon the traditional factors that influence exploration and development, including the level of upstream investment interest coupled with technological developments, both of which can be influenced by government policy in terms of access to acreage and fiscal terms. It will also increasingly be influenced by issues such as where new projects sit on the cost-curve – and crucially at what stage this level of production cost becomes uncompetitive – as well as the domestic public opinion and the Norwegian government's continued 'social licence' to produce. Both are explored below.

[31] It is likely that specific city air pollution policies will also play a significant role.
[32] It would take major technical developments to allow for electric-powered medium and heavy-goods vehicles, but liquefied natural gas (LNG) could be an option.

Figure 2: Norway's oil exports 2000–18 (b/d)



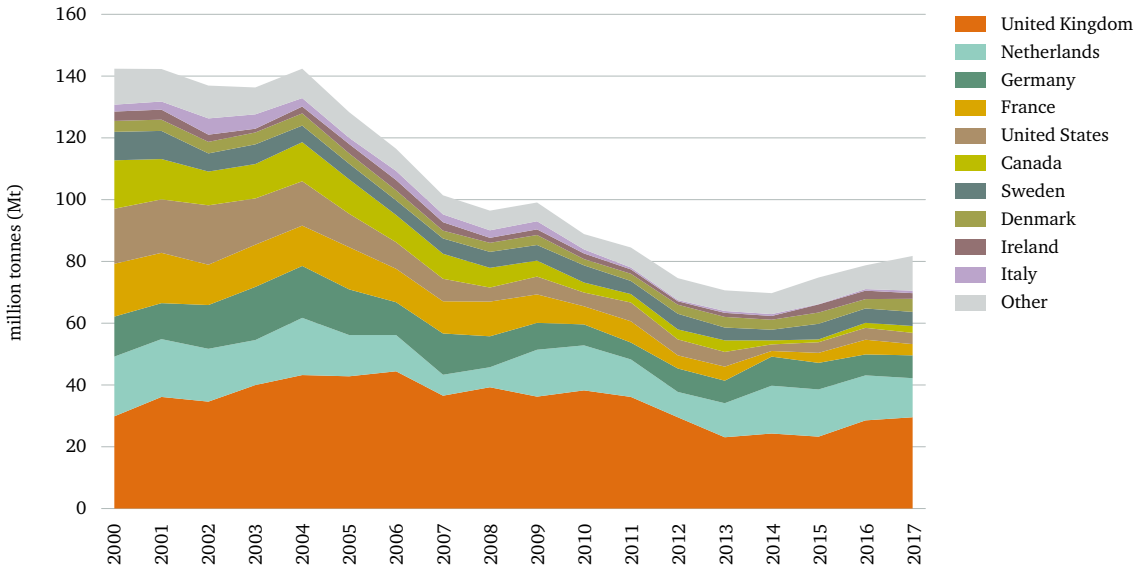
Source: BP, Statistical Review of World Energy, 2019.

The destination of Norwegian exports is shown in Figure 3. Norway has a clear competitive advantage over other producers in terms of proximity to the European market. It also has a reputation as a reliable supplier that should help it maintain its market share. However, as a result of the energy transition described above, European oil demand is likely to fall rapidly and far faster than in other regions, given the green pressures on European governments, and more disruptive shifts in mobility, particularly in cities. If this became a reality, Norway and other European producers would have the option to export to other parts of the world, although the competitiveness of this would be affected by transport costs.

> Shareholders in European oil and gas companies, linked utilities and industry tend to be far more aggressive than those in the US when it comes to holding the companies to account on climate change issues.

Shareholders in European oil and gas companies, linked utilities and industry tend to be far more aggressive than those in the US when it comes to holding the companies to account on climate change issues. In any case, competitive advantage in the crude oil market is almost entirely driven by price. Thus, Norway can expect falling oil revenues as a result of both lower volumes and lower prices driven by oversupply as other global producers try to avoid stranded assets.

Figure 3: Norway's oil exports, by importer



Source: Chatham House analysis of UN COMTRADE (2019), www.resourcetrade.earth.

Ultimately, Norway is in a good position to manage this decline. Unlike most oil-producing countries, it is in the process of diversifying its economy and is no longer as oil-dependent as many other producers. Further diversification is under way. Norway has also developed the world's largest sovereign wealth fund, explored in further detail below. In its assessment of the country's 'adaptability' in light of climate impacts – including a shrinking oil sector and declining oil revenues – Norway's Climate Risk Commission found that it is relatively less exposed than most oil producers, given its high income and well-diversified economy, and is more adaptable, with the Norwegian economy continuing to evolve as it has done over the past century with similar long-term returns on capital and labour across sectors.[33]

Gas supply and demand in Europe in 2030 and 2050

Decarbonization pathways also suggest increasing competition between existing gas suppliers as they seek to secure markets between now and 2030. Gas is already facing strong competition from energy efficiency and price-competitive renewable energy, and the potential role of gas in the energy transition remains contested (see Annex).

Key issues that emerge include the credibility of natural gas as a lower-carbon fossil fuel. The emissions associated with gas are typically lower than those for oil and especially coal, and this should, in theory, mean that coal and oil leave the energy system first and that natural gas declines at a slower rate. Not all gas is equal, and there is growing international awareness and concern over methane leakage from gas production and infrastructure. Methane is a far more potent GHG than CO_2 and in some cases – where there is significant methane leakage from already energy-intensive LNG,

[33] Norwegian Climate Risk Commission (2018), *Climate risk and the Norwegian economy,* Official Norwegian Reports NOU 2018: 17 Summary, p. 24, https://www.regjeringen.no/contentassets/c5119502a03145278c33b72d9060fbc9/en-gb/pdfs/nou201820180017000engpdfs.pdf (accessed 22 Feb. 2020).

for instance – gas can have similar emissions to coal. The growing profile of fugitive emissions presents a potential competitive advantage for Norway, given its reputation for best practice in upstream emissions mitigation and tight infrastructure.

> For 2030, there will probably be a slight increase in gas demand, as coal-to-gas switching has a lot of potential even with current carbon prices. Afterwards, that demand would fall, but how fast very much depends on the demand side.
>
> Andris Piebalgs

Another issue is the lack of a strategy for decarbonizing gas systems. As previously mentioned, a strong case exists for gas to be a bridge to a lower-carbon energy system but there is little detail of the length or destination of this bridge. While gas will struggle to compete with renewable energy in new markets, there may be potential to displace coal and higher-carbon power sources with natural gas where infrastructure is already in place. However, this role is currently constrained by the lack of a clear strategy for decarbonizing gas systems or phasing out natural gas.

Hydrogen and alternative gases

If natural gas is to have a role as a bridge fuel, then there needs to be a clear strategy in place to ensure the phasing-in of hydrogen gas – including biogas and blue and green hydrogen – as well as the phase-out of natural gas. This means policy measures and finance to support research and development (R&D) in green hydrogen, to stimulate market demand and, over time, to upgrade existing gas transport infrastructure and demand-side appliances so that they can handle ever-higher quantities of green gas blending. The European Commission's forthcoming Gas and Decarbonisation Package could provide guidance here, alongside national energy and climate plans. The European Green Deal communication calls for the revision of the Trans European Energy Network regulation to ensure consistency with net-zero, including the fostering of the deployment of new innovative technologies and infrastructure such as hydrogen.[34] For incumbent gas suppliers such as Norway, this could represent a significant market opportunity, but will require serious engagement with the end goal of net-zero.

> Most of the analysis we've seen suggests that gas will continue to play a critical role in the energy transition, as a fully electric alternative is considerably more expensive. By 2030 natural gas will still be very significant in Europe, and we anticipate the beginning of decarbonization through some hydrogen facilities.
>
> Dominic Emery

There is growing support, in governments and certain industries, for a greater, potentially significant, role for hydrogen in decarbonization, as an energy source – or more specifically as a vector, carrying energy from generation to supply – for heating, heavy-goods transport and industry.[35]

Hydrogen can be a substitute for natural gas in many energy and industrial processes. Furthermore, hydrogen can be blended with natural gas by up to 10 per cent in the existing natural gas network, and therefore reduce its carbon intensity, while using existing infrastructure. Alternative hydrogen is and can be used to create synthetic natural gas (SNG) produced from hydrogen and CO_2.

[34] European Commission (2019), *The European Green Deal*.
[35] Industry can burn hydrogen to produce high-grade heat and use the fuel in several processes as feedstock, either directly or together with CO_2 as synfuel/electrofuel. In steelmaking, for example, hydrogen can work as a reductant, substituting for coal-based blast furnaces.

> The best strategy would be coal-to-gas switching as a first step, then blending 5 per cent or 10 per cent, then a real hydrogen/zero emission system. There is also a lot of expectation that renewable electricity could be transformed into clean hydrogen, but there is no clear regulatory process and the costs are high.
>
> Andris Piebalgs

> It is often overlooked that hydrogen is already today a huge industry, with around 70 million tonnes of hydrogen being produced every year for use in oil refining and chemicals. This is not a trivial amount: 70 million tonnes of hydrogen could in theory power around 500 million cars, which is half of today's global car fleet.
>
> Fatih Birol

The production of hydrogen using electricity, through electrolysis, could increase flexibility in a power system dominated by variable renewables. While there have been significant falls in the costs of battery production and therefore the short-term storage costs of electricity, in the longer term, seasonal storage – important in a solar-dominated power sector – may require different solutions. The creation of hydrogen and using existing gas storage infrastructure and knowledge may help to address the seasonality problem. Therefore, the greater use of hydrogen is seen as an attractive and some would say essential element of decarbonization.

However, this discussion of hydrogen's potential is not new. In 2003, the then President of the European Commission Romano Prodi established a high-level group on hydrogen, with an intention that hydrogen and fuel cells would in the next 20 to 30 years considerably change economic growth patterns by bringing about a decentralized energy system.[36] The conditions necessary to deploy hydrogen on a much larger scale are changing rapidly, with recognition of the need for new approaches in hard-to-reach heavy industry sectors and in heating, while falling costs of renewables are changing the power mix and increasing the importance of system flexibility. However, there are still many technological, economic and thermodynamic challenges to developing a hydrogen economy in Europe and beyond.

There are different ways of producing hydrogen, with quite distinct impacts. The most widely used technology currently requires fossil fuels, mainly natural gas reforming into hydrogen (H_2) and carbon monoxide (CO) or CO_2 in a steam methane reformer (SMR), a product that is widely known as grey gas (hydrogen produced from coal is also referred to as black gas). Annual hydrogen production uses 205 billion m^3 of natural gas – 6 per cent of global consumption – and 107 million tonnes (Mt) of coal, with corresponding annual CO_2 emissions of 830 $MtCO_2/yr$.[37]

The costs of grey hydrogen are about €1.50 per kg ($1.65/kg). However, if the use of hydrogen is to be compatible with decarbonization objectives, then the CO_2 produced would need to be captured and/or used – when this is done then the gas is often referred to as blue hydrogen. The costs of CCS/CCU are not fixed, but current estimates, according to the IEA, are 'in the range of' €50 to €70 per tonne of CO_2. The IEA notes that the 'price is lower in specific cases like ammonia production', but it could add between €0.50 and €1.0/kg of hydrogen production ($0.55 to $1.10/kg), although scaling up and standardization are likely to lead to cost reductions.[38]

[36] European Commission (2003), 'EU unveils vision for the energy source of the 21st century: hydrogen and fuel cell technology', 16 June 2003, https://ec.europa.eu/commission/presscorner/detail/en/IP_03_848 (accessed 22 Feb. 2020).
[37] IEA (2019), *The Future of hydrogen: Seizing today's opportunity*, report prepared for the G20, Japan, https://www.iea.org/reports/the-future-of-hydrogen (accessed 23 Mar. 2020).
[38] Van Hulst, N. (2019), 'Commentary: The clean hydrogen future has already begun', Hydrogen Envoy for the Ministry of Economic Affairs and Climate Policy, The Netherlands, 23 April 2019, IEA, https://www.iea.org/newsroom/news/2019/april/the-clean-hydrogen-future-has-already-begun.html (accessed 22 Feb. 2020).

A carbon-neutral mechanism for the production of hydrogen is the electrolysis of water using zero-carbon energy sources, primarily solar or wind. This creates a product known as green gas,[39] which accounts for 2 per cent of global hydrogen production. However, according to the IEA, if all the currently dedicated hydrogen production were produced through electrolysis this would result in an annual electricity demand of 3,600 terawatt-hours (TWh) – equivalent to 13 per cent of global consumption.

According to Bloomberg New Energy Finance (BNEF), green hydrogen costs may fall to as low as $1.40/kg by 2030 from the current range of $2.50 to $6.80. This would mean that 'once the industry scales up, renewable hydrogen could be produced from wind or solar power for the same price as natural gas in most of Europe and Asia'.[40] If hydrogen is to be widely used, the production of blue or green gas is clearly necessary to meet emissions reduction objectives; however, neither is currently economic and both have technology uncertainties. Moving towards economically viable hydrogen production will require government fiscal and/or policy support in order to go from the pilot to the deployment stage.

> The gas industry and the Norwegians also have to engage on the long-term destination: about net-zero. This means engaging in discussions about how we get there – not just in the 2040s but action in the 2020s. This implies a discussion on the role for biogas and hydrogen, and how we phase them in.
>
> Jess Scott

Hydrogen could play a role in decarbonizing both energy and industry, but it is neither technically nor economically guaranteed, and its environmental credibility is questionable given the production methods. Consequently, the EU, its member states and industries within it, are undertaking research, piloting and demonstration projects to help advance innovation and learning. Such action was recommended by the European Commission in its 2018 Clean Planet for All roadmap: these measures would be necessary for the EU in its goal of 'regaining leadership and seizing the first-mover advantage'.[41] In the UK, the Northern Gas Network is working with the city of Leeds to produce a blueprint for the city to decarbonize the gas system by using 100 per cent hydrogen.[42] Europe already has more than 45 demonstration projects to improve power-to-gas technologies, where the main technology is an electrolyser.[43]

> Renewable-based hydrogen and electric fuels will start competing with gas sooner than expected; low-cost electricity and developments in the heating sector have major implications for gas-exporting countries such as Norway.
>
> Tomas Kåberger

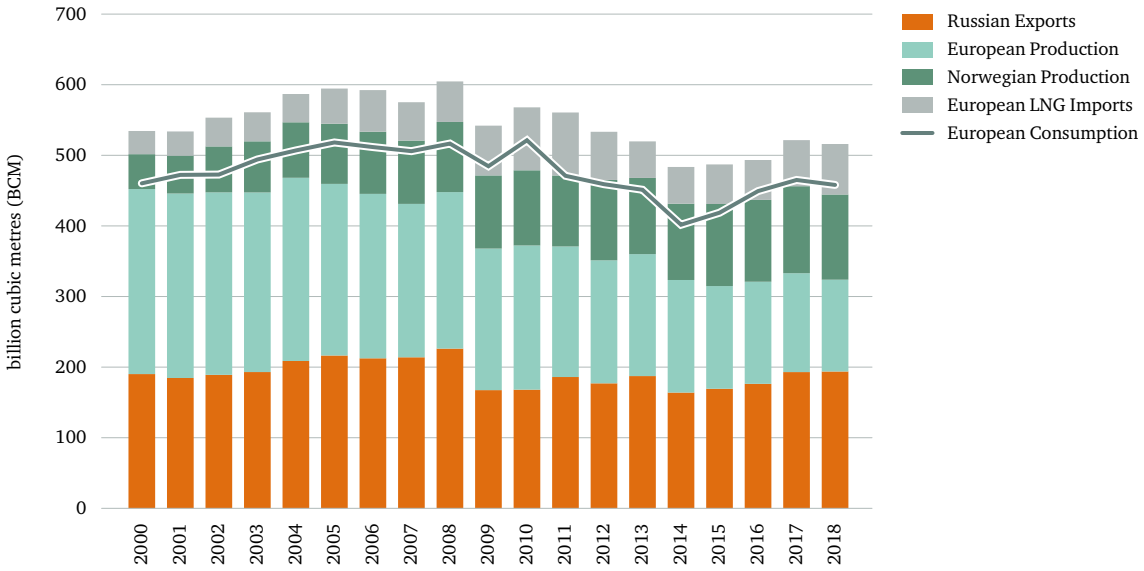
Regional competition

While the growth of global LNG capacity has increased international gas trade, regional dynamics still matter far more for gas than they do for oil. This is largely due to gas infrastructure requirements and the expense of LNG transport. Competition between gas suppliers is therefore likely to be focused

[39] World Energy Council (2019), *New hydrogen economy – hope or hype?,* https://www.worldenergy.org/assets/downloads/WEInsights-Brief-New-Hydrogen-economy-Hype-or-Hope-ExecSum.pdf (accessed 22 Feb. 2020).
[40] Mathis, W. and Thornhill, J. (2019), 'Hydrogen's Plunging Price Boosts Role as Climate Solution', Bloomberg 21 August 2019, https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef (accessed 22 Feb. 2020).
[41] European Commission (2018), *In-depth Analysis in Support of the Commission Communication*.
[42] H21 (2020), 'About H21 gas network', https://www.h21.green/about/ (accessed 30 Jan. 2020).
[43] Fairly, P. (2019), 'Europe Stores Electricity in Gas Pipes', *Scientific America*, 1 April 2019, https://www.scientificamerican.com/article/europe-stores-electricity-in-gas-pipes/.

on a handful of regional markets, and in Norway's case, within Europe. European gas demand has stagnated since the turn of the century, reflecting several factors. Europe is a mature market with limited opportunities for new gas uses. European population growth is low and in many countries, declining. Industry has meanwhile migrated from Europe towards lower-cost operating environments particularly in Asia. The huge energy efficiency gains experienced in Europe since the oil price shocks of the 1970s have also reduced demand. Nonetheless, as seen in Figure 4, Europe's gas imports have increased as a result of declining domestic European gas production. Russia and Norway supply almost two-thirds of these imports, as Figure 5 shows.

Figure 4: EU gas consumption and imports 2000–18



Source: Chatham House analysis of BP Statistical Review of World Energy 2019.

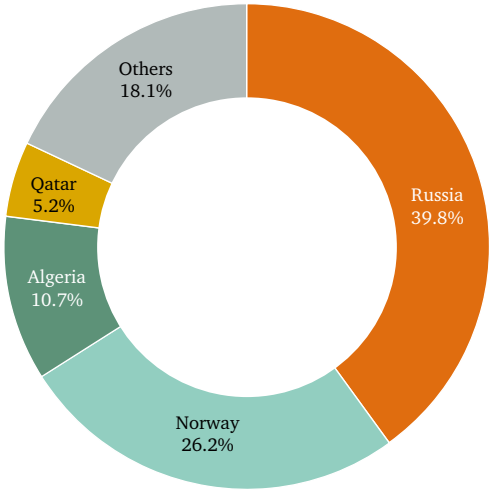
Much of the increase in gas imports has come by pipeline from Russia, although Russian imports have raised several concerns. Most obvious were problems with high costs when the gas price was contractually linked to oil prices. There was also concern over security of supply where Ukraine was a major transit country. To some extent the pricing problem has been solved as Gazprom altered its pricing policy and aligned gas prices with the European hub prices generated by growing competition. Security concerns have also been to some extent mitigated by new pipelines, such as Nord Stream, which avoid transit problems. However, concern over dependence on Russian gas remains, particularly in Central and Eastern European countries, where Russia tends to be the supplier of last resort.

Europe's trend towards rising imports has also been encouraged by the increased availability of lower-cost LNG as new plants come online in the US and Australia, among other countries. The trend towards increasing US LNG supply is likely to continue. On the supply side, more oil production from the US Permian Basin means more associated gas, which is pushing down the domestic price of gas in the US.[44] This has the clear potential to feed growth in LNG capacity. On the demand side, European energy security concerns, particularly where Russia is concerned, are supporting plans for more

[44] In some cases, to negative prices see *Financial Times* (2019), 'Negative gas prices are set to stay in an industry based on faith', 1 August 2019, https://www.ft.com/content/ff4d72e9-65b6-3466-9002-f8b561191dde (accessed 24 Mar. 2020).

LNG re-gasification plants. How Russia will react to this is an important question; Russia's failure to diversify its economy[45] leaves it extremely vulnerable to shifts in energy policy and to the energy transition more broadly.

Figure 5: EU gas imports by source, 2017



Source: Eurostat (2019), https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2c.html (accessed 11 Nov. 2019).

While European gas demand is largely driven by power and industry, there is also a strong seasonal dimension to consider. Winter demand is roughly double that of summer, as a result of the need for heat in buildings. Traditionally, Europe's climate change targets were considered the primary driver of policies supporting growing gas demand. With emerging net-zero targets, however, a critical question is the extent to which gas will remain a key supplier of heat in the EU, or whether gas demand will be dramatically reduced with the electrification of heat and the transition of gas systems to biogas and (green) hydrogen, as well as continued efficiency improvements in residential heat. Technological advances and policy commitments – particularly UK and EU targets for net-zero by 2050 – suggest the latter is increasingly likely.

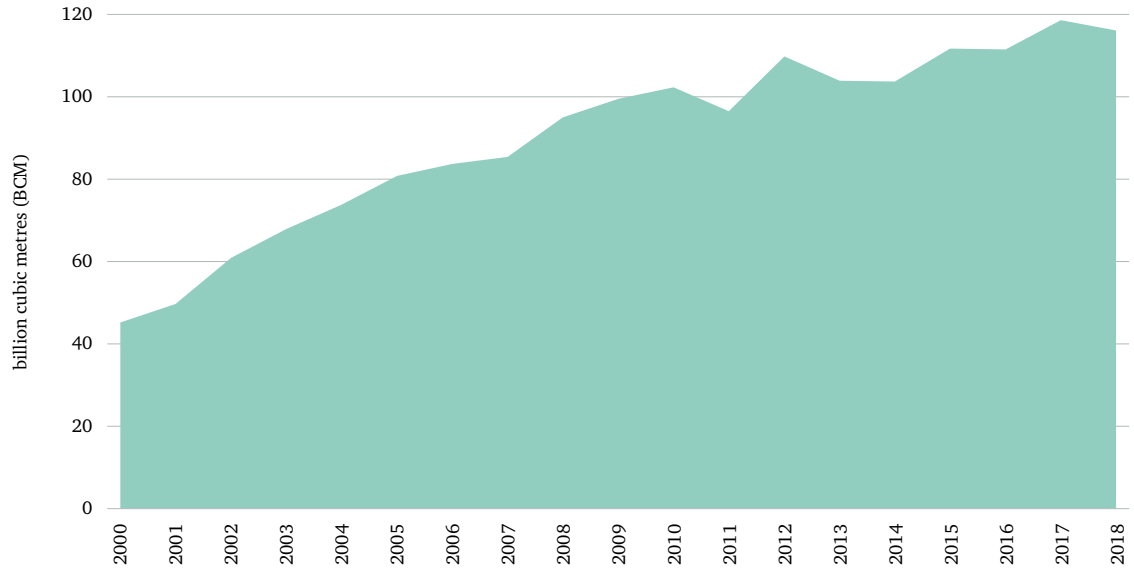
Implications for Norway

It is in this context that Norway's gas exports to Europe have gradually increased. In terms of European gas supplies, Norway is seen as an attractive option as it is a reliable supplier. Given that virtually all of Norway's gas exports are by pipeline, transport is cheaper than LNG. It is also seen as coming from a tight system compared to Russian supplies and those from the Middle East and North Africa (MENA) region and Central Asia, where there has not been the same investment in the mitigation of fugitive emissions. Similar concerns will apply to US LNG exports, given the existing scale of flaring and the recent rollback of federal regulations on fugitive emissions.

[45] In 2017, oil and gas exports accounted for 64 per cent of Russia's exports and 40 per cent of government revenue, see Russia Matters (n.d.), 'Claim in 2018: "Russia relies heavily on energy exports for close to three-quarters of its export earnings and over half of its budget"', https://www.russiamatters.org/node/11300 (accessed 11 Nov. 2019). For Norway, the figures were 40 per cent and 21 per cent, see Norwegian Petroleum (n.d.), 'The Government's Revenues', https://www.norskpetroleum.no/en/economy/governments-revenues (accessed 11 Nov. 2019).

In many ways, if the gas is available, Norway is likely to be seen as the supplier of choice for the EU. Competition from LNG is much more likely on a spot basis, depending on relative prices and weather conditions. As with oil, Norwegian gas supplies towards 2050 will depend upon investor interest and government policies on gas depletion – including access to acreage and fiscal terms – and increasingly on the cost of production and civil society acceptance (both discussed in greater detail below). It will also depend on how the debate around fugitive emissions develops within Norway and internationally, and the scope that regulations define for gas as a bridge fuel.

Figure 6: Norway's gas exports 2000–18



Source: BP Statistical Review of World Energy, 2019.

Norway's role as a responsible oil and gas producer

There is an increasingly active civil society debate around Norway's plans to open new acreage for exploration. Growing civil society pressure has already forced greater scrutiny of new oil and gas exploration, and the Norwegian government was forced to abandon plans to open the Lofoten Islands to oil exploration, in light of the environmental risks that development would pose to the area's pristine natural environment. Norwegian academics and civil society groups have also been at the forefront of international calls for supply-side policy measures designed to limit fossil fuel supply. These include the Lofoten Declaration, which has been signed by more than 300 organizations and which calls for wealthy countries to halt oil development and manage the decline of existing production,[46] and more recent calls for a supply-side climate treaty.[47]

As a high-income, high-capacity oil and gas producer, Norway is well placed to set an example of international leadership in three areas.

[46] Lofoten (2020), *The Lofoten Declaration*, http://www.lofotendeclaration.org/ (accessed 22 Feb. 2020).
[47] Asheim, G. B., Faekhn, T., Nyborg, K., Greaken, M., Hagem, C., Harstad, B., Hoel, M. O. Lund, D. and Rosendahl, K. E. (2019), 'The case for a supply side climate treaty', Policy forum, *Science Magazine* 365(6451): pp. 325–327, https://science.sciencemag.org/content/365/6451/325 (accessed 24 Mar. 2020).

The first is Norway's management of its existing oil and gas production, and particularly the importance of producing the cleanest oil and gas supplies possible. Norway is already a leader where the strict management of upstream emissions is concerned, and through the integration of renewable energy and CCS, is making progress towards the decarbonization of oil and gas production. Leadership in these technologies could provide a competitive advantage for Norway, both in terms of the cost and carbon-intensity of its production. In 2020, Equinor announced plans to reduce the absolute GHG emissions from its operated offshore fields and onshore plants in Norway by 40 per cent by 2030, 70 per cent by 2040 and to near-zero by 2050. This implies annual cuts of more than 5 million tonnes by 2030, corresponding to around 10 per cent of Norway's total CO_2 emissions.[48] The Norwegian Oil and Gas Association launched a similar ambition on behalf of the whole oil and gas industry in Norway, with a 40 per cent reduction by 2030 compared to 2005, and near-zero by 2050.[49] The 2030 target will be realized through large-scale industrial measures, such as energy efficiency, including through digitization and the launch of several electrification projects; further reductions will require the development of new technologies and new value chains.

> As a high-income, high-capacity oil and gas producer, Norway is well placed to set an example of international leadership in the hydrocarbons sector.

These commitments sit within a fast-evolving landscape of climate commitments from the oil and gas sector, including net-zero carbon emissions and scope 3 targets. In 2019, the Spanish oil and gas company Repsol become the first major producer to announce its intention to achieve net-zero carbon emissions by 2050, and in recognition of this, wrote-down the value of its fixed assets by €4.8 billion.[50] In February 2020, BP announced its target of becoming a net-zero carbon emissions company by 2050, or sooner, including achieving this goal across its production and operations, halving the carbon intensity of its products and investing in low-carbon technologies, and restructuring the company to deliver this.[51] The credibility of these commitments will become clearer later in 2020, when BP announces details on how they will be implemented. In April 2020, Shell followed suit, announcing its commitment to become a net-zero company by 2050.

The second area in which Norway can lead the way is in its decisions regarding the continued exploration and the expansion of oil and gas production. The exact scale of Norway's resource base continues to be debated, particularly in the Barents Sea, which is a focus for exploration activity. At a global level, however, the production of proved and probable reserves already far exceeds a 2°C carbon budget – or the amount of carbon that can be produced while remaining below 2°C. As such, the continued exploration and expansion of oil and gas carries climate-related risks, both for the Norwegian economy and for international climate commitments. In its recent assessment of cost-curves for production under different scenarios, the non-governmental organization (NGO) Carbon Tracker placed the break-even price for oil production at around $60 per barrel under a 2°C scenario,

[48] Equinor (2020), 'Equinor aims to cut emissions in Norway towards near zero in 2050', 6 January 2020, https://www.equinor.com/en/news/2020-01-06-climate-ambitions-norway.html (accessed 22 Feb. 2020).
[49] Norsk Olje & Gass (2020), 'The oil and gas industry sets targets for zero emissions', press release, 6 January 2020, https://norskoljeoggass.no/om-oss/nyheter/2020/01/nye-klimamal2/ (accessed 31 Jan. 2020).
[50] Repsol (2019), *Repsol will be a net zero emissions company by 2050*, press release, 2 December 2019, https://www.repsol.com/en/press-room/press-releases/2019/repsol-will-be-a-net-zero-emissions-company-by-2050.cshtml#:~:text=Repsol%20will%20be%20a%20net%20zero%20emissions%20company%20by%202050,to%20assume%20this%20ambitious%20goal (accessed 24 Mar. 2020).
[51] BP (2020), 'BP sets ambition for net zero by 2050, fundamentally changing organisation to deliver', press release, https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bernard-looney-announces-new-ambition-for-bp.html (accessed 24 Mar. 2020).

and well below $40 under a 1.6°C scenario.[52] Climate-risk assessments against such cost-curves across the Norwegian continental shelf – where the cost of production ranges from as low as $20 on the new Johan Sverdrup field, to well above $60[53] – have emerged as a key recommendation of the Norwegian Climate Risk Commission.

The third area in which Norway can lead in the energy transition is in a move away from fossil fuels globally, and evolving attitudes to exported (i.e. scope 3 or value chain) emissions. Norway is not a major emitter of GHG, not least because its power sector relies largely on hydropower, and it plans to become carbon-neutral by 2030. However, this only considers domestic emissions, and does not include the emissions associated with Norway's oil and gas exports, which are accounted for in their country of consumption. While some maintain that greater awareness is needed for a 'polluter pays' principle, including through carbon trading systems, scope 3 emissions are clearly becoming part of the conversation where the oil and gas sector's transition is concerned. In this context, there is some inconsistency between Norway's position as a climate leader at home, and as a fossil fuel exporter abroad.

Norway has demonstrated leadership in transparency and good governance of the oil and gas sector. A continued emphasis on reliable data and disclosures around the upstream emissions associated with the sector, the resilience of oil and gas sector plans in light of national and international climate commitments, and exported emissions and Norway's international reputation as a climate leader are all crucial to supporting an informed civil society debate on Norway's choices as a responsible oil and gas producer, and an international climate leader.

Use of sovereign wealth funds

The Norwegian sovereign wealth fund (SWF) has led on fossil fuel divestment, having announced divestment from coal companies and, more recently, from pure oil exploration and production companies. Reducing exposure to fossil fuel assets makes sense, given Norway's existing exposure to oil and gas prices, as a producer country. However, such divestments – dumping shares in small oil and gas exploration companies while maintaining holdings in international oil companies, for example – have raised questions regarding the effectiveness of such moves in managing financial risk. Norway's leadership within the One Planet Group of SWFs could help advance understanding here, through the development of frameworks for the disclosure of climate-related financial risks.

> The step that the Norwegian Sovereign Wealth Fund has taken in no longer investing in coal is not sufficient but a significant signal that coal is the worst perpetrator in the fight against climate change.
> Zoe Knight

There is also growing recognition that divestment must be coupled with the reallocation of capital to clean areas of the economy. With the world's largest SWF of more than $1 trillion, Norway's largest export is ultimately capital. The decisions it makes in terms of managing climate-related risks and adopting sustainable investment approaches carry real weight in international capital markets. Norway has been active in the development of Paris-compatible sustainable finance taxonomies

[52] Carbon Tracker (2019), *Breaking the Habit – Why none of the large oil companies are 'Paris-aligned', and what they need to do to get there,* https://www.carbontracker.org/reports/breaking-the-habit/ (accessed 22 Feb. 2020).
[53] Down and Erickson cite a range of breakeven costs from well below $50 to well over $100 for key Norwegian oil resources (based on Rystad data, 2016), see Down, A. and Erickson, P. (2017), *Norwegian oil production and keeping global warming 'well below 2°C'*, Stockholm Environment Institute, https://mediamanager.sei.org/documents/Publications/SEI-DB-2017-Norway-oil-production-well-under-2C.pdf (accessed 22 Feb. 2020).

at the EU level, and through the One Planet Group, which is considering the reallocation of capital in support of the energy transition, as well as the integration of climate-risk factors. By ensuring transparency and supporting international alignment in these areas, Norway can play an important role in managing climate risk and financing transition.

> As an EU commissioner for development, it was clear that some Asian or African countries attempted to get fast access to energy sources and receive favourable conditions to invest in coal. The SWF should look at where to prioritize investments, and this should be in renewable electricity worldwide.
> Andris Piebalgs

Linked to this is the debate about the SWF's future strategy. The SWF will be considering where to prioritize investments, and this could include investment in low-carbon technologies and infrastructures, particularly in fast-growing emerging and developing economies. Through blended finance mechanisms, for instance, renewable energy and other sustainable investments could be de-risked, and could provide an alternative to fossil fuel infrastructure for countries with access to energy resources. The question of whether the SWF should invest in new industries at home may also arise over time. SWFs do not typically invest in the domestic market, given their role in hedging against national exposure to price volatility, and the risk of overheating the economy, but there may be a case for reassessment over time.

> The economy will need new industries to substitute employment and income that has been generated by oil and gas over decades. Using the fund to support industrial development in Norway could be a way to speed this up.
> Tomas Kåberger

Norway and the future of the EU's electricity market

Europe's power decarbonization objectives and the growth of renewables

The deployment of renewable energy and the decarbonization of electricity is occurring at a much greater pace than in the heat and cooling sectors and in transport. This is mainly due to the availability of technology and the limited impact on consumers. This has led to the development and deployment of solar and wind at scale, which has resulted in falling renewable energy prices and lower subsidies. Globally, as the prices of renewables have fallen, their deployment has accelerated, leading to a virtuous circle of further deployment. Initially government or consumer subsidies were the motivating and economic force behind renewable deployment. Now, it is often purely economics that drive sales, with solar and wind being built without financial support in the EU and other parts of the world. This raises new challenges for governments, industry and regulators, as the integration of higher percentages of variable renewables into the grid requires new governance structures and technologies.

Subsidies and now lower levelized costs of electricity from renewables have transformed the power mix in the EU. In 2018, 93 per cent of new electricity capacity came from just three renewable sources, wind (10.1 GW or 49 per cent), solar PV (8 GW or 39 per cent) and solid biomass (1.1 GW or 5 per cent). Since 2000 an additional 168 GW of wind and 115 GW of solar has gone on the European grids, compared to 97 GW of gas and decreases of 18.8 GW of nuclear, 42.9 GW of coal and 41.1 GW of oil generation.[54]

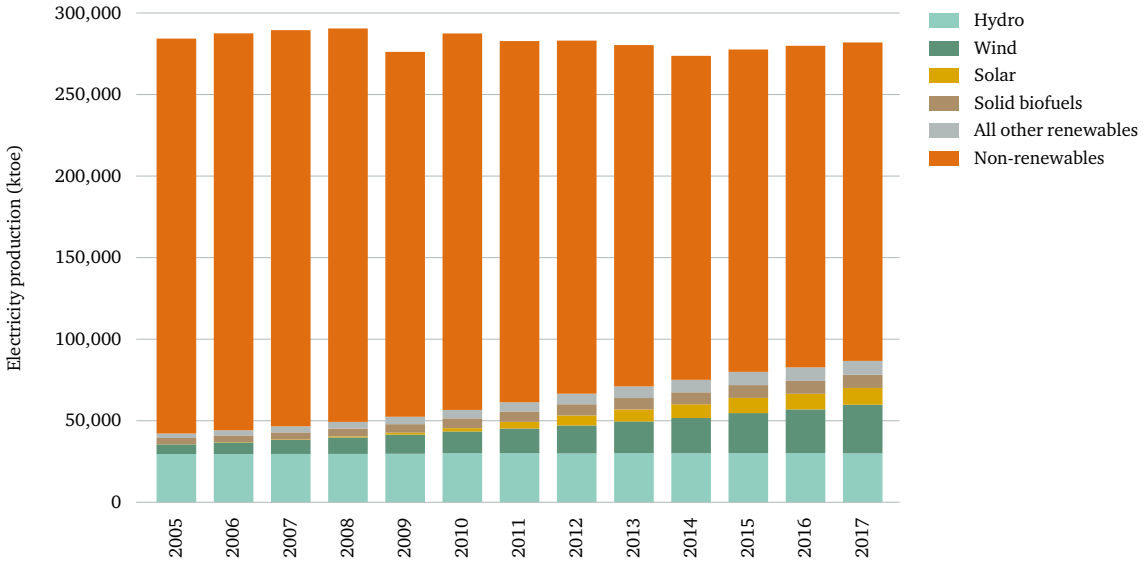
[54] WindEurope (2019), *Wind energy in Europe in 2018*, report, https://windeurope.org/about-wind/statistics/european/wind-energy-in-europe-in-2018/ (accessed 1 Oct. 2019).

In terms of power generation, renewables in 2017 provided 30.75 per cent of the EU's electricity (17.5 per cent of total energy consumption). An additional 15 per cent of the EU's energy will need to come from renewables if its 2030 target is to be met, a considerable escalation of deployment. Within the power sector, it is likely that by 2030, between 55 per cent and 70 per cent will need to be renewably sourced, according to those interviewed for this project. Eurelectric now assumes that 80 per cent of the EU's electricity can come from renewables by 2045, and by that time wholesale power prices are expected to reach €70 to €75 per MWh, which is significantly lower than other existing projections.[55]

> The deployment of renewable energy and the decarbonization of electricity is occurring at a much greater pace than in the heat and cooling sectors and in transport. This is mainly due to the availability of technology and the limited impact on consumers.

The Norwegian target for renewable energy deployment by 2020 is 67.5 per cent of total energy, up from 61 per cent in 2010. The renewables percentage within heating and cooling generation was 33.3 per cent in 2005 and 36.4 per cent in 2010. This figure is expected to increase to 43.2 per cent in 2020. The renewables proportion of electricity was 97 per cent in 2005 and 96.9 per cent in 2010 (see Figure 8). For 2020, a renewable percentage of 113.6 per cent has been calculated for electricity production (as a result of electricity exports).[56] The renewables share of the transport sector was 1.2 per cent in 2005 and is estimated at 4.1 per cent in 2010 and is expected to increase to 10 per cent in 2020.

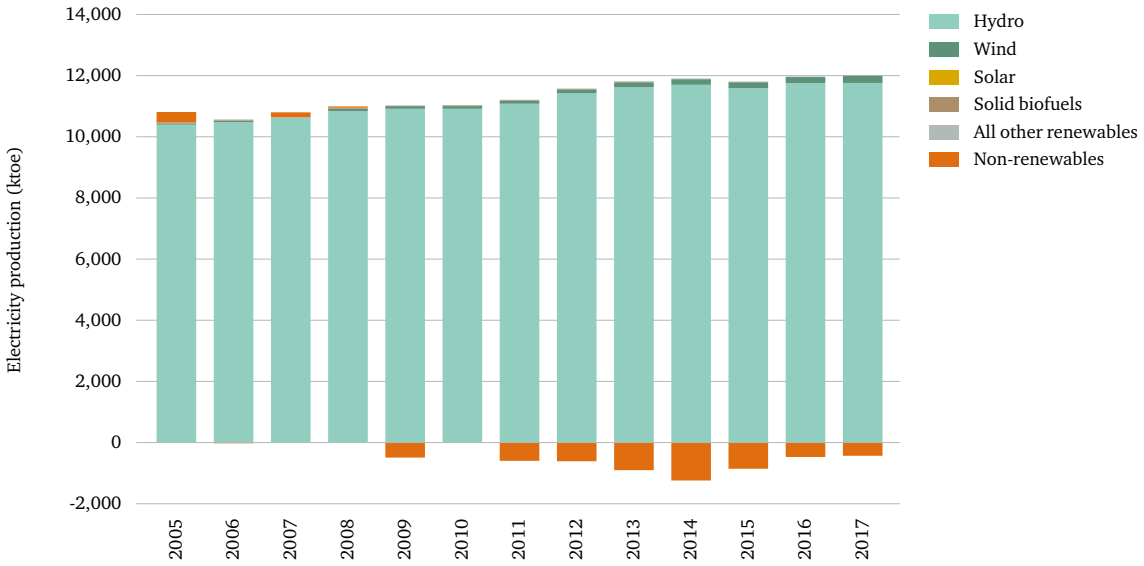
Figure 7: Sources of EU28 electricity production



Source: Eurostat (2019), Electricity production figures, see https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production,_consumption_and_market_overview.
Note: ktoe – kilotonnes of oil equivalent.

[55] Eurelectric (2018), 'Europe's power sector can decarbonise by 2045', https://cdn.eurelectric.org/media/3533/pr_decarbonisationpathways_final-h-E98C22DD.pdf (accessed 1 Oct. 2019).
[56] Ministry of Petroleum and Energy (2013), 'National Renewable Energy Action Plan under Directive 2009/28/EC', https://ec.europa.eu/energy/sites/ener/files/documents/dir_2009_0028_action_plan_norway__nreap.pdf (accessed 22 Feb. 2020).

Figure 8: Sources of Norwegian electricity production



Source: Eurostat (2019), Electricity production figures, see https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production,_consumption_and_market_overview.
Note: ktoe – kilotonnes of oil equivalent.

As the price of renewable energy continues to fall, it may not only change the power mix, but potentially the locations of heavy industry. Manufacturing bases and factories are often located close to sources of cheap energy, although other factors also affect location choice.[57] If the price of solar or wind power continues to fall – with solar contracts in Portugal, for example, reaching a low of €20/MWh[58] or offshore wind in the UK falling to as low as £39.65/MWh (€44.43)[59] – this may have implications for existing clusters of heavy industry across Europe, including those in Norway.

> Today, many renewable technologies are cost-competitive with conventional energy sources, and by 2020 all commercially available renewable technologies in many parts of the world will be cheaper than fossil fuels. However, the open question is: will the transition be fast enough to effectively stop climate change and limit the temperature increase to 2°C?
>
> Reiner Baaker

To date, the decline of coal power in European countries has tended to boost demand for renewables rather than for gas. As referenced above, the EU has progressively raised its renewable energy targets, most recently to at least 32 per cent by 2030. National renewable energy plans, the implementation of the EU Emissions Trading System (ETS) and support for carbon prices – at the EU level with the introduction of the Market Stability Reserve and at the national level in some countries with the introduction of carbon floor prices – have helped to squeeze coal out of the market. The UK's commitment to a coal phase-out by 2025 was underpinned by the introduction of a carbon floor price and the rapid expansion of renewable energy (particularly wind). The cost of wind power in the UK

[57] These include domestic tax or regulatory structures, access to innovation, the skills base, and market access.
[58] Holder, M. (2019), 'Reports: Portugal solar auction attracts record low bids', 29 July 2019, Business Green, https://www.businessgreen.com/bg/news/3079660/reports-portugal-solar-auction-attracts-record-low-bids (accessed 22 Feb. 2020).
[59] Durakovic, A. (2019), 'Breaking: UK Offshore Wind Strike Prices Slide Down to GBP 39.65/MWh', 20 September 2019, *OffshoreWIND.Biz*, https://www.offshorewind.biz/2019/09/20/uk-offshore-wind-strike-prices-slide-down-to-gbp-39-65-mwh/ (accessed 22 Feb. 2020).

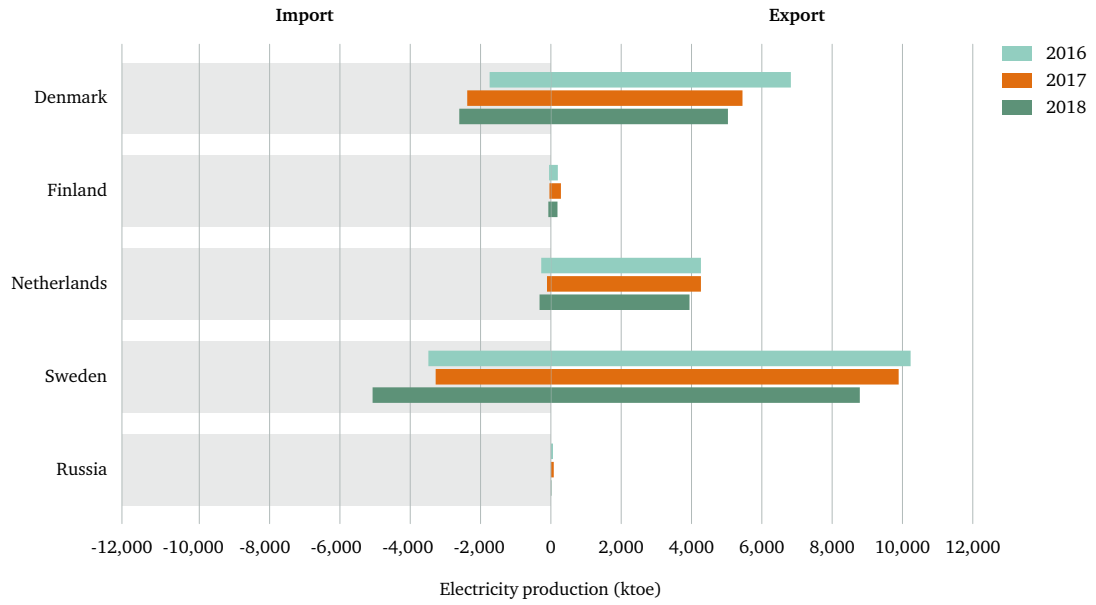
fell below market prices and effectively became subsidy-free for the first time in September 2019.[60] Looking ahead, it is likely that the power sector will go directly from coal to renewables, unless they have other interests in gas.

The role of Norwegian hydropower in the European internal energy market

In addition to climate, efficiency and renewable energy targets, the EU has introduced a target for the installation of electricity connections – interconnectors – between member states. This proposes that by 2020 at least 10 per cent of an EU member state's peak demand can be met from interconnectors (i.e. that the electricity can be imported from another country), with the intention of this rising to 15 per cent by 2030.

Most Norwegian electricity flows into the Nordic market, which covers Denmark, Finland, Sweden and Norway, and is divided (even within each country) into different price zones. Within the market, Norway is a net exporter of power, as can be seen in Figure 9. The only other major international link is to the Netherlands with the NorNed interconnector. This came into operation in 2008 and is now a major export route for Norwegian power (approximately one-third of net exports in 2018). On average over the last three years Norway has seen a net export of around 13 TWh of power annually. This equates to about 11.9 per cent of total electricity generation in the country.[61] Norway's significant hydropower capacity is seen as not only a regional resource, but increasingly of strategic value for Europe, especially with the need for greater flexibility with changing supply and demand technologies should there be sufficient infrastructure, adequate price signals and domestic support.

Figure 9: Export and import of electricity, Norway 2016–18



Source: ENTSO-E (2019), Power Statistics, https://www.entsoe.eu/data/power-stats/.

[60] Note that Norwegian SOE Equinor was among the successful bidders. See Thomas, N. (2019), 'UK renewable energy auction prices plunge', *Financial Times*, 20 September 2019, https://www.ft.com/content/472e18cc-db7a-11e9-8f9b-77216ebe1f17 (accessed 24 Mar. 2020).
[61] European Network of Transmission System Operators Electricity (ENTSO-E) (2018), 'Ten Year Network Development Plan', https://tyndp.entsoe.eu/tyndp2018/ (accessed 24 Mar. 2020).

> Norway has an important role as an exporter of electricity to the European market, which is in both our interests. It is also CO_2-free, which is why we are so interested. We would like the Finnish to do more as well but they believe that it will raise prices domestically.
> Pierre Schellekens

Significantly more electricity exports outside the Nordic regional market are expected with the planning and construction of new interconnectors to the German and UK markets. In total, an additional 4.2 GW of interconnectors could be in operation within a decade – compared to 6.1 GW currently in operation (see Table 1). This could have impacts on power prices in Norway and potentially the Nordic region. The interconnectors, particularly to the UK market, also offer an important mechanism to increase the use of offshore wind, as they can become the backbone of an offshore grid network, connecting various marine renewable energy resources.

Table 1: Norwegian electricity interconnectors

Connection to	Size	Status (expected start-up)
Denmark	1.6 GW	Operational
Finland	100 MW	Operational
Netherlands – NorNed	700 MW 450 kv HVDC	Operational
Russia	100 MW	Operational
Sweden	0.6 GW	Operational
Sweden	0.7 GW	Operational
Sweden	0.25 GW	Operational
Sweden	2.15 GW	Operational
Germany – Nordlink	1.4 GW 500 kv HVDC	Under construction (2020)
UK – NSN	1.4 GW 515 kv HVDC	Under construction (2021)
UK – NorthConnect	1.4 GW 500 kv	Pending licence

Source: Global Transmission Report (2019), 'Data & Statistics', https://www.globaltransmission.info/archive.php?id=1424 (accessed 30 Mar. 2020).
Note: HVDC = high voltage direct current.

Interconnection is just one mechanism for achieving grid flexibility. Other means are flexible demand, greater supply flexibility from conventional generators, and static and mobile storage (in EVs). Currently, grids are generally the most economic instrument to balance supply and demand, but significant changes are taking place with all of these new technologies and operational and control equipment. The relative economics of each will change over time. Most notable has been the fall in battery costs, both for mobile and stationary storage. BNEF have tracked the cost of lithium-ion battery packs and note that the costs have fallen from $1,160/kWh in 2010 to $373/kWh in 2015 and then to $176/kWh in 2018.[62] The uncertainty over technology costs and potentially political and policy uncertainties, such as Brexit, may delay the deployment of large infrastructure projects, such as the construction of interconnectors.

[62] Goldie-Scot, L. (2018), 'A behind the scenes take on lithium-ion battery prices', Bloomberg New Energy Finance, 5 March 2019, https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/ (accessed 2 Oct. 2019).

> A more connected power sector is necessary for greater renewable deployment. As has been the big discussion in the clean energy package, the first thing we need to do is to use the interconnectors that we have… The power sector will become massively decentralized but the major players that you see today will continue to exist; some may merge, some disappear because they don't choose the right strategies.
>
> Kristian Ruby

There is an increasing reliance on and an anticipated role for smaller and decentralized energy sources, particularly solar PV. These trends may appear contradictory. While there is likely to be a rise in prosumers (consumers who generate their own electricity and exchange it on the grid), many urban areas will be unsuitable for sufficiently large-scale generation and so heavy industry in these regions will require significant high-voltage transmission systems. Large-scale, particularly offshore, renewables that are capitalizing on falling technology costs will also rely on long-distance and high-voltage transmission grids. It is likely that the renewable-dominated power sector will be both decentralized and well-interconnected and therefore investment in the distribution system is as important as investment in the transmission system – if not more so.

Increasing power demand

While the EU and Norway have targets for improving energy efficiency, the decarbonization of the energy sector is likely to lead to the gradual electrification of transport and, more slowly, of heat and/or the increased use of hydrogen. This will have multiple impacts on the existing power sector, including changing demand, consumption patterns and centres of demand.

Electricity accounts for 19 per cent of total final energy consumption globally, while in the OECD and Europe, it is slightly higher at 21.4 per cent. However, meeting carbon reduction targets will lead to significant increases in electricity generation as well as an increased share of total energy consumption. According to the IEA, global consumption could rise from 23,000 TWh to between 34,000 TWh and 37,000 TWh, depending on the extent of energy efficiency, by 2040.[63]

Global EV electricity demand could rise 200-fold by 2040, to more than 1,400 TWh.[64] In the EU, under some scenarios cited in analysis funded by the European Commission, the number of EVs could rise from less than 1 million in 2018 to 35 million in 2030 and 190 million by 2050. This could lead to an additional power demand of 356 TWh – 34 per cent of final energy demand in passenger vehicles – and 10 per cent of total power demand by 2050.[65] Norway has been at the forefront of EV deployment globally, with a share of 47 per cent of worldwide light vehicle sales in the first quarter of 2019, up 10 percentage points from 2018 – although for the first time, Germany has overtaken Norway in absolute sales numbers.[66] Norway's experience in encouraging sales of EVs and their grid integration, especially in areas of high deployment, offers important policy and regulatory experience for the EU and beyond.

[63] IEA (2019), *World Energy Outlook 2019*.
[64] Froggatt, A. and Quiggin, D. (2018), *The Power of Flexibility: The Survival of Utilities During the Transformations of the Power Sector*, London: Chatham House, https://www.chathamhouse.org/publication/power-flexibility-survival-utilities-during-transformations-power-sector (accessed 22 Feb. 2020).
[65] Klettke, A. and Moser, A. (2018), 'Effect of electromobility on the power system and the integration of RES', European Commission, Contract no. ENER/C2/2014-639, https://ec.europa.eu/energy/sites/ener/files/documents/metis_s13_final_report_electromobility_201806.pdf (accessed 22 Feb. 2020).
[66] Irle, R. (2019), 'Europe Plug-in Sales for 2019 H1', EV Volumes.com, http://www.ev-volumes.com/country/total-euefta-plug-in-vehicle-volumes-2/ (accessed 2 Oct. 2019).

> For Norway, using electric cars makes good sense and although Norway represents just a fraction of the world's vehicle market, its successes and lessons learned in electric mobility deployment can be inspirational to many other countries and regions.
>
> Fatih Birol

> It would be good to see Norway doing an outreach programme to other countries: talking about lessons learnt, how things could be done more cheaply, and so on. They could put more thought into public transport and sharing, so EVs become not just something for personal users, and consider what is needed to incentivize sharing and to disincentivize individual vehicles.
>
> Jess Scott

The buildings sector accounts for around 32 per cent of global final energy consumption, using the equivalent of more than 35,000 TWh of electricity per annum. In Europe, 71 per cent of all energy is used for space heating of residential building stock alone. The decarbonization of the heating sector is likely to be driven by broad efficiency and supply options, some of which will be electrified, such as heat pumps. Other options are likely to see the greater use of renewable energy, including solar and biomass. Analysis for the European Commission suggests that electrical space heating in the residential sector could grow from around 5 per cent in 2015 to between 22 per cent and 44 per cent in 2050, depending on the deployment of different technologies.[67]

Norway's heavy industry in an energy transition

CCS and the prospects for fossil fuels in industry

Scenarios based on current policies tend to anticipate some demand growth for gas to 2030 followed by a slight decline to around today's level by 2050. By contrast, 2°C pathways tend to show little demand growth to 2030 and a sharper reduction of around one-third of demand by 2050. The pathway taken will depend on how fast and how orderly the energy transition is, and the role of CCS and negative emissions technologies (NETs). CCS and NETs play a critical role in energy scenarios, often increasing the 'available' carbon budget by 50 per cent or more.

> CCS is an interesting one as it provides a fall-back for reaching net-zero if there isn't the reliability or abundance of renewable supply.
>
> Philip Cunningham

In a net-zero world, all gas supply would have to be decarbonized (by CCS) and/or replaced with biogas or green or blue hydrogen. The failure of CCS to materialize at the speed or scale anticipated would have severe implications for future gas demand, yet this risk is not typically made clear to decision-makers in government or business.

Despite considerable political support for CCS, the global roll-out has not occurred. In 2008, the G8 announced strong support for the launch of '20 large-scale CCS demonstration projects globally by 2010' with the aim of beginning broad deployment of CCS by 2020.[68] The EU in 2007 committed to having 12 'demonstration plants of sustainable fossil fuel technologies in commercial power generation' operating by 2015, as part of plans to use CCS with new fossil-fuel power plants by 2020.[69] To date, however, none of these plans have come to fruition.

[67] European Commission (2018), *In-depth Analysis in Support of the Commission Communication*.
[68] G8 Declaration (2008), 'Climate Change: CCS', http://www.g8.utoronto.ca/evaluations/2008compliance-final/07-08-ccs.pdf (accessed 22 Feb. 2020).
[69] Teffer, P. (2017), 'After spending €587 million, EU has zero CO_2 storage plants', EUobserver, 6 October 2017, https://euobserver.com/investigations/139257 (accessed 22 Feb. 2020).

Although further, and in some cases more ambitious, targets to reduce emissions have been introduced over the past decade, CCS is not widely seen as a viable solution. This is in part due to a lack of progress and the clear failure to meet agreed objectives, but also – at least in the electricity sector – because the economics of CCS become less attractive as the costs of alternatives fall.

> We do not see a big role for CCS in electricity. You might see some CCS for electricity outside Europe but there isn't a compelling need for it inside Europe. There is, however, a need for CCS in two areas – heavy industry and industry that has process-related emissions.
> Pierre Schellekens

The prospects for CCS appear to hinge, at least in the short term, upon industry rather than the power sector, and there is a view that it will be essential in hard-to-abate industrial sectors. CCS could have a role in those industrial processes that emit CO_2 that are not related to energy use, such as in the production of clinker during cement fabrication. Norcem Brevik cement plant and Fortum waste management facility in Oslo are linked to the Northern Lights transport and storage-project, led by Equinor with key partners Shell, and Total; the national parliament is expected to make a decision on investment in CCS at Norcem, Fortum and Northern Lights in 2020/21. Its sponsors describe it as the world's first full-scale cross-border CO_2 storage project, using gases from industry and the subsequent ship transportation and sub-seabed storage. In 2020, the state-owned enterprise Gassnova, which manages a CCS project in Norway, will review progress made in the Northern Lights project and make its recommendations to the government, allowing for investment decisions by private partners and approval by the parliament. If approved, construction is scheduled to take three years, becoming operational in 2023/24.[70]

> The Norwegians have pipelines everywhere and depleted oil fields and reservoirs, so whether the route of the money goes via the Norwegian gas industry or wherever is unclear.
> Michael Liebrich

Heavy industry, with its high energy costs, is susceptible to international competition on energy and carbon prices. As a result, there is an argument that unilateral action on heavy industry will only result in the offshoring of production, rather than a change in global production. To create a level playing field between producers on energy and carbon emissions, global production standards must be introduced and enforced, along with border carbon tax adjustments for the importation of products, or pricing carbon on a global basis. The European Green Deal communication states that the Commission will propose a 'carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage'.[71]

However, even if CCS is developed at scale and the economics improve, unless carbon is adequately priced, CCS will always be more expensive than not capturing the carbon. Therefore, there is a growing realization that creating a use for the CO_2 will significantly improve the economics of CCS. The trend now is therefore towards carbon capture, use and storage (CCUS). An increasing number of governments and industries are researching and developing CCUS programmes, which include using CO_2 to create synthetic fuels; using micro-organisms, similarly to photosynthesis, to create ethanol; or incorporating the gas into concrete. Understanding the energy required, the economics and the environmental implications of these processes is often still in its infancy, and therefore extensive research and piloting will be required.

[70] CCS Norway (2019), 'The Full-scale CCS project in Norway', https://ccsnorway.com/ (accessed 28 Nov. 2019).
[71] European Commission (2019), *The European Green Deal*.

> CCS will have to play a much bigger role. Real growth points will be some time in 2040 to 2050, and it will be a steady start to 2030 and then a much more rapid growth to 2050.
> Dominic Emery

Given the market opportunities of CCS and CCUS, globally many countries and companies are engaging in their development, for example, such as the US and China. Public subsidies for industrial CCS are likely in the EU,[72] with a focus on support for transporting carbon to enable industry clusters and entire carbon storage and use value-chains. In this context Norway is seen as potentially globally important, given its experiences in marine environments and piping as well as with heavy industry. Norway also has depleted offshore oilfields suitable for sequester. It has also put in place a relatively large industrial CCS project that captures carbon from the Oslo waste incinerator and a cement plant, then transports the CO_2 and stores it deep under the Norwegian North Sea.

Evolving business models in heavy industry

Heavy industry has sought to be energy efficient, in order to be economically competitive. The threat of higher energy prices and the introduction of, or rise in, carbon prices have also accelerated action. However, the prospects of a net-zero economy will require more transformative action from industry and for changes in the way, and the extent to which, products are used. These changes include:

Energy production and consumption: Some heavy industries are seeking to ensure that the energy they use is renewable by becoming prosumers (producing and consuming their own power). Others are seeking to become more flexible in their operations in order to help maintain the supply-and-demand balance.

Shift to a circular economy: Many sectors are now looking to develop a more circular approach, whereby they consider not only the recycling and reuse of their products but their processes of production and service provision.

- The aluminium sector, which is extremely energy intensive, is continually developing new methods to improve efficiency of production while seeking to decrease the percentage of post-consumer waste. However, there are moves to create fully 'closed-loop' cycles. Similar considerations are also under way for the steel and plastics sectors, which will require clearer manufacturing and recycling standards.
- There are opportunities to apply circular solutions for various by-products of refinery processes, which are not being burned for energy generation. These solutions, for example, include lubricants, the use of improved bitumen for road construction, and recyclable packaging. Long-term solutions will need to be found to use oil as a resource without burning it and releasing CO_2. The circular economy concept might be a useful approach to unlock material innovation. Other areas of interest include bio-derived chemicals and fuels, for example the recovery of used cooking oil to convert to aviation fuel.

[72] In July 2019, Artur Runge-Metzger, director at the European Commission's climate action directorate, stated, 'We know there will have to be a public subsidy for CCS to make it happen'. See Simon, F. (2019), 'EU clarifies funding scope for CO_2 capture technology', Euractiv, https://www.euractiv.com/section/energy-environment/news/eu-clarifies-funding-scope-for-co2-capture-technology/ (accessed 27 Feb. 2020).

Evolving geographical competition for heavy industry

As the price of renewable energy continues to fall, companies in heavy industry may look to shift their production base, which has traditionally been located near low-cost energy sources. Flexible production methods and the variability of solar and wind will become less significant as cheap capital, greater automation and variable power prices may lead to production being located where the power supply is cheapest. Alternatively, short-term storage costs may continue to fall or the cost of long-distance transmission decrease. Any of these scenarios casts doubt over the continued competitiveness of heavy industry and their power sources in northern Europe.

The marine environment will become increasingly important for renewable energy. Existing technologies, such as seabed-mounted wind, are seeing dramatic falls in costs. In recent contracts, prices in the UK were settled at £39.65/MWh (€44.43/MWh) – below the current market price of electricity – down from £120/MWh (€134/MWh) in 2015.[73] New technologies, such as floating wind farms, are opening in deeper water with the advantages of higher wind speeds and being further from populations. If floating wind farms follow the trend of both onshore and other offshore wind, then wider experience and economies of scale will rapidly lead to falling costs and greater competitiveness, enabling deployment at significant levels. The European Commission has stated that between 230 GW and 450 GW of offshore wind will be necessary for the EU to meet its 2050 net-zero carbon targets, while capital expenditure on offshore wind including grids will need to rise from around €6 billion a year in 2020 to €23 billion by 2030, and thereafter up to €45 billion.[74]

> Offshore wind farms are so captivating because the real estate is almost infinitely large: if you go for floating offshore where you can get to very high capacity factors, the cost can come down to wholesale prices in the next 10 or 20 years. But looking out to the 2050 horizon, why not put industry offshore where the power is?
>
> Michael Liebrich

Marine developments also play an important role in the economic development of coastal communities, which have also been left behind as traditional industries, primarily fishing, have diminished.

[73] Eglon, M. (2019), 'Subsidy-free UK offshore wind is here', TaylorHopkinson, 23 September 2019, https://www.taylorhopkinson.com/subsidy-free-uk-offshore-wind/ (accessed 22 Feb. 2020).
[74] Wind Europe (2019), *Our Energy, Our Future*, 26 November 2019, https://windeurope.org/about-wind/reports/our-energy-our-future/ (accessed 22 Feb. 2020).

4. Conclusions and Recommendations

Within the EU there is growing public and political pressure across a majority of member states for more ambitious action on climate change. Some have already adopted a 2050 net-zero carbon emissions target and proposed legislation for the EU as a whole. This would have significant implications for energy consumers and fossil fuel producers inside and outside the EU. It will particularly affect Norway, not only as a supplier of energy to the EU, but as a member of the European Economic Area, as there would be pressure to adopt similar binding domestic carbon reduction legislation.

More ambitious climate targets will accentuate many of the uncertainties of the energy transition, such as the rate of change and the costs of innovations, for example in renewable energy technologies and electric vehicles. While deployment rates for these technologies will be heavily influenced by market developments, the drive to deliver more ambitious climate targets will require greater policy interventions and investment in core infrastructure. The more interventionist the policies, the greater the political risk.

Meeting ambitious climate targets and transforming industry rely on the adoption of new technologies that are yet to be tested at scale, such as CCS or CCU and the use of hydrogen. The success or failure of the commercialization of these technologies will have a profound impact on the use of fossil fuels across sectors, and on the fate of existing transport and production infrastructure. Despite these uncertainties, it is clear that there will be significant disruption to all elements of the fossil fuel industry and the sectors that are dependent on it. Key for energy producers will be to create technologies and business models where there is a clear first-mover advantage in rapidly reducing GHG emissions.

Key for energy producers will be to create technologies and business models where there is a clear first-mover advantage in rapidly reducing GHG emissions.

Oil demand may peak and decline considerably faster than many anticipate today. As a result, global competition will intensify between the large, low-cost oil producers and the rest. This will likely drive prices down, increasing the risk that productive assets are stranded and prospective ones left undeveloped. In contrast with previous eras, declining prices are unlikely to be offset by rebounding demand, as governments seek to implement sales taxes or reform subsidies, and as clean technologies increase their market share, permanently destroying global demand. Accounting for around 3 per cent of global oil supply, Norway will have limited influence on market dynamics, but it can carve out an influential role as a responsible producer that assesses the climate risk presented by policy decisions relating to oil supply. On the demand side, Norway can share its experience with EV roll-out and help other countries transform their transport sectors, as the tipping point for EVs approaches.

Some fossil fuel-producing countries have embraced the pivot to gas as part of the transition. However, the transition will be disruptive, initially affecting the power and coal sectors but eventually impacting gas and oil. The slower that emissions are reduced, the more disruptive transition is likely to be if carbon targets are still to be met. There are serious questions concerning the role of natural

gas as a bridge fuel, given the general acceptance of the need for decarbonization and therefore the phase-down of natural gas and/or the phase-up of green gas (biogas and green hydrogen). Norway has an opportunity to help shape such a long-term strategy because of its interests as an incumbent producer and preferred supplier to Europe, and its potential growth capacity in CCS and green gas markets. However, this will require meaningful engagement with the end goal of net-zero emissions.

Due to its renewable resources – primarily hydropower – Norway has one of the most decarbonized power sectors in Europe. These resources are an important part of the Nordic power market, helping to balance supply and demand efficiently and economically across the region. Construction of additional power lines to Germany and the UK will expand Norway's role as a key supplier of low-carbon electricity in Europe and, perhaps more importantly, provide increased system flexibility for the European internal electricity market – a vital element of a renewable energy-dominated power sector. However, system flexibility can come from different sources, for example an increase in the use of EVs will lead to lower battery production costs and the possibility of vehicle-to-grid balancing, both of which can change the economic value of interconnectors.

The continual deployment of renewables and the consequential fall in their associated electricity costs may challenge the economic advantage of the current locations of heavy industry. Large-scale deployment of offshore renewables, particularly wind, offers a competitive advantage to countries such as Norway with offshore and marine experience and industries.

Finally, Norway has a crucial role to play as an exporter of capital. With the largest sovereign wealth fund in the world, Norway's policy approaches and investment decisions can have real impact at home and abroad, helping to support an orderly transition through the effective management of climate-related financial risk and the growth of low-carbon sectors.

Annex: Expert Perspectives

All of the interviews were undertaken in late 2019 and early 2020 before the COVID-19 pandemic and the recent disruption in the oil sector emerged.

The transition towards renewable energy cannot be stopped and has become a major geopolitical force

Rainer Baake is the former state secretary at the German Federal Ministry for Economic Affairs and Energy

Summary

The transition towards renewable energy has become a major geopolitical force. The implication of proposed targets for net-zero emissions, including in the EU, is that fossil fuels will have to stay in the ground and that improved efficiency (as a priority) and renewable sources will take their place. As a gas supplier for Europe, Norway is preferable to Russia. But it also has a responsibility to make a realistic prognosis of future gas demand, in light of the European Union debate of a net-zero emission target for 2050. A wisely designed energy transition is a great opportunity for economic modernization, for both the EU and Norway. If Europe wants to be a major player in the economic world of 2050, it has to be a leader in this transformation.

The global transition from fossil fuels to renewable energies is a reality that cannot be stopped. Renewable sources, particularly wind and solar, have grown at an unprecedented rate over the past decade. The world added more solar power capacity in 2017 than coal, gas and nuclear plants combined. Technological development and economies of scale have resulted in significant cost reductions.

Today, many renewable technologies are cost-competitive with conventional energy sources, and by 2020 all commercially available renewable technologies in many parts of the world will be cheaper than fossil fuels. However, the question remains: will the transition be fast enough to effectively stop climate change and limit the temperature increase to 2°C?

EU governments and the EU institutions are considering a net-zero emissions target for 2050, which would be welcome. However, as climate change progresses, the pressure on public institutions to implement effective policies is going to increase. The implication is that fossil fuels will have to stay in the ground and that improved energy efficiency (as a priority) and renewable sources will take their place.

Gas and oil demand and global implications

Natural gas is an important transition fuel and Norway is a reliable and responsible supplier. Gas turbines are flexible generators that can easily be combined with the intermittent generation from wind and solar. However, natural gas will have to be substituted with CO_2-neutral synthetic gas ('power-to-gas') over the next two decades.

The global energy transition has become a major geopolitical force. We are witnessing changing power structures of states and regions. Without substantial economic reforms (which require political reforms), Russia will not be on the winning side.

Norwegian companies that produce gas and oil have a responsibility towards their shareholders, which in my opinion requires a realistic prognosis of future demands in light of the European debate of a net-zero emission target for 2050.

The decision that the Norwegian sovereign wealth fund should no longer invest in coal has been economically wise and environmentally responsible. In Germany this decision was well-recognized and had implications in the political debate there.

The consequence of an EU net-zero emissions target is a phase-out of ICEs between 2030 and 2040. In light of the 2050 net-zero target the question will be: do we allow newly produced cars to be used for 10 or 20 years? It is very much to be welcomed that Norway is a leader in rolling out electric vehicles and related infrastructure.

The age of opportunity

A wisely designed transition to efficiency and renewable energies would be a great opportunity for economic modernization, for both the EU and Norway. If Europe wants to be a major player in the economic world of 2050, it has to be a leader in this transformation.

In the energy transition, Norway's hydro resources are a very valuable asset – if enough grids allow their optimal use. Grids would be used in both directions: on days when wind and solar electricity production in Europe is low, this will result in high wholesale market prices and significant income opportunities for Norwegian hydro. In times of high wind and solar production, and low wholesale prices, Norway can cover its own demand from these sources and spare its hydropower for times of highest market value.

The EU is proposing a greater number of interconnectors between countries and for the 2030 target this goes far enough. A more connected power sector is not a prerequisite for more renewable deployment, but grids are our most economical instruments to balance supply and demand in a renewable energy world. This new energy world will be predominantly decentralized, since power generation from wind and solar will be distributed over the country. But decentralization must not be confused with regional or national autonomy, which would be very expensive for consumers. The new renewable energy world will be both – decentralized and well interconnected.

There seems to be no future for CCS: for power plants that use fossil fuels, CCS for generators is uneconomical. We have cheaper options. We should use our limited geological storage capacities for those economic sectors where we cannot substitute fossil fuels through renewables: these are certain industries that produce non-energy related CO_2 emissions. As of today, we have no other technical solution to minimize these CO_2 emissions. CCS for these industries will be expensive. Therefore, we need an effective global climate policy with international treaties that prevent 'carbon leakage'.

Norway is among key leaders on carbon capture and clean hydrogen

Dr Fatih Birol is executive director of the IEA

Summary

At least 65 jurisdictions, including the European Union, have set, or are actively considering, long-term net-zero carbon emission targets. These economies together account for 21 per cent of global gross domestic product and nearly 13 per cent of energy-related CO_2 emissions. The *World Energy Outlook*'s Sustainable Development Scenario is consistent with the net-zero goals being reached in full. The oil and gas industry is well placed to contribute to the energy transition. Norway is among the leaders in both carbon capture, use and storage (CCUS) and clean hydrogen production, and could play an important leading role during the decarbonization transition. Norway has also been the global leader in EV deployment, with a 46 per cent sales share of electric and plug-in hybrid electric cars in 2018.

The Sustainable Development Scenario of the *World Energy Outlook* (WEO) is consistent with the goal of net-zero carbon emissions being reached in full. In this scenario, fossil fuels drop from 70 per cent of total EU energy demand to less than 40 per cent in 2040. Energy-related carbon emissions drop by 75 per cent over the same period, on course for net-zero by 2050.

The oil and gas industry is well placed to contribute to the energy transition by scaling up the supply of low-carbon liquids and gases, and leading the development of capital-intensive technologies such as CCUS and hydrogen that unlock emissions savings in 'hard-to-abate' sectors such as heavy industry.

Oil and gas demand outlook

In the WEO's central Stated Policies Scenario, European gas demand is 20 per cent lower in 2040 than today. In the IEA's Sustainable Development Scenario, demand is reduced by nearly half.

Declining coal and nuclear capacity provide an upside for gas over the next decade, but this is offset by increasing efficiency gains, especially in buildings, and greater penetration of renewables. By 2040, the market share for gas in heat demand in buildings will have been reduced by increased electrification as well as greater deployment of modern bioenergy.

However, gas infrastructure retains a strong role in ensuring security of supply, for meeting seasonal peaks in heat demand as well as for providing back-up to intermittent renewables in the electricity sector.

In the Stated Policies Scenario, oil use in passenger cars peaks in the late 2020s but there is no definitive peak in overall oil use, given increases in petrochemicals, trucks and the shipping and aviation sectors. The largest increases in production between 2018 and 2040 come from the US, Iraq and Brazil. OPEC plus Russia's share in oil production falls to 47 per cent for much of the 2020s – a level not seen since the 1980s. The oil price required to balance supply and demand in this scenario edges higher to nearly $90/barrel in 2030 and $103/barrel in 2040.

In Europe, oil demand in 2040 is 45 per cent lower than today. Most of this decline comes from passenger cars, but there is also a decrease in oil demand for buildings, given stated policies to ban the installation of oil boilers in new houses and phase out existing equipment.

Over the next decade, the US will jostle with Qatar and Australia for position as the world's largest LNG exporter. The US is the largest source of new capacity, capturing about 40 per cent of new projects coming online to 2030. In the Stated Policies Scenario, the US on average provides around one-fifth of total EU LNG imports.

Other emerging LNG exporters well-placed to serve European import demand include Russia and Mozambique, as well as new supplies from established LNG exporters such as Qatar and Nigeria. Most new LNG supplies, in fact, are earmarked for growing Asian import markets.

Future of hydrogen and CCS

It is often overlooked that hydrogen is already today a huge industry, producing around 70 million tonnes of hydrogen every year for use in oil refining and chemical production. This is not a trivial amount: 70 million tonnes of hydrogen could in theory power around 500 million cars, which is half of today's global car fleet.

Scaling up hydrogen is not an easy task, but it is doable. It requires hydrogen to move beyond existing uses in oil refineries and chemical plants to other industries, such as in transport or the buildings sector. Moreover, it requires bringing down costs for clean hydrogen production, and for this to be achieved, there is a complementary role that natural gas can play. Hydrogen can be blended into the vast natural gas infrastructure and thereby significantly boost demand for hydrogen and drive down costs. A 5 per cent blend in global gas demand would result in a hydrogen demand of 20 MtH_2, an amount that could provide heat for almost 50 million homes.

The IEA has consistently highlighted that CCUS is a critical element in a broader portfolio of energy technologies needed to decarbonize key industrial sectors, including cement, iron and steel, and chemicals production, which will remain the building blocks of modern societies. Industry accounted for one-quarter of direct CO_2 emissions in 2017. If emissions resulting from the use of electricity and heat are also taken into account, the sector is responsible for nearly 40 per cent of CO_2 emissions.

In this context, the deployment of CCUS is critical to achieve international climate targets, alongside other options such as adoption of best available technologies, energy and material efficiency, and fuel and feedstock changes. Industry sector emissions are among the hardest to abate due to requirements for high-temperature heat, process emissions and the lock-in effects of long-lived facilities and infrastructure. Unlike alternative mitigation options, CCUS is the only technology that can address all of these challenges, while reducing the cost and complexity of the industry sector transformation.

Energy-intensive sub-sectors of industry – particularly the steel, chemicals, aluminium and cement sectors – are key heavy users of electricity and other energy carriers in Europe today, with some of them competing on a global market. Therefore, coordinated efforts across regions and countries are needed to support industrial productivity while bringing down emissions. Some strategies to achieve this goal include, for instance, the adoption of standards to reduce the average CO_2 intensity for production of key materials over time, together with complementary measures such as differentiated market requirements (e.g. a government-mandated minimum proportion of low-carbon steel in targeted products). These approaches could give an early market signal, enabling industries to prepare and adapt more gradually to the energy transition.

Norway's role

Norway is among the leaders in both CCUS and clean hydrogen production – these are key components of the longer-term options for decarbonization in several energy-intensive sectors. The country operates two long-established major CCUS projects (Sleipner and Snøhvit CO_2 storage projects), which have achieved safe and permanent storage of CO_2 in dedicated deep saline formations.

Moreover, it is currently developing a full-scale CCS project, including two capture facilities (Fortum waste-to-energy and Norcem cement) and a CO_2 transport and storage hub (the Northern Lights project). Therefore, it could play an important leading role during the decarbonization transition.

Norway has also been the global leader in electric mobility deployment, with a 46 per cent sales share of electric and plug-in hybrid-electric cars in 2018, which is much higher than any other country in the world. It succeeded in encouraging drivers to adopt electric vehicles, thanks to a clear and stable policy framework that includes tax breaks and tolls and fees exemptions throughout the country, as well as via the deployment of an accessible charging infrastructure network. Electric power trains are more energy-efficient than their ICE counterparts, and so they can contribute to CO_2 emissions savings if the power mix is low carbon. For Norway, using electric cars makes good sense and although Norway represents just a fraction of the world's vehicle market, its successes and lessons learned in electric mobility deployment can be inspirational to many other countries and regions.

The EU has set strict CO_2 standards for promoting EV penetration within the continent. As a result, EV sales registration has increased by around 40 per cent in 2019 compared to the previous year. We expect this trend to continue, with the market share of electric cars reaching 25 per cent by 2030 from less than 2 per cent today. EU car manufacturers will offer more than 200 electric models within the next two years from the 60 available today.

Future of renewables

The share of renewables in the EU's power sector was 33 per cent in 2018. Renewables will account for 55 per cent of electricity generation by 2030 and more than 70 per cent by 2050 in WEO 2019's Stated Policies Scenario – which incorporates the latest historical data, stated policy targets and continued technology development. Wind power is on track to become the largest source of electricity in the EU by 2026, particularly with the deployment of offshore wind accelerating.

Hydropower facilities provided 95 per cent of total generation in Norway in 2018, and enabled the export of 10 TWh of electricity to neighbouring markets. Interconnectors provide the essential means of making the best use of hydropower's output and flexibility. Norway's hydropower will be an important contributor to the overall flexibility package in Europe, alongside other power plants, demand-side response and energy storage. Overall power system flexibility needs are set to increase as the share of wind and solar PV doubles to almost 30 per cent by 2030 in our Stated Policies Scenario.

Heating challenges

Heating is the largest user of energy in European buildings, and today only 15 per cent of energy demand for heating is met by electricity, lower still for space heating. There is significant potential to electrify heating in Europe, principally via heat pumps. Policies, such as the Energy Performance

of Buildings Directive, are helping to pave the way to a more electrified and efficient buildings sector in Europe. In the Stated Policies Scenario, the share of electricity in energy use for heating rises to 20 per cent by 2040.

Power and grid companies are taking steps in preparation for these developments. The charging infrastructure is being developed to support electric vehicles, though government support is needed to keep pace with increasing needs. Grid development requires lead times of a decade or more in some cases, and so there is a risk of it lagging behind without clear plans for the electrification of transport and heating.

Europe is very much at the vanguard of climate policy ambition. However, the EU and Norway together account for less than 10 per cent of total global energy-related CO_2 emissions. Full implementation of net-zero ambitions in Europe, on their own, would make a measurable but not decisive difference to the emissions trajectory of the Stated Policies Scenario, as most of the growth in CO_2 emissions comes from developing economies with growing energy demand.

This underlines that achieving the goals of the Sustainable Development Scenario and the Paris Agreement will require not only an unprecedented effort, but also a broad one. Europe can be a climate leader for others, by demonstrating how determined policies, market designs and support for R&D and technological innovation can unlock emissions savings while keeping energy reliable and affordable.

Norway is missing the opportunity to lead the world

Mark Campanale is the founder and executive chair of Carbon Tracker
(Based on an interview)

Summary

As a major fossil fuel exporter, Norway faces huge systemic risks if it fails to adjust to the energy transition. Because of some far-sighted political leadership, it also has the opportunity to lead this transition. It could finance the transition as well as export know-how on EV deployment, while making the most of its advantage as a low-methane-leak-rate gas producer in the short to medium term. This would make economic sense, avoiding a disastrous leap into stranded assets, and enable the country to reconcile seemingly contradictory forces within it.

As we look ahead to 2030, demand for oil is likely to have peaked and declined. Oil prices will have to decline as they cannot compete with EVs. We estimate that EVs will be cheaper than those with an ICE within two to three years on a global basis and that demand for oil will peak in the 2020s. As soon as it is clear that the alternative technology is cheaper, there will be rapid adoption and transformation; adoption rates will not be linear but exponential. An indicator is the capital deployed by motor car manufacturers in retooling and re-engineering – every week there is an announcement from Toyota, Volkswagen etc. and this gives an indication of what will happen in three years' time.

The investment case for traditional fossil fuels is diminishing monthly. The key trend will be a collapse in return on capital for oil companies, which will make the sector less attractive to investors. Bankers will raise the cost of capital for oil and gas companies and for the fossil fuel economy as a whole. Renewables will have a much lower cost of capital.

The reason for this is that the ICE will be competing with EVs on price as well as performance, forcing prices downwards as markets trend towards the lowest-cost forms of transport. Lower prices for petrol at the pump will ultimately erode oil prices. In support of this point, research by BNP Paribas – *Wells, Wires, and Wheels – EROCI and the Tough Road Ahead for Oil*[75] – concludes that oil needs a long-term break-even price of $10 to $20/barrel to remain competitive in mobility.

There is no shortage of oil. Proven resources are enough to last 50 years. But oil will in the future mainly come from the lowest-cost producers. When Carbon Tracker builds cost curves, we always find that the lowest-cost producers will win – which largely means the Middle East. Highest-cost producers will become uncompetitive as prices at the pump drop to compete with cheaper EVs. Countries with lighter, less carbon-intensive fuels such as Norway will also have a competitive advantage over other nations, so long as they remain low cost.

For the fossil fuel sector, the biggest challenge will not so much be a steep decline in demand but rather changes beyond their control to the price of their products. We now have a technology that is cheaper and arguably more efficient and less expensive to maintain – and it's only getting cheaper. This can, in effect, act as a ceiling to the price that fossil fuel companies can charge for gas or petrol in the tank. They will no longer be able to charge monopolistic-type prices.

[75] Lewis, M. (2019), *Wells, Wires, and Wheels – EROCI and the Tough Road Ahead for Oil*, Paris: BNP Paribas Asset Management, https://docfinder.bnpparibas-am.com/api/files/1094E5B9-2FAA-47A3-805D-EF65EAD09A7F (accessed 12 Feb. 2020).

In economic terms there was not much price elasticity in the past, because of no real alternatives to the ICE. Now that there are alternative options the effect of a cap on prices is to demolish return on capital for the fossil fuel sector. It has happened in the coal sector, and it will happen in gas and petrol, although transportation fuels could arguably be slower to switch.

Impact of India and China

It's hard to predict when the ICE will be phased out in Europe and elsewhere. The critical years will be 2022 to 2025. At that point EVs should be cheaper, there should be mass availability and hopefully Europe will have started to build charging points and infrastructure at a much larger scale. If that happens, then governments could bring forward a ban on the sale of ICE cars. They may take old cars off the road – or perhaps do what London does, which is to charge drivers differently, according to vehicle type.

Most of the forecast oil demand growth is in India. It spends $60 billion a year in foreign exchange on oil, so currently its focus is energy security and independence. It would be far better to move to electric scooters and *tuk tuks*, then the country could move very quickly to small electric vans.

China alone has around 200 independent EV producers. Any one of these could become world-class. If this were to happen, Norway could suffer like every other oil-producing country.

Like other major oil and gas companies, Equinor uses a central scenario that shows demand for oil and gas going up, for both petrochemicals and transportation fuels. Carbon Tracker's earliest reports in 2013 first coined the phrases 'wasted capital' and 'stranded assets'. This analysis warned of a likely considerable misallocation of capital, wasted capital, and stranded assets in infrastructure and production. Its recent analysis, such as 'Balancing the Budget: Why deflating the carbon bubble requires oil & gas companies to shrink' warns that investment in new production is typically not required as we head towards net-zero carbon by 2050. Major companies like Equinor are stuck in a way of thinking, which is outdated and not appropriate for the 2020s. Instead, an alternative strategy for a swift transition is needed. Where a current return on capital is generated, instead of reinvesting into exploration and development, arguably it should be returned to government or shareholders in dividends and share buy-backs. Or capital should be put into new investment to develop world-class, alternative low-carbon businesses.

Role of Europe

Europe's leadership is important and within Europe there is pressure. Green parties are gaining further support in France, Germany, and Ireland – even the pre-Brexit UK re-elected Green members of the European Parliament. Now that Greens in the European Parliament are in the ascendancy, the European Commission is planning cross-border taxes that reflect the real environmental cost of manufactured products. EU governments and EU institutions are putting in place and/or considering a net-zero emissions target for 2050. I have no doubt that more governments will set these kinds of targets.

For some sectors, decarbonization will be really challenging, particularly for domestic heat. Tens of thousands of houses would need to be retrofitted each month to reach the goals of net-zero. There is a question whether natural gas will remain a key supply of heat in the EU or whether green gas, electrification and/or efficiency will reduce demand.

CCS not the answer

To meet the role that CCS is forecast to play, we will need 300 CCS plants every year for the next 10 years. And even then, that only extends the carbon budget by 15 years – then we must start over again. CCS sounds great in theory but there are a lot of problems; particularly who will pay for it in practice. If you incorporate the cost of CCS into fossil fuel prices, it will suppress demand for fossil fuels – which may not be a bad thing. But oil and gas companies and coal-fired power stations are unlikely to pay for this – they want governments to pay and say this quite openly.

The other problem is location. Coal-fired power stations are not in places where you can store CO_2, such as over rock formations. You would have to dismantle them, which is hugely costly. If you pipe the CO_2, that's very expensive as well.

Norway's short-term gas advantage?

Gas companies tend to believe that gas is a transition fuel and there will be a staging post from coal to gas to renewables. But if people aren't in gas already, they will want to go straight from coal to renewables. This was one of the reasons for the crushing blow to the share price of General Electric in 2018. They miscalculated demand for gas turbines, their forecast demand for gas turbines was demolished and shareholders paid the price.

Gas-fired power stations are closing because of the cheap combination of solar and wind. In many parts of the world, renewables are now cost-competitive or cheaper than gas. There has been a huge increase in the efficiency of solar, which will kill the economics of gas, just as it did with coal. Right now people think the gas outlook is optimistic, but it's doomed along with coal. Why would banks put up hundreds of millions of dollars to finance LNG, which is really expensive, needs to be put in a ship, converted back, then put in power station? LNG is a very vulnerable sector.

Russia is currently the world's biggest energy exporter. It is already suffering from its inability to generate super returns from oil and gas. This is a great challenge for the Russian state and President Putin may start to look vulnerable in a few years' time.

Meanwhile, there is growing awareness of fugitive emissions from large amounts of Europe's gas imports from places like Algeria, Libya and Azerbaijan, which have not invested in better infrastructure. Norway is the exception as it has much higher standards. Although gas will lose out eventually to renewables, Norway could in the meantime do more with what could be a short- and medium-term competitive advantage in Europe: demonstrating that it produces cleaner gas compared to other countries.

There are other aspects of being a responsible gas producer that are relevant to Norway. Gas should be used close to the source of production, for example, to produce plastics. In addition, a responsible producer should not consider fracking. It's a disaster from almost every perspective: nobody is making money, it generates huge emissions, it pollutes the groundwater, and it destroys the landscape. Nor is it justified for Norway to open new reserves in the Arctic, either economically or environmentally.

A Norwegian belt and road?

EV deployment can be an advantage for Norway, given its experience in the rapid roll-out of this domestically. This is particularly likely, if mass production and manufacture can push down costs faster, and there is large-scale roll out in large cities, especially charging points.

Norway could therefore become an exporter of clean energy, knowledge and experience. Norway's role as an exporter of capital is a significant asset, which allows it to provide capital for these new technologies.

The Norwegian SWF no longer invests in coal. This is the right thing to do, as it saves money – coal is underperforming. But the fund should extend this logic to coal-fired power utilities or to those too dependent on coal-fired power. There is an argument that if Norway makes money from oil and gas, which is hugely risky, it should not double its exposure to risk. The fund should be massively investing in low-carbon projects around the world, in the same way that China is pursuing its 'belt and road' initiative. Norway could go the other way, investing in greening infrastructure is a commitment it has already made, although much more needs to be done. They could invest in the fastest-growing economies in the world – but they perhaps lack an understanding of the opportunity at the moment.

The instincts of politicians in Norway are right; the problem is that the instincts of people in finance are wrong because they are planning for business as usual. But they have the advantage of knowing how financial markets work and how to invest money. So you have two distinct and powerful groups that don't know how to speak to each other.

Energy transition is caught between what people say they want and what they do

Phil Cunningham is managing director of exploration and production, Total Norway
(Based on an interview)

Summary

The energy transition is caught in a conflict between what people say they want and their actions – and these actions underpin consumption. The political will has caught on faster than many people expected. Momentum behind targets for net-zero emissions will increase although it is difficult to put time frames on this. Targets may not kill off fossil fuels but the industry will have to find ways to adapt: to become less carbon-intensive and find ways to offset and capture the carbon produced. Norway is itself in an effective transition to clean energy and considers this an important step. Yet, its fossil fuel industry is a significant economic and social pillar in terms of employment and tax, even if its global impact is relatively small.

Norway as a gas producer

Norway's role is an interesting one. It only produces around 3 per cent of global gas. However, many believe it to be more significant due to its proximity to Europe, for which it can provide gas very reliably, in comparison to Russia, for example.

In the context of the energy transition, the question is whether Norway should continue to produce hydrocarbons. Perhaps this has not been fully thought through in terms of how big a part of the Norwegian economy the fossil fuel industry is, and the dramatic impact a change would have on employment and tax receipts. Rather than causing a major shift in the source of heat and power, the demand for these could just be met from elsewhere.

Hydrocarbons have had a large presence in Norway and there is an especially high level of consciousness about it here. They are a rich and progressive society so locally emissions are low, use of EVs is high, homes are well-insulated, and there is a lot of hydropower.

But is it acceptable to continue to produce fossil fuels and send them overseas? There is a debate on that. People need the facts. People tend to overestimate Norway's importance: globally it only accounts for 2 per cent of oil production. If it were all switched off tomorrow, the world would adapt quickly. People need to understand what that means in terms of data on the environment and the local economy. Gas will remain a key source of supply for the foreseeable future: it is reliable and economically attractive. Its growth will be checked by taxes such as carbon taxes. Coal is already out of fashion due to its high-carbon intensity, but gas and LNG are bridges to net-zero emissions. As well as working to abate the energy intensity of production, a responsible gas producer should share information about the environmental side of gas so that consumers can make decisions about where to get their energy from.

US gas may become more important globally as LNG is increasingly commoditized. Previously you needed huge reserves and to sell in advance. Now with spot cargoes, companies such as ours are building a portfolio that can be optimized among suppliers and consumers, and with ships and terminals in different parts of the world. If LNG becomes truly commoditized like crude, this would have a large impact on gas in general – and that would be felt in Norway.

Oil and the Arctic

There is a big question in Norway about exploring and developing the Arctic for oil. Personally speaking, there is no need to start exploring for oil there. Companies are not expecting the oil price to go up to $100 or $200 a barrel any more – although if it did that could flip the switch to EVs. The industry is going to need to remain efficient and have low development costs to prosper and meet consumer demand.

The transition away from the ICE is happening much more rapidly in Norway than was imagined a couple of years ago, driven forward by technology. However, only about 50 per cent of the barrel is used in petrol or kerosene or diesel engines. As long as the underlying demand for the other 50 per cent continues to grow, oil projects will not be shut down, although its growth may be flattened by the reduction in demand from transportation in time.

The big inflection point will be when EVs improve, especially battery technology for heavy goods vehicles, and charging technology. The minute electrification becomes cheaper and more reliable, it will overtake. The Bronze Age didn't end because they ran out of bronze, but because they invented something better – steel.

Points of transition

Norway produces its electricity almost entirely from renewable sources, mostly from hydropower. Its gas remains important for other countries whose use of renewables is much lower. Renewables are mostly increasing in those markets but it will be a race between increasing power demand and how to add to that capacity. Globally, it should keep pace. Gas producers in Norway have to consider that demand will fall rather than continue to grow or even remain static. It will be very hard to get to fully renewable or net-zero carbon with the demand profile as it is today. We have to consider the impact of insulation, energy efficiency and new technologies that will help get more from every molecule.

It's accepted that major operators are also going to have to do everything available to improve efficiency on the production side: carbon capture and making the production of hydrocarbon less energy-intensive by electrifying offshore facilities. We are looking at electrifying some offshore facilities here in Norway but if we were to switch off gas turbines, there is not yet the distribution infrastructure to get the electricity there.

Power and grid companies will be the limiting factor for offshore electrification networks. Who is going to invest in that? Certainly current models don't pay off. As with railways, it is hard to make money from them, but it is essential infrastructure so investment is made as with other forms of economic growth. The other thing that can help with this is fully integrated micro generation and micro storage. For example, solar panels on the roof can help charge your car. At night your car can provide short-term energy supply to the house, or a battery in the house could replace the car. We may see more of these smart systems when the costs come down. The cost of infrastructure to incorporate green efficient systems is a limiting factor and you need scale.

Hypothetically a greater number of interconnectors between countries is good if it can help excess capacity in one place to offset unusual demand in another. Yet it depends on what the costs are and what the losses are in moving power from one place to another – whether it is actually efficient.

Norway is a leader in rolling out EVs and related infrastructure, and it does work here. I have an electric car and I don't have range anxiety because there are so many charging points. Cars are getting better all the time. If everybody in Norway had an electric or hybrid car it would have a small impact on global emissions but it would show what is possible and what works. For a country that has the will and the wealth, it is important that this happens here and that it is taken very seriously. Nevertheless, recently there has been a rise in protests against road tolls on ICE cars. A new political party has emerged to resist these tolls, which did well in the recent elections. The Greens also did well, suggesting that for Norway, the issue of the environment and climate change is now beginning to polarize people.

CCS is interesting as it provides a fallback for reaching net-zero if there isn't the reliability or abundance of renewable supply. Total Norway is part of the joint-venture project to set up the Northern Lights CCUS. It has been designed to not only receive CO_2 from Norwegian industry but also to be able to expand to accept CO_2 from other parts of Europe. We think CCUS will be important but you still need proof of concept. The cost needs to come down so that it can compete with a CO_2 tax or other environmental tariffs. It will also have a role in heavy industry, for example, cement production, which is very energy-intensive and linked to development. If you can capture the carbon in that, that would be very attractive. There is work to be done to make it more economically viable. It will have a role in refineries and offshore or even onshore hydrocarbon production because of the awareness, and even pressure, on energy companies to show they are doing their bit. We are about to bring a major platform online with partners. It will be the least carbon-intensive yet; very low-carbon emissions per barrel produced and per cubic metre of gas produced. It takes all its power from onshore and won't have a continuously lit flare. It will have a very energy-efficient design, which demonstrates that raised consciousness is already having an impact here.

Positive example

Norway has a special opportunity to progress some of these technologies and be a positive example. The need to transition in Norway and Europe is not as great as in other parts of the world as the country is not so energy-intensive. It is right to do this in Norway where society can afford it. The UK is not as rich but there is the political will and the technology, and they should be fast followers. It will help the technology to become more efficient before it spreads more widely.

There is a gap between what people say they want and what they do. The question is how do we find solutions in a realistic time frame. The pressure groups would reply that the planet can't wait – and it's hard to disagree with them – but we need some reality on what it takes: switching off all hydrocarbons next year would not work.

Norway's leadership should continue

Dominic Emery is chief of staff at BP International plc
(Based on an interview[76])

Summary

Norway is taking a leadership role in electric vehicles, driving CCS, and, through Equinor, is taking a prominent role in a future hydrogen economy. The country is also supporting land carbon and natural climate sinks at scale through overseas investment. Norway has always been very open to being the test bed for new technologies.

Norway is establishing a leadership role in decarbonizing natural gas. Equinor – Norway's largest energy company – has not only developed a vision for a transition from methane to hydrogen, but is also a partner in the H21 project, designed to support conversion of UK gas networks to carry 100 per cent hydrogen. Hydrogen for heat could meet a major challenge in temperate countries such as the UK where gas demand peaks during cold winter days, and where instantaneous energy required from the gas and heating systems can be up to five times that of the power system. So, having the ability to bring on gas quickly is significant. Under such circumstances, it will be challenging to replace a gas-based heating system with an electricity-based heating system.

Most of the analysis we've seen suggests that gas will continue to play a critical role in the energy transition, as a fully electric alternative is considerably more expensive. By 2030 natural gas will still be very significant in Europe, and we anticipate the beginning of decarbonization through some hydrogen facilities. CCS will have to play a much bigger role – likely with real growth sometime between 2040 and 2050. Biomethane will be important but will require scaling up and is limited by sources of supply.

As the EU drives towards carbon neutrality by 2050, transition will have to take place very rapidly. Therefore, we could see a case for hydrogen demand growing rapidly towards the middle of the century, which could start to displace natural gas in the 2040s to replace heat.

Non-EU producers

Gas from other non-EU countries that want to penetrate the EU will need to consider decarbonizing options for the mid-century. Russia has always been a reliable supplier of gas to Europe and may react in two ways: their gas could become decarbonized either at source or at point of use for combustion in power facilities or in industrial processes.

Meanwhile, the cost of gas production in the US is falling dramatically as result of shale gas technologies and scaling, so now any gas project needs to beat the cost of US gas. US shale gas will continue to be competitive. However, ultimately if one believes in the need for a decarbonized gas and hydrogen economy, either that gas needs to be brought to market and burned in power stations using CCS to decarbonize the power generation; or the other option is for natural gas to get converted to hydrogen or to ammonia. One could imagine a future hydrogen or ammonia transportation business looking like the current global LNG business.

[76] Interview took place on 9 September 2019.

Responsible producer?

Gas is a naturally declining resource and a responsible gas producer is justified in wanting to develop new reserves. Future hydrogen sources can be developed in two main ways: one is hydrogen from decarbonizing methane, a well-known process in refining, then the CO_2 is captured and stored – this is blue hydrogen. The other source is through the electrolysis of water by renewable power to create hydrogen – this is green hydrogen. Blue hydrogen, from methane, still requires a source of natural gas. For blue hydrogen, as existing reserves deplete, it is necessary to develop new gas resources to enable a future hydrogen-based economy.

So Norwegian CCS and CCS capabilities will be important. Norwegian energy can play a role in providing hydrogen for the industrial sector. From a global perspective, for the Paris Agreement to be met, CCS will be essential, not least because of hard-to-abate sectors like cement, steel and petrochemicals, which will need CCS.

Industry overall has a greater need for CCS than the power sector, as heavy industry has few other options, although hydrogen could be an effective alternative. Heavy industry will also need to decarbonize through changing production systems and processes, and through driving greater circularity in manufacturing activity. Aluminium is becoming more circular, and there may be applications that will allow a steel modal shift to carbon fibre. There are a number of different approaches that will be required to decarbonize – from a modal shift to use of different types of energy, to greater circularity, and use of CCS.

CCS was seen as the main answer to reducing carbon emissions, or at least a big part of it, a decade ago. It is certainly still necessary – perhaps 5 Gt to 10 Gt will be required by mid-century particularly for the hard-to-abate sectors globally. Europe may account for a more modest proportion of that, perhaps 1 Gt.

Oil demand

A number of countries are beginning to make commitments to phasing out the ICE, but hybrid engines will continue for some time. There is also a big difference between light duty and medium/heavy duty vehicles. The solution for light duty looks likely to be electrification, supported by a strong drive to electrification in Europe through the provision of subsidies, and the growth of charging points. Where much of the domestic electricity supply is renewable, such as in Norway, light duty electrification makes a lot of sense from an emissions perspective.

For medium and heavy-duty vehicles, it's still challenging to get batteries that are size and weight-appropriate, and alternatives such as hydrogen or biofuel e-fuels may be more appropriate. If biofuels are developed, it will still be for the ICE. If hydrogen is developed, there will be more fuel-cell type long-distance vehicles. With light duty electrification there seems to be a clearer long-term outcome; for heavy duty it's too early to determine the winning technology. What is likely is that the ICE will coexist with low-carbon or zero-carbon fuels like electric fuels or biofuels for a period of time.

Demand for oil globally is likely to peak at some stage in the next 20 years. The Paris Agreement requires net-zero in the second half of the century, likely to be 2050 in those countries pressing for change sooner. There are early movers like the EU, but oil demand will still grow – in particular

for emerging economies, for some decades. In addition, there will continue to be demand for non-combusted use of oil into petrochemicals, even assuming more effective management of plastics in general.

Outside Europe

The EU's commitment to rapid decarbonization is likely to be sustained. China's centralized five-year planning is driving material low-carbon business development. The US will be a driver, despite the federal position on climate change. For businesses or nations wanting to secure leadership positions, there are plenty of opportunities. A good example is Denmark, where Ørsted, the energy company, has used its capabilities in offshore wind and is exporting them globally, particularly to the US.

Norway is also providing learning opportunities for other countries. What are the challenges, what can other countries learn, is there anything in particular to be worried about? Is there undue pressure on grids? Learning from their experience will be valuable.

Norway plays an important role in conjunction with Denmark on renewable power, and will continue to play an important role with hydro, helping to balance out intermittent wind. In general, most commentators have been surprised by the relatively limited negative impact of renewables on grids in terms of grid-balancing challenges and intermittency. Norway will continue its balancing role but the ability of renewables to be successfully integrated in the grid has worked better than anticipated.

Experience from UK offshore wind, which is quite a successful centralized power generation, shows that even with more renewable penetration, the centralized grid will continue to be important. In more isolated communities, decentralization will make sense. People will install more solar panels on roofs, and there will be more opportunities for peer-to-peer power trading, more batteries and electric vehicles – more opportunity to trade power village to village and more digital solutions.

The sovereign fund

Coal is the highest CO_2-emitting fossil fuel and there are a number of funds that no longer invest in it for that reason. There has been significant debate about the pros and cons of oil and gas investments by the sovereign fund in the Norwegian press. The reality is that oil and gas investment is a relatively small part of the fund's investment and as of now, the fund continues to maintain investment.

From Norway's perspective, exported emissions are also a big challenge. The country has bountiful renewable energy, a high penetration of electric cars, and is less dependent on hydrocarbons for the domestic economy. Norway has been investing in major overseas decarbonization opportunities such as land carbon at scale. If Norway can be at the forefront of the hydrogen economy, which appears to be the case, being able to export gas that eventually can be decarbonized and/or support the decarbonization of that gas at point of use, then the issue of exporting carbon can be managed.

The energy transition may be quicker than expected

Tomas Kåberger is a member of the Board at The Research Council of Norway; affiliate professor, Chalmers University of Technology; board member, Vattenfall; industrial growth executive, InnoEnergy; executive board chair, Renewable Energy Institute, Tokyo; senior adviser, GEIDCO, Beijing

Summary

Natural gas will have a shorter life span than often expected because the cost of solar and wind has dropped dramatically in the past five years. Developments in battery technology mean a combination of solar, wind and battery storage will take a significant share of the demand that gas was expected to supply. Renewable-based hydrogen and electric fuels will start competing with gas sooner than expected; low-cost electricity and developments in the heating sector have major implications for gas-exporting countries such as Norway. While many hope there will be another 20 years of prosperous development, others in Norway are well aware that the 'Kodak moment' for the domestic fossil fuel industry may be coming.

In the past five years the cost of renewables has dropped so quickly that their development is now not as dependent on subsidies. Solar and wind have become cheaper than crude oil per unit of energy. These shifts are hidden because oil prices are in dollars per barrel and gas prices in dollars per British Thermal Unit, while electricity costs are given in dollars per megawatt hour. But we have seen clear steps already taken and milestones passed. Target-setting – such as net-zero targets – is still important but is increasingly the result of industrial development rather than government interventions. It has become important to act quickly and proactively, rather than wait for policies in the EU or at member-state level. Those who wait tend to lag behind the most progressive industrial developments.

Both gas and renewable electricity have flexibility and volatility aspects: when there is not much solar and wind, gas has been seen as the energy solution. But when there is lots of solar and wind, these are now cheaper than storable gas. A reduction in the cost of batteries has resulted in a scale-up of battery manufacturing. This is a long process that started with mobile phones and laptop computers, and has now accelerated anew because of automotive industry innovation. It means that a combination of solar, wind and batteries will take a significant share of the market that gas was expected to supply.

In addition, it is becoming increasingly economically feasible to produce hydrogen from solar and wind when there is surplus solar and wind power available – when otherwise the price of solar and wind would drop due to oversupply. This hydrogen can be used as a natural gas substitute; it can be transported through the grid; it can be an alternative in some industrial processes; and it could combine with CO_2 to produce methane and methanol. This range of electro-fuels will start competing with natural gas faster than anticipated to date.

If, on top of that, there are climate policy initiatives to put a price on methane leakage and CO_2 production, natural gas will have a shorter lifespan than was believed five years ago. The EU power sector will be between 50 per cent and 75 per cent renewable in 2030, and 100 per cent before 2050, up from the current 33 per cent. This has major implications for gas-exporting countries. In heating, green gas, heat pumps and heat storage hydrogen will also reduce the market for natural gas faster than previously anticipated. Another dramatic shift in relative costs has come as the efficiency of heat pumps has improved, bringing down costs of heat from electricity, at the same time as the cost of electricity has decreased.

The Russia factor

Russia is trying to slow the transition down as much as possible. It is effectively the national representative of incumbency. Norwegian gas is believed to be supplied from a system that is tighter, with less leakage of methane. That may result in policy instruments that may give Norwegian gas an advantage. But there may be other political factors and if the value of the gas decreases, Norway may not be competitive. There will be economic pressure on Norwegian gas companies to cut costs and avoid new developments.

Shale gas in the US seems to be an investor-driven cash-consuming industry but may not be a long-term sustainable industry at the current price levels. If prices go up, then US gas will also meet competition from renewables and green gas. It's a tough business – and we will see whether it will provide LNG transported to Europe at competitive levels.

Responsible gas exporter?

A gas exporter could choose to focus on cheap new reserves that they expect to be competitive even when renewables are very cheap. It could go for opportunities in natural gas and other gases for peak demand management and energy storage. Or it could open up to combining its gas business with a renewable electricity business. That would be a more robust survival strategy, other than focusing solely on natural gas, which will decrease in importance. How quickly this will happen is unknown, but the direction of travel is certain. This is happening already: Denmark's Dong has completely changed its business from almost entirely fossil to almost entirely renewables, and changed its name to Ørsted. Statoil in Norway has changed direction at least by developing offshore wind as a significant component of its business, and changed its name to Equinor.

There may also be a debate on whether the Norwegian SWF should invest in new industries in Norway. The economy will need new industries to substitute employment and income generated by oil and gas over decades. Using the fund to support industrial development in Norway could be a way to speed this up.

The future of oil

Transformation will also be fast in the transport sector, reducing demand for automotive fuels, which will decrease demand for oil. Prices will fall, and the balance between supply and demand in the longer run will reduce the value of oil and make the most expensive sources of oil unprofitable. In 2030 and 2050, oil will come from the cheapest sources, oil wells with marginal costs in the order of $10/barrel, while more expensive ones such as oil sands, shale oil and deep sea oil will not be competitive.

Most, if not all, major car manufacturing companies have stopped their traditionally large efforts and R&D of new engines. They will continue to produce those that rely on standard diesel and petrol, which will be in operation for some time. But the share of sales of EVs will increase faster than most have predicted, as they are superior in price and performance. However, when electrification is really increasing and there is political ambition to speed up the transition for GHG mitigation reasons, economic incentives punishing fossil fuels may make standard diesel and standard petrol produced

from biomass and electro-fuels more competitive. Even among the remaining traditional ICE fleet there may be a significantly reduced share of fuels based on fossil fuels. So, it may be wrong to assume that oil demand will be stabilized by the remaining ICE fleet.

The lowest-cost solar and wind power is provided at 1.5–2 US cents per kWh. This is less than half the price of crude oil and often below the price of liquefied fossil methane per unit of energy. So, even without carbon pricing, it has become possible to produce hydrogen from renewable energy and to compete with fossil gas.

A learning curve that reduces the cost of electrolysis equipment may make this opportunity even greater. Installations may provide even cheaper forms of hydrogen while producing only during periods when electricity prices are below the average price.

In China and India, in addition to the ambition to contribute to reducing climate change, there is a strong incentive to reduce air pollution. As the technical means for this are almost identical to those for reducing fossil fuels, the policy instruments will meet both demands. In China they are leading in many areas such as the electrification of bus fleets. In Europe we are proud when 20 per cent of a city's bus fleet are electric but in Shenzhen, with some 20 million people and 20,000 buses, it is already 100 per cent electric. We also see growth in renewables in India. Some of these economies do not have a stagnated market with strong incumbent established energy companies that try to resist their development, and so they can move faster.

CCS will be limited, because it will be for industrial processes where it will compete with other systems based on renewable electricity. I have been involved in developments that use cheap electricity to produce hydrogen for fuel production where traditionally petroleum was used, and where it is possible to use hydrogen instead of coal to produce steel iron ore. A few industrial processes exist, such as cement manufacturing, where it is hard to avoid CCS if climate neutrality is to be reached. Possibly developing CCS from biogenic CO_2 flows would yield a negative carbon balance. With strong enough incentives, we could start creating negative emissions, and then CCS could reach a larger market. But renewable electricity has now proven itself capable of outcompeting CCS in many other applications where CCS was considered a solution 20 years ago.

CCS is no longer a large expensive component of net-zero scenarios. This means that reaching net-zero has become a lot cheaper in the past five years. The direction is clear but the pace may be slowed down by incumbent industry that mobilizes political support in some countries. Yet it's encouraging that despite what US President Donald Trump says, coal-fired electricity generation has decreased by more than 70 TWh in the first six months of 2019.

Norway's balancing role

Norway is also a leader in rolling out EVs and related infrastructure. This is definitely useful for the energy transition. One reason this has worked well is that the country has built a distribution grid to meet electric heating demand. Norway now has the opportunity to increase wind and solar much more easily than countries that do not have the same hydropower-balancing capacity. It will be extremely important that they succeed: the traditional Norwegian advantage of low electricity prices that attract heavy industry like aluminium smelters will not automatically continue when solar becomes the cheapest electricity, and this may give other countries further south an advantage.

Norway must succeed in deployment of a suitable mix of solar and wind combined with hydropower in order to compete on energy prices for heavy industry – one of the few, besides the fossil fuel industry, that is still doing reasonably well in Norway.

They also have opportunities for battery manufacturing where their renewable electricity with relevant mineral resources in the region could ensure a successful industrial development. It's a pity that the high labour costs of the Norwegian oil and fossil fuel sector is making Norway less competitive in the industrial sector.

Norway has an impressive suite of decarbonization activities but could go further to balance the source

Zoe Knight is MD of the Centre For Sustainable Finance, HSBC
(Based on an interview)

Summary

Norway is a responsible producer and has led the way regarding its process for producing and using oil and gas. In addition, its policy, pricing and corporate responsibility levers are all working together to generate a faster energy transition pathway. But the commercialization of CCS remains crucial to decarbonizing industry and Norway's SWF can do more to ensure a net-zero future.

Turnaround needed on high levels of gas

The energy transition definitely should happen and taking a hard look at oil and gas is a large part of that. They supply around 60 per cent of our energy needs globally. With electrification as the main solution, demand for oil is displaced in a more straightforward fashion, whereas demand for gas could be augmented due to the expansion of electricity supply. Gas is cleaner than coal and widely touted as a transition fuel but is nowhere near where power needs to be to generate a net-zero outcome. There is a tension between electrification being the way forward and how that power is provided. That's a critical issue. EU targets are for 40 per cent renewable energy in 2030 and net-zero emissions in 2050 so a turnaround is necessary from current high levels of gas.

The need for carbon sinks

Norway has been a progressive country in addressing climate change in all aspects from scope 1 exploration, production and refining, all the way through to transport. It has supported and implemented carbon pricing and been a key figure in the REDD+ framework from early in the climate talks. It is one of the most progressive cases that other countries can learn from, but that doesn't get us to net-zero on its own. You can make all the reductions that you want but you still need something to balance the source. You've got to have a package of solutions to enable that net-zero goal.

Net-zero is a good straightforward way of measuring as opposed to science-based targets because whatever level you're examining at – country, individual, facility – it is clear where you need to be. Remaining emissions need to be removed and absorbed in a sink. Exporting emissions is not really the solution as the carbon budget is a finite budget for the planet as a whole. In terms of global oil and gas demand, supply from Norway, where conscientious and advanced production and treatment methods are employed, is more beneficial overall than from more polluting sources elsewhere.

In its processes, Norway is a responsible gas producer in how it produces and uses gas. Hopefully more extraction would not be necessary as efficiency gains advance, in industry and heating. With power, it is not so clear as electrification to solve climate goals is critical, which points to increasing demand for power. Ideally that will come from renewable sources but the outlook for that split is not so certain.

CCS key for decarbonizing industry

CCS is vital and Norway has been progressive here too. An interesting innovation that it may be leading on is a collaboration across industry with a provision to invest in CCS. It is helpful to provide a de-risking toolkit to be able to invest in CCS, which, though crucial to the net-zero objective, is yet to be commercial.

CCS for the construction and other heavy industries is particularly important as the emissions are so hard to abate. Cement is one of the most expensive areas to decarbonize. This is amply highlighted in the report that we have collaborated on with the Energy Transitions Commission, *Mission Possible*.[77] Cement decarbonization would cost $110–$130 per tonne. Even after you make the transition of switching from coal to gas kiln heating, CCS will in any case be required to capture the process emissions. CCS becomes a competitive option if the electricity price rises to above $46/MWh.[78]

Norway's contribution to net-zero

The step that the Norwegian SWF has taken in no longer investing in coal is not sufficient but is a significant signal that coal is the worst perpetrator in the fight against climate change.

Norway has instituted an impressive bundle of activities towards net-zero. It has effectively decarbonized its power supply and is lucky to have hydropower in that framework. It has had carbon taxes for a long while so its carbon pricing mechanism is in place – a key lever for decarbonization that many other countries could aspire to. And it has implemented other regulations. A major one is that it has introduced legislation around phasing out combustion vehicles and bringing in EVs. Possibly it doesn't have specific legislation on the oil and gas industry other than the carbon tax, but the oil and gas industry itself is quite progressive in trying to lessen carbon intensity per barrel produced. So in Norway you have got the policy and pricing levers and the corporate responsibility lever all working together to generate that faster pathway.

The other thing to bear in mind is that Equinor is operating in other locations so you get that ripple effect of achieving innovation and best practice and climate-related goals outside its national jurisdiction.

Shipping is a harder-to-abate area but it is important to switch to hydrogen and battery in the coastal and short-distance routes. Norway is currently introducing strong regulatory requirements for such solutions.

[77] Energy Transitions Commission (2018), *Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century*, https://www.sustainablefinance.hsbc.com/reports/mission-possible (accessed 22 Feb. 2020).
[78] Ibid.

Norway's potential leadership role in dealing with global climate change

Michael Liebreich is founder of Bloomberg New Energy Finance and visiting professor at Imperial College
(Based on an interview)

Summary

Renewable energy will form the bulk of electricity demand in Europe and even globally. Norway, with its hydropower, can provide the necessary scale of interconnection in Europe to achieve this. However, it does have legitimate concerns that this approach will drag it into a higher-cost electricity market that would disadvantage its own industry. Norway has excelled in emission reduction policies, which seem at odds with the oil and gas industry that has created its wealth. It now has the opportunity to export its expertise in clean energy practices and also has resources that will be in demand with decarbonization. It needs to appreciate more the leadership role it can take.

Due to difficulties in building nuclear energy resources economically, renewable energy will make up almost the entire power sector in Europe by 2050. But variability in renewable energy resources means that other more controllable fossil-fuel based power sources will continue to be in use. Renewables are so cheap that there will also be a very high penetration of them globally in 2050. Grids need to be renewed and a lot of investment poured into power production, but getting energy supply from renewable sources to 85 per cent globally is foreseeable.

Although the variability in renewable energy supply will be managed through batteries and demand response, the remaining 5–10 per cent of demand for energy will be provided by fossil fuels. This will be unabated fossil fuels, because to build all the capacity to monitor, capture, transport, compress and store the carbon, and yet only use it for 5–10 per cent of the time makes no sense (unless we have a very high carbon price). We don't need baseload power; we need flexibility, which is why gas makes more sense than nuclear for this purpose. Nuclear cannot be cycled up and down, whereas gas can.

CCS will be too expensive, so limiting the carbon emissions will require direct air capture or bioenergy with carbon capture and storage (BECCS), generating carbon credits. In the future there will also be a large degree of optimization, with everything smart and digital. It's a difficult business model to make money on in five years but by 2050 it will be completely normal. There will be heat-pumped district heating selling flexibility into the power markets. The technology kind of exists; no one's put them together with the power markets and then created the aggregation and services yet.

High-carbon price needed

A carbon price is needed for societies to go clean. It would facilitate the use of hydrogen and natural gas coupled with CCS. There will be some CCS for combined cycle gas turbines (CCGT) plants, and for industry: steel and cement. There may still be a place for natural gas in 2050, in a reduced capacity, either as baseload with CCS, or industry with CCS, or to provide flexibility without CCS but then something else to abate or offset it like capturing CO_2 from the air.

But who will pay? If you really want to get to net-zero you're probably talking about a carbon price of between $100 and $150 per metric ton. At some level, European consumers will pay for it and the revenue will get funnelled over to whoever is capturing, moving around and sequestering the carbon. The Norwegians have pipelines everywhere and depleted oil fields and reservoirs, so whether the route of the money goes via the Norwegian gas industry or wherever is unclear.

A very high-carbon price will also drive high technology solutions. They might be ultra-high voltage DC lines for solar from Morocco. A wind lull can go on for three weeks and batteries are not going to fill the gap, nor will thermal energy storage. It is not just a case of the lights going out. When everything is electric – the police cars, the hospitals, the trains, the supermarkets, the food production and so on – you really need to have a resilient system.

Offshore wind as game changer

Offshore wind has really knocked renewable energy from the margins into the mainstream. It is great to see the oil and gas industry espousing it and transferring skills. The main problem with offshore wind is that there is a large amount concentrated in one area and this correlation leads to a severe power cut if they go offline.

Offshore wind farms are so captivating because the real estate is almost infinitely large: if you go for floating offshore where you can get to very high capacity factors, the cost can come down to wholesale prices in the next 10 or 20 years. But looking out to the 2050 horizon, why not put industry offshore where the power is? Ships could dock and be fuelled in the middle of the Atlantic off a floating platform. You could even have floating solar offshore and batteries and produce hydrogen and ammonia for shipping. In a closer time horizon, even if you had fixed bottom offshore (as opposed to floating deep offshore installations) a bit further out, it still makes up an important piece of the puzzle.

Electric transport wave

The electrification of heating will be a lot slower than transport; it is more difficult and capital-intensive, in the order of £20,000 per home. Transport on the other hand is poised to take off. It is already visible in Norway, which made EVs cheaper through tax breaks. The rest of the world will make EVs cheaper by battery experience curves and uptake will be rapid.

Norway went from zero to 50 per cent EV sales in eight years. According to Bloomberg New Energy Finance figures, by 2040 more than half of car sales will be electric and more than 30 per cent of all vehicles in the world will be electric. In Europe that proportion will be higher. Daimler is no longer developing its next generation of ICE for its cars. For trucks it's different, but for cars and light trucks for the first time in 150 years there is no development platform for petrol or diesel vehicles. Similar things are happening in Volvo and VW, the ICE has reached an evolutionary dead-end.

Amazon is also going electric. By 2025, I predict most home deliveries will be electric. At present globally only about 2 per cent of car sales are electric but this is common with logistics curves. Logistics curves model consumer behaviour such as black and white TVs changing to colour, normal phones to smart phones, and now ICE vehicles to EVs. It works like this: 0–1 per cent takes forever; 1–5 per cent penetration is like waiting for a sneeze; and then 5–50 per cent is the sneeze. After that it slows down. We're in that waiting for a sneeze period with electric cars. Everyone knows it's coming and it'll affect all light duty vehicles apart from those doing more than 250 miles regularly.

Heavy long-distance trucking is no longer employed as a model. Logistics managers use distribution centres strategically located and roughly 90 per cent of the delivery journeys are within a 100-mile zone. The prospect of using hydrogen for any transport other than cross-continent should be regarded with enormous scepticism. A battery will have a 250-mile range. We just need to build out the grid and add the charging infrastructure at the edge of the grid.

Charging points are the sticking points. District network operators will hold this development to hostage unless someone pays them. There are small innovative companies such as Pivot Power (just sold to EDF) that are circumventing them, with big charging hubs connected to transmission grids.

Norway's vital balancing role

Norway's hydropower production is a fabulous smoothing mechanism for all of Europe and it needs to be monetized. However, that implies a net sale of electricity into high-cost electricity markets that will absorb the low-cost electricity from Norway and drive up the country's power prices. But on the positive side there is a whole set of revenues to be earned from balancing, storage and meeting peak demand. So the discussion in Norway needs to be around how revenues from the balancing markets compensate the average Norwegian, and Norwegian industry, for the fact that the cost of their large-scale power will be higher.

That's a difficult debate to have because from the point of view of a Norwegian smelter, their costs will go up with higher power prices, while someone else will be making money in the European balancing market. But protecting domestic smelters is probably not the best long-term approach for Norway compared with playing its role in the European clean energy transition across the board, using all of its assets. The sticky question remains: how do you allocate the value captured from balancing services? How do you get to that political consensus, approving those interconnections and trading arrangements – because there will be winners and losers within Norway?

Norway is muddling along in the middle ground. Statnett, the Norwegian power system operator, is connected to other European markets and Norway does make money from balancing. It is happening, but is it ready for the scale that will be required? There is a sense that they're holding back.

The more interconnection there is, the cheaper electricity is, but the more you have to think about resilience. There is less chance of a system black out event but the severity of one increases. It is possible that this is not being considered. For example, what happens when police cars are electric and they are needed to guard substations? A crisis can occur when the power falls in a system with such interdependencies.

Norway could export its leadership skills

Norway is a leader in rolling out EVs and related infrastructure but it has a modesty about saying 'we are world class'. Norway could do more to bundle the capabilities from Statkraft and the engineering service providers responsible for that, and export these assets. The UK has exported a number of different service models but this is not seen so much in Norway, apart from with DNV (a Norwegian verification and sustainability group). The country is also world-class in eliminating gas flaring and could export that as a package of services including finance, government access and engineering services to solve flaring in other countries.

Norway has a very efficient oil and gas sector but they still sell oil and gas. Within Norway there may be a certain amount of embarrassment that it has done so well out of selling carbon to other countries. So the idea of selling services based on the Norwegian lessons in transitioning to a zero-carbon economy provides a good flipside: they have done so well at home at (1) choking off demand, and (2) capturing the benefits for Norway, in terms of jobs, technology, clean air and so on.

A moment of truth is coming in the next decade, which is that we can't exempt high-carbon industry from carbon pricing. Inevitably, we need to be talking about carbon border adjustments[79] because without it, production just goes elsewhere. To date, industry has been exempt or given them free carbon permits to prevent polluting industries moving to other countries. The WTO should develop frameworks for carbon border adjustments that are light-touch. We could end up with buildings reinforced with glass fibre but still using steel. Why? Because steel is not paying its carbon price. The alternatives to steel are more expensive but if we always choose the cheapest option we may as well look at a world that is 4°C warmer. Experience curves demonstrate that the more expensive material and technology becomes cheaper anyway.

Norway could play a catalytic role in helping the world deal with climate change. It should aim for decarbonization by 2050 and in the meantime its oil and gas industry and heavy industry need to be ethical suppliers of their products. Norway has done a huge amount to reduce emissions in scope 1 and scope 2 exploration. But the focus should be less on efficient production, which extends the lifetime of that business by making it more competitive, and more on choking off demand and working on CCS solutions.

[79] A tax that is placed upon the carbon created in the production of imported goods.

Norway is key for energy security, competitive markets and CCS

Andris Piebalgs is a former EU commissioner for energy and development

Summary

Norway is an influential country – it is sustainable, transparent and supports global processes including on climate change. It is a positive, not a negative, thing that Norway is a gas producer and that it maintains CCS as an option. The country's SWF no longer invests in coal. It should scale investment in global renewables in developing countries that need fast access to energy and are otherwise investing in coal for which they get better financial incentives.

While some countries have previously blocked this approach, there is no doubt now that the EU will soon have a clear goal for carbon neutrality by 2050. The carbon price will drive coal-to-gas switching and governments will not resist this, hopefully. But there is no clear gas strategy yet, other than a general expectation that markets will grow with better environmental characteristics: biomethane could definitely grow, but it's not clear how the hydrogen economy would develop and what intermediate steps there will be. This is where the biggest uncertainties lie and where this could unravel.

It could be assumed that first there will be developments at member-state level and then an EU gas strategy will follow. The best strategy would be coal-to-gas switching as a first step, then blending 5 per cent or 10 per cent, then a real hydrogen/zero-emission system. There is also a lot of expectation that renewable electricity could be transformed into clean hydrogen, but there is no clear regulatory process and the costs are high.

It's too early to say whether carbon neutrality can be achieved by 2050 in the EU. But if 2030 targets are reached, including targets for energy efficiency, then definitely carbon neutrality can be achieved by 2050. If 2030 targets are not reached, perhaps EU member states might decide to put in place new mitigation measures.

The key issue is that energy demand should fall; however, in the last few years energy demand has been rising. The trend is wrong and is worrying. We tried to tackle this, with the EU phasing out incandescent lightbulbs, but nobody has tried anything similar since then. Why is the same not being done with SUVs? Nobody is mentioning this. Some member states had some press backlash on lightbulbs after unanimously supporting the introduction of these measures; that then affected the European Commission's ability to do further work on these issues. It is doubtful whether there is now much courage for similar measures, so we need to use taxes and other market measures that may not be as effective.

For 2030, there will probably be a slight increase in gas demand, as coal-to-gas switching has a lot of potential even with current carbon prices. Afterwards, that demand would fall, but how fast very much depends on the demand side, as this could change what happens in heating and transport and perhaps will move us more towards electrification. In that case, gas remains a last-resort option for strategic storage or storage in general, or in some niche like long-term transport. Currently we have 450 billion m^3; in an ideal world we could go down to 200 billion m^3 in 2050 in a carbon-neutral scenario, but that would also involve a different type of gas. In the simplest scenario, it would all be biomethane; in a more complicated case, it would include a lot of hydrogen.

During my time as EU energy commissioner (2004–10), we had huge expectations from hydrogen, but things have not progressed a great deal. The big difference now, however, is the Paris Agreement, and more agreement among member states. The 2020 targets will also be reached and that gives courage for 2030 and 2050.

In heating, natural gas can be replaced by electricity. The climate law in the Netherlands already foresees this, so gas will lose part of the heat market supply. The main strength for gas is the electricity sector, because of the need for system flexibility. In the heating sector, the future of gas will depend on measures at member-state level. Things may change in the Netherlands but I don't see a change for the moment in Latvia, Germany or the UK.

Norway plays a huge role in all prospects: it is key for security of supply, and key for competitive markets. Also, CCS now has a second chance thanks to Norwegian support – without it, it would be abandoned as an option. CCS is something that heavy industry should embrace because there are processes where it is the only way to avoid carbon emissions. But the big challenge is that if energy becomes expensive, factories begin to close down. For the future of heavy industry, there needs to be global action to reduce the cost of decarbonization measures on this sector. The alternative would be a carbon border tax as some are proposing in the EU – and this would be a disaster for the global economy.

Competitors

The EU will continue to have a good competitive and diversified gas market. Norway fits well in the European market and will continue to provide gas and retain its competitive advantages in this market. But Russia remains as a competitor and the energy transition is a challenge for it as its economy is built on hydrocarbons and it faces significant economic losses from a global transition to zero carbon. In my work as a commissioner, there was never the impression that Russia is hostile to low-carbon strategies. If there is sufficient demand in the EU, the Russians say they will use their pipeline system to carry hydrogen; they are open-minded and are making proposals. Ultimately, Russia will follow whatever developments happen in the EU internal market, and where that goes depends on us. As for competition from LNG for Norway, that still depends on what prices will be in other parts of the world. Norwegian gas will need to be competitive for consumers, whoever is in the market. But Norwegians have learnt this.

Gas exploration is justified, especially if countries are trying to replace coal. Norway offers a good benchmark for production, trade and transparency in the whole process. Norway being part of the group of international gas producers is a positive thing, not a negative thing – but ultimately it is their decision what to do next.

It is right for the Norwegian SWF to no longer invest in coal, because you start to move away from dirty fuels. But it is important to invest in alternatives, to strengthen renewables, wind and solar, and to scale up this type of investment. As an EU commissioner for development, it was clear that some Asian or African countries attempted to get fast access to energy sources and receive favourable conditions to invest in coal. The SWF should look at where to prioritize investments, and this should be in renewable electricity worldwide.

Oil demand

The German government's decision to limit oil boilers is just one example of how oil demand will be affected by EU net-zero targets. However, the assumption is that change will not happen in a top-down way, but rather bottom-up, with more electric cars, more public transport, more alternatives to oil in heating. There will be a gradual move out of oil but the pace depends on each particular member state. But don't expect a clean break – it will be more of a gradual transition, where growth plateaus rather than going down. Gas is definitely more sensitive to policy change and there could be abrupt change with gas perhaps being pushed out, while oil is harder to push out of the market.

As long as figures show that people are still buying a lot of SUVs, there is some discrepancy in what people are doing and what they are saying, despite the rise in awareness about climate change. There will not be a sharp change unless EVs get much cheaper. For that, battery prices need to go down and electricity tariffs need to change, to make electricity cheaper. For the moment electric scooters are the most visible change in big cities, and you can't change mobility patterns this way. Perhaps if enough countries were to ban the sale of ICE vehicles by 2035 then the transition could be faster, but if it happens later it will be a problem as we cannot expropriate the property of people who own cars already. Then there is the emotional value, too. Manufacturers will need to make vehicles that people love to drive. In addition, in Asia and Africa, life expectancy is going up, so there will be a continued market for oil. Even air quality measures are not very consistent, mostly affecting diesel cars. For the moment, those measures don't appear to be influencing oil demand.

Electricity trends

From a level of 33 per cent in 2018, renewable energy could make up 65–70 per cent of the EU power sector output in 2030, with nuclear and fossil fuels accounting for around 30 per cent. For 2050, it could be all renewable or renewable plus nuclear. It is unlikely that the system will get very decentralized – although if that prediction turns out to be wrong it would not be a bad thing as it would mean society will have changed. But how can we achieve our targets without huge wind parks in the North Sea? There could be other trajectories: reduced consumption and increased flexibility with EVs are all possibilities that could develop within the EU framework, but current trends do not favour this. We will also have congestion on the borders, which means we need more interconnection. It costs money, but it is the best way to use the capacity we have developed, in particular renewables.

Norway offers a good example on EVs. More public knowledge about their experience with EV deployment would be important as a lot of these policies are decided at national and regional levels. It would be good to know how much it cost and how it was achieved, to show whether their scheme is sustainable enough and cheap enough to be replicated. Also, Norway is huge, and their travel points in sparsely populated areas where people really need vehicles could provide a successful example for China, India and the US.

Countries that are not as rich as Norway can also introduce EVs. Bhutan is doing so – it has a different and specific situation, and is a much smaller country. Together with India, they have developed substantial hydropower resources; the electrification of the country is a 'side benefit'. But it also shows that this is not something exclusively for the developed world.

It is decision time for Norway

Kristian Ruby is secretary general of Eurelectric, the union of the electricity industry
(Based on an interview)

Summary

Norway needs to pull out of oil and gas and focus its know-how on rolling out renewable energy in the North Sea and the rest of Europe. If we are serious about mitigating climate change and reaching set goals, we have to be serious about the energy transition. There will need to be a more explicit choice of direction. Norway's clean power system is inspirational, yet it still exports fossil fuels to the rest of the world. Norway could make a decision at government level to go for net-zero.

On the one hand Norway has a clean power system and electrification rates that are a worldwide inspiration. On the other, it is a major oil and gas nation that continues to extract and export fossil fuels to the rest of the world.

At some point there will need to be a more explicit choice of direction and a plan for how to move towards a net-zero-emissions economy. All major companies should be involved in that. It is not enough to change image. You have to change operations as well. Blue hydrogen is not going far enough as a decarbonization strategy. A credible approach would need to consider systematically how to move in a new direction and, for instance, leverage competencies in offshore oil for offshore wind instead. Another thing would be to look at how to fast-track the transition to a carbon-neutral gas system. A good litmus test for all energy companies is to assess: how much do we invest in carbon-neutral solutions and how much in fossil fuels?

Carbon capture and storage

CCS is an option but the challenge going forward will be the cost issue. We have to assume abatement costs of €150/tonne according to our assessment. That is very high. We put that in the category of 'the most difficult to abate' tonnes. Sometimes we're limiting our thinking of CCS to human-made technologies. The cheapest form of CCS is simply photosynthesis, planting trees. Of course that takes time but it is the most cost-effective option.

It is a more costly and complex task to abate tonnes of carbon emissions with CCS in the industrial form that we have, than working with renewable energy. It doesn't take much to realize that the process of extracting fossil fuels from the ground, burning them, processing the smoke, and then piping parts of it deep underground is a complex thing to do, compared to building a wind farm and creating electricity from that.

However, CCS will be used in places where companies have large amounts of capital invested in high-carbon value chains. They can only continue on that path by including the CCS component. So we see a role for CCS but it is a limited one. By 2030, we will see a few commercial applications and by 2050 we will need to have figured out CCS solutions.

Electrification

The pace of electrification will depend on two interdependent aspects: investment and political will. An electric car today is as good if not better than an ICE car. You just need a push from governments to nudge consumers into switching. Governments must help and support the roll-out of the infrastructure otherwise this won't take off at the speed needed. The same applies to heating. Heating systems are deeply embedded in local government and structures, and therefore you need to engage with governments, at regional and municipality level, to make this happen. These things are really interdependent and the investment will only flow if there is the concomitant thrust from government.

In concrete terms, our expectation is that the legislation in the EU will be delivered – if not over-delivered – and the implication of the agreed legislation is that by 2030 there will be 30 to 40 million electric cars and vans on the road. So this is going to take off at a significant pace. We expect the European member state governments and local authorities to back up action in this space as we know that the whole decarbonization project is highly dependent on something happening in transport. If we don't do anything about transport emissions, we're not going to solve the problem.

The power system

In Europe the power system is going to be around 55–60 per cent renewable by 2030 and more than 80 per cent by 2050. Norway should be more bullish about the build-out of renewables in the North Sea and the northern European region overall. It is holding back because of the effect this will have on power prices.

If we want to be serious about the pace of reaching climate change goals, we have to rethink our approach to the power system. We can't only think about the price level at which the market clears every day. The agenda for the power sector in the next 10 to 30 years is a massive build-out of renewable energy and so enormous amounts of investment are being channelled into the sector. That renewable energy will be the backbone of the new energy system in Europe. There's no way around that, so a view that building out renewable energy around a country is going to mess with its prices is counterproductive. We have to rethink our approach to markets so that it doesn't stall the build-out of renewables.

A more connected power sector is necessary for greater renewable deployment. As has been the big discussion in the clean energy package, the first thing we need to do is to use the interconnectors that we have. There have been a large number of interconnectors that have not been used at all to the extent that they could have been used, and this has been a matter of countries playing a zero-sum game, of keeping out foreign power that could have been used to tackle internal congestion. So the first and foremost challenge is actually to use the interconnection potential that we have. Subsequently each interconnector should be assessed on a fundamental cost-benefit analysis. It is difficult to establish a specific target by 2030. For instance, would that be 15 per cent of overall demand, or of production?

Possibly we focus too much on transmission and not enough on distribution. Distribution is the last mile to houses. The future energy system will see an enormous decentralization – a lot of electric cars connected, a lot of heat pumps connected to the distribution grid, a lot of grid-edge technologies, a lot of solar parks and a lot of individual onshore turbines connected to the distribution grid.

So – to use a metaphor – we have a tendency to focus on the highways rather than all the other small roads that people use on a daily basis. We need to see a balance of investments in these two different infrastructures. We have to invest much more in distribution grids going forward.

The power sector will become massively decentralized but the major players of today will continue to exist; some may merge, and some disappear because they don't choose the right strategies. Looking forward to 2030 we will also see new names – hopefully names that we usually associate with oil and gas will emerge as major players in renewable energy and electrification. For them and for society, there seems to be no way round this. They should step up to the plate and start channelling their investments in the right direction.

Those who fail to take action will not survive

Pierre Schellekens was deputy head of cabinet to the EU commissioner for climate action and energy, Miguel Arias Canete
(Based on an interview)

Summary

The energy transition is making great strides in the power sector and has made inroads in industry. The transport sector is still some way behind but electrification of passenger vehicles is coming. Europe is the global leader in the transition but it cannot sit back. It is only partially down the road and big challenges lie ahead. Companies need to make the necessary changes now to prepare. With deep structural reform, there are winners and losers, depending on how you develop and adapt.

Industry needs to be forward-looking

Services are central to the European economy where many of the companies see the potential of the energy transition rather than the risk. Large parts of industry can transition at a low cost through efficiencies and by using other forms of energy. But heavy industry – aluminium, steel, chemicals, cement – will be impacted. They are not necessarily doomed like the coal sector where there is support, labour market action and measures to help people move into other forms of activity. But heavy industry is the interesting in-between category that has a choice to make. They need to evolve. Forward-looking measures are being taken. Look at what the Swedish steel industry is doing with hydrogen. The Austrian steel industry is also investing in different pilot projects that use hydrogen.

Their survival depends on how they innovate and develop technologies. By 2050, we would certainly hope, (a) to be carbon neutral; and (b) to have a thriving steel, chemical and aluminium industry in Europe. There will be support from the EU side, and research and other measures that the public sector should take, but of course it will also depend on company decisions. Fundamentally the energy transition is a structural reform of the economy. As with all structural reforms, some companies prepare, reform and live through such transitions while others don't take the necessary actions.

A lot of carbon reduction can be done with the current structures. But there is reform of production processes in these industries where, for instance, in terms of process-related emissions, CCS can offer a solution. The steel, cement, and perhaps even more so the chemicals sectors must prepare.

The steel sector in Europe does seem aware of this. They're in a difficult position now because Chinese steel is being dumped on the market. Supply of steel is much higher than demand especially now that selling steel to the US has become difficult. But they are not ignoring this challenge and a part of the European steel industry is preparing.

Until a global equivalent carbon market develops from raising the ambitions in the Paris Agreement, which are revised upwards every five years, free allocation of permits will be necessary to spur innovation. It works towards reducing emissions while at the same time not putting industry at a competitive disadvantage to an extent that they can't overcome.

CCS vital for industry and negative emissions

We do not see a big role for CCS in electricity. You might see some CCS for electricity outside Europe but there isn't a compelling need for it inside Europe. There is, however, a need for CCS in two areas – heavy industry and industry that has process-related emissions. Emissions in industry will have to head towards net-zero by 2050.

Biogas will increasingly be used as an application for heat. Biomass is more suitable for heat than electricity as it gives more energy. Biomass, which is classified as zero emissions, combined with CCS generates negative emissions. We are committed to net-zero by 2050 but emissions will remain, in agriculture and industry. Land use, soil, and forests provide a sink, but CCS goes further in providing a route to negative emissions and therefore providing a solution for those remaining emissions. It is a very viable option.

Some geographical integration is helpful for CCS and biogas, in having heavy industry zones, but we would also envisage CO_2 being shipped to Norway or elsewhere by pipelines in the future. It can also be shipped by boat. We are already financing some of these projects.

Closing the variability gap with renewables

The European Commission assumes that there will be 55 per cent of renewables in the power sector by 2030, and 85 per cent by 2050. Some of the growth of renewable electricity will come from the marine environment. There will be the continued increase in offshore wind power and possibly new forms of energy such as from wave, tidal etc.

The gap not met by renewables in 2050 is likely to be provided by nuclear with zero CO_2 emissions. There would be a rather small baseload, probably less than 15 per cent, provided by nuclear. As time goes on, not all renewables will be variable, there will be progress with battery storage, and so nuclear will contribute. But the fluctuation with renewables will increasingly be less of a problem. A more connected power sector is of course necessary for greater renewable deployment.

Interconnection and Norway's position

Interconnection enables the smoothing out of variability and the EU current target of 15 per cent interconnection by 2030 would provide stability in the market. A higher target is not currently foreseen. The target for 2020 is at 10 per cent. Most member states will meet this. There will be some exceptions, such as some parts of the Iberian Peninsula and southeast and central Europe. They're more at 7 or 8 per cent but that will increase by 2030. The 15 per cent target does create sufficient flexibility in the marketplace. It would be better if it were higher but that level is good and realistic. Some member states are far beyond that, at 30 per cent, whereas others are not near. Islands like Malta and Cyprus will have none and then will leap to 40 per cent with an interconnector, as in the case of Malta. But then there are areas where it is more complicated, for cost reasons partly, but also vested interests.

Norway is far beyond the target when you look at how much it connects to the Nordic market and through that to the European market. There are major projects between countries such as Norway's connection to the Netherlands with the world's longest high-voltage subsea cable, the NorNed; and the interconnector to the UK under way; and one to Germany is also planned.

Norway has an important role as an exporter of electricity to the European market, which is in both our interests. It is also CO_2-free, which is why we are so interested. We would like the Finnish to do more as well but they believe that it will raise prices domestically.

In terms of electricity, Norway is essentially part of the EU market; there's no real difference between them and Sweden and Denmark. For all practical purposes they are part of the Nordic market, and they have two options: either they leave the Nordic market or they stay in the Nordic market and apply EU rules. With the European Economic Area (EEA) agreement, through the third energy package that they did last year, EEA countries implement EU legislation where they have to adhere to the European Agency for regulation. We've just renegotiated the electricity market rules, concerning balancing and network codes and so on, and in turn they will have to integrate those new rules into Norwegian law.

Norway's lead on EVs

Norway is a leader in rolling out EVs and related infrastructure at high cost. It is useful for the energy transition. It is taking down barriers on what is possible; it is allowing costs to go down and allowing the technology to be tested. In that respect of course, it is useful. But when you see the cost of that in terms of tonnes of CO_2 avoided, and the very generous tax breaks, both for registering and running a new car, not all member states could afford that route. What they're doing is helpful for us all in taking the first steps, but it is an expensive measure. It is a specific Norwegian solution that relies very much on the strength of their public finances.

Electrification a disruptive technology to prepare for

While power companies will welcome the electrification of transport and heating, the grid companies may not be ready for it. The power sector will be largely decentralized. It will be necessary to centralize capacities but consumers selling their own production to the grid will only increase.

Electrification of transport does not present the same grid issues of smartness and flexibility. There's a lot more of that to come. There will be a need for more grid functions and in some areas maybe a new grid.

Electrification of transport will likely occur around 2025–30, mainly in passenger cars. It's unlikely that all cars will be electric but by 2030 a large share of new cars will be. Electrification is going to happen and if countries don't make themselves ready, then they won't meet the needs of the future. They'll be missing an opportunity on a colossal scale.

All this points towards increased electricity production and consumption. Is the EU helping to prepare for this? Electricity market rules are going in that direction, but companies have a self-interest. We can do things like help to establish the framework, targets, rules, charging stations and so on, but a lot has to be done by the private sector.

Transport still a challenge in the transition

The transition is certainly happening in the energy sector. In 1990 we were at 5 per cent renewables and most of that was hydropower; today we are at 30 per cent and by 2030 we're likely to be at 55 per cent. Within the EU the comparative efforts of the member states make renewable energies more competitive. The ball is rolling, that's for sure. It is happening less so in the heat sector,

but it is still promising. The challenge before us is the energy use by the transport sector. While consciousness and awareness of the problem is there, real delivery is still ahead of us. Cars have become more fuel-efficient. Since we introduced the first rules for emission reductions by new cars 10 years ago, CO_2 has been cut from 165g/km to somewhere less than 120g/km today. Cars are more efficient than before but unlike in energy and industry, transport sector emissions are still linked to activity. This is much more difficult to address than in the energy and industrial sectors.

Gas and the rise of renewable gas

Gas is part of the transition. You will see a slightly reduced use of gas within the EU. However, because our own production is declining – Dutch production is decreasing – there will probably be stable imports for a few years ahead.

After 2030 we will see this decreasing in Europe. There will be a shift towards renewable gas in combination with hydrogen. There will be a higher share of renewable gas, some gas imports such as from Norway, but then in the 2030s when the transition starts to become established, we will see a decrease in gas consumption. Some gas will still be used in the 2040s. Natural gas will remain a key supplier of heat for some years to come but then will harshly and progressively be replaced by green gas. For example, around 5–10 per cent of France's network is supplied by green gas.

In terms of gas imports, the important thing is to diversify. Norway will play an important part. We are still quite dependent on Russia, less than we used to be but still too dependent. Norway plays an important role because it is a market economy so it is simple – if you pay for your gas, you get your gas – which is not always the case with Russia.

Then comes LNG gas from the US and other sources. We will buy more gas from the US but Norway is special because its infrastructure is so well established with pipelines down to Belgium and France. Its role is important. A responsible gas producer operates by commercial rules. Whether that justifies opening other reserves is a decision for the companies themselves.

Oil, and progress so far

Most EU member states don't use oil as they used to for electricity and heating. Oil is still used for transport, petrochemicals and plastics, although the latter will see a reduced use and more recyclable plastic. Our use of oil will decrease first and foremost in the transport sector but also in the plastic sector.

The idea that we should stop exporting so that we don't export emissions is ludicrous. If you were dumping products on the global market that didn't comply with environmental standards then one should feel some shame about that, but that is far from the case here. A product produced in Europe has a far lower carbon footprint than one produced in most other places in the world.

We started the transition and we have come some way down this road. In some countries it hasn't started yet, and it's very important that they start the process, in view of the total impact on the climate. That said, we're nowhere near being able to sit back on our haunches. We're not that good yet. Europe and the rest of the world need to transition away from fossil fuels.

You can't discuss being a bridge without discussing the destination

Jesse Scott is international senior adviser at Agora Energiewende
(Based on an interview)

Summary

Norway's future as an energy nation is closely linked to the future of the gas industry. But the industry must urgently move from just talking of natural gas (fossil methane) as a bridge for the energy transition and start discussing the detail of the destination, and what this really means for gas as a climate-compatible energy vector (such as biomethane, hydrogen including both blue decarbonized natural gas and green e-gas). Norway is doing good things domestically compared to other countries, as are Norwegian companies. It would be good to see them take a more aggressive leadership role outside Norway, for example, shaping some of the sector business positions and in outreach around EV infrastructure.

There will be a net-zero long-term framework at EU level, and most member states will have a framework at national level. The message is getting through in all sectors, including the oil and gas sector. The discussion needs to go beyond overly broad 'policy roadmap' discussions. There should be a concrete debate about what the real implications are for the sector and for each company and each country. There is also some level of split in the sector. On one side are companies with gas assets physically in Europe, that own pipelines and therefore are thinking about long-term asset preservation to 2050, and want green gases to be developed; and on the other, those more on the production side that are thinking in terms of 'business as usual' supplying natural gas in Europe for 10 to 20 years until a phase-out, while they focus increasingly on other parts of the world.

The European Commission is now preparing a gas and decarbonization package of legislation, which in theory will be published in draft form in early 2020. There is potential for the proposal to contain an ambitious new framework for the gas sector, including for climate-compatible gases, hydrogen and biogas. Parts of the gas sector that are thinking long term and about low-carbon technologies have some ambitious proposals about how certain technologies could develop, for example, through having gas quality standards for hydrogen established at EU level.

Role of gas in the transition

The European wind industry is openly campaigning for a switch straight from coal to renewables, as a way to rapidly decarbonize the electricity system. However, for a much more rapid CO_2 emissions win, today, we could also switch off coal-powered stations and switch on gas-powered ones for a limited time period.[80] However, this should be done in the knowledge that we also would need a plan for gas abatement, on how to phase in alternative green gases.

As Jonathan Stern said in a recent paper, the gas industry will only be successful if it talks about both aspects of the transition, not just the first part. You can't discuss being a bridge and refuse to discuss the destination. There is a risk that we might miss a major opportunity for a huge emission saving. Some dates of coal phase-outs are still way into the future, whereas the coal-to-gas switch could technically be done in a month or two, for example, by bringing some mothballed plants back into play.

[80] Stern, J. (2019), *Narratives for Natural Gas in Decarbonising European Energy Markets*, OIES PAPER: NG141, https://www.oxfordenergy.org/publications/narratives-natural-gas-decarbonising-european-energy-markets/?v=79cba1185463.

A recent IEA report[81] on gas found that since 2010, coal-to-gas switching has so far saved around 500 million tonnes of CO_2: an effect equivalent to putting an extra 200 million EVs running on zero-carbon electricity on the road over the same period. But perhaps the most interesting finding of that report was that, 'there is potential in today's power sector to reduce up to 1.2 gigatonnes of CO_2 emissions by switching from coal to existing gas-fired plants'. In other words: we can still achieve two and a half times as much again as has been done in the last eight years (without building anything new, no 'locked in' infrastructure).

In the heat sector, green gas, electrification and/or efficiency will start to reduce demand. The Dutch are trying hard with electrification in their heating sector, so we'll see how successful they are. This is important, as among the G20 countries, the Netherlands and Norway are the obvious examples to look to regarding natural gas and routes to net-zero. There is also a really interesting project in the city of Leeds, in the north of the UK, to switch to hydrogen for heating in the mid-2020s. This is going to serve 1.5 per cent of the UK population in phase one, so is a significant test. We are already seeing biogas projects, with Ireland being the most interesting place, already injecting biomethane into its gas grid and looking at waste in particular. We will see some of this nibbling away at edges of gas demand from particular end users. The sector has factored in a decline in demand over time and they are unlikely to be massively surprised by what is happening.

Within this context is the proposition that the Russians seem to be airing: that in principle they could put (blue) hydrogen blend into their gas supply in pipelines to Europe, because they think that this would create a premium product for the European market in line with our need to have lower carbon options. In principle the idea is that there would be a commercial advantage for a product that is lower carbon. This may be interesting – but will it happen? It is hard to know how credible this is; for instance, whether the Norwegians have a view on this.

Ultimately it all depends on what EU regulations will look like. If we had CO_2 regulations across the gas infrastructure, including pipelines, which had to comply with targets for declining carbon intensity over time, not only would there be switches to pure biogas or pure hydrogen at a bottom-up level, but there would also be an incentive for transmission system operators to look for a less carbon-intensive supply. For now, the Emissions Trading Scheme (ETS) carbon price has no impact on transmission operators, which is why it is time to think in terms of CO_2 standards throughout the economy.

The gas industry and the Norwegians also have to engage on the long-term destination: net-zero. This means engaging in discussions about how we get there – not just in the 2040s but action in the 2020s. This implies a discussion on the role for biogas and hydrogen, and how we phase them in.

It would also be good if natural gas advocates and lobbyists could be less hostile in their messaging – and some are very hostile – about electrification. It is true that full electrification of the transport system is challenging, but calling it a stupid idea doesn't help to sell gas. Attacking electricity, as happens, is a terrible negative message, and it means no possibility for power and gas to take joint positions on energy transition. You need to be more constructive to have an influence in the EU. It is a shame to say that gas lobbyists – across the whole gas sector – are really bad at this stuff.

[81] IEA (2019), *The Role of Gas in Today's Energy Transitions World Energy Outlook special report*, Fuel report, https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions (accessed 27 Mar. 2020).

Electric vehicles

A phase-out of the ICE is likely to happen fast, not driven by energy policy but by city air pollution policies, linked to a much broader reconfiguration of how we do transport in urban areas. What really matters for emissions outcomes is sharing: lots of individuals in individual vehicles, however smart the cars, whatever fuels they use, is a huge energy burden – lots of people sharing vehicles, public transit or 'Uber buses' is more important.

Norway is a leader in rolling out EVs and related infrastructure. On this, Norway has an important role as demonstrator and first market; even if other countries are not as wealthy as Norway, the fact that somewhere there is a serious EV market does make an impression. It would be good to see Norway doing an outreach programme to other countries: talking about lessons learnt, how things could be done more cheaply, and so on. They could put more thought into public transport and sharing, so EVs become not just something for personal users, and consider what is needed to incentivize sharing and to disincentivize individual vehicles.

Decarbonization is far more complicated for heavy goods vehicles. We have public transport solutions, such as to invest a lot more in railways. But then you have difficulties building large new infrastructure. Meanwhile the gas sector is preparing to compete with oil – they would like to see LNG trucks. An oil-to-gas switch for heavy goods vehicles would be equivalent to a rapid coal-to-gas switch. There is a lot of interest in this in parts of the gas sector, and it could be a very credible policy agenda in the near future.

Follow the money

The Norwegian SWF no longer invests in coal. This shows how powerful the social licence campaigns have been. Of course, this is not sufficient, but it is an interesting symbolic step. However, what we really want is fully green-compatible investment innovation, for all the things that we have to deliver to have a green energy system. Therefore, Norwegian participation in the green bond world is far more exciting than their decision on a coal exit. The Norwegians have been very proactive in talking about how to get big investment flows, about which sustainable finance taxonomy categories can be Paris Agreement compatible. This is a de facto signal about what kind of investment packages are not aligned with the Paris Agreement. Green bonds are a big part of that. Major institutional investors, pension funds, insurance funds and SWFs are fundamental to that conversation in the bond market.

Heavy industry

We are beginning to see a change. Clearly the chemicals and steel sectors can do lots to reduce carbon emissions. Regarding cement, even if 'green' cement exists, we should be using less cement overall. The implications for some industries are more promising than for others; some find decarbonization quite interesting. For example, the paper sector has become interested in demand-side offers in the power market, as a flexibility resource: a nice second business revenue stream for them.

Heavy energy users have made a big shift towards efficiency. Whether this is related to efficiency policies or driven by economic crisis is unclear – the shift seems to correlate to the economic crisis in terms of timing. What you will see eventually is a move to having their own generation and own

consumption and considering energy in their sites as much as they possibly can. BMW in South Africa is apparently heading to 90 per cent own generation in a couple of years. That is partly due to uncertainty on the power grid, but they also want to control their own energy resources, costs, planning and so on. We're likely to see more of that.

Traditional energy will still fuel global economic growth but should be managed with tight emission controls

Adam Sieminski is president of the King Abdullah Petroleum Studies and Research Center (KAPSARC) and senior adviser for the CSIS Energy and National Security Program
(Based on an interview)

Summary

A transition towards cleaner energy sources is under way, while emissions from traditional sources have the potential to be more tightly controlled. In reality, traditional sources of energy will not be phased out rapidly due to the appetite of growing economies outside Europe where there will remain a rising need for oil and natural gas. Hydrocarbon fuels will be in demand for some time to come, but production techniques should be employed that minimize emissions. Norway is in a good position to be a harbinger for that.

Some people think the energy transition means an immediate halt of fossil fuel use but transitioning abruptly away from hydrocarbon fuels is unrealistic. Aiming for a target of net-zero carbon emissions does not preclude the use of such fuels; it just means you have to find some way to manage the carbon. The methods proposed to deal with the carbon are the four 'Rs': Reduce, Re-use, Recycle, Remove. Reduce encompasses energy efficiency, non-biomass renewables and nuclear power. Re-use and recycle refer to techniques such as CCS, carbon sinks, bioenergy and utilization – finding something to do with the CO_2. There are ongoing experiments such as using CO_2 to grow algae that contains oil content, which has a combustible part that can be recycled as a fuel. Remove is about capturing the carbon again either underground or in the air.

To date, attempts to achieve the net-zero emissions goal mainly include reducing the accumulation of CO_2 in the atmosphere through improvements in the 4R elements of a circular economy rather than through some regulatory ban on the use of fossil fuels.

An energy transition is happening, but transitions have always happened. We evolved from wood to coal, and coal to oil and natural gas, and now from oil, gas and coal to nuclear and renewables. The transition at present includes the use of lower-carbon fuels. The speed is linked to how quickly the global economy is growing, and what alternative fuels are available. Technological breakthroughs such as those in batteries would unleash the pickup of electric vehicles.

Future of natural gas

While renewables are the energy source projected to grow the fastest, natural gas is also growing rapidly in all scenarios. Oil is more questionable because of the transition to EVs but likely has a strong role to play in uses that are difficult to substitute, for example in aviation and heavy trucking. Natural gas used in power, in industry, in buildings, especially commercial buildings, and non-combusted use, mainly petrochemicals, means there is still going to be a strong demand for natural gas. However, it is important that its methane emissions are controlled and that this is done well. The large companies are doing a fairly good job at that. During the production process or during transportation, methane is inadvertently leaked unburned into the atmosphere and methane is a very strong GHG.

Flaring gets rid of the methane but does create CO_2 and heat, and is not desirable because it wastes a resource that could be used for economic activity and economic growth.

From a demand standpoint, the analysts at the EIA believe that natural gas is behind growth in electricity; and after renewables, it is the fastest-growing fuel.

On the supply side, in the US, hydraulic fracturing means there is a lot of gas in places like the Marcellus Appalachian gas play in the eastern part of the US and in Oklahoma and Texas that will be processed over the long term. It is worth being wary of precise projection points like 2050 as they are based on continuation of trends and have been proven not to be a good predictor of what actually happens. There has always been a geopolitical event, a weather event, an economic event, or a technological breakthrough like hydraulic fracturing that completely changed the outlook for oil and gas production in the US.

Oil's future economic activity

There is still a need for oil. Even in the most ambitious scenarios of displacement by EVs, you still have a significant amount of oil being produced in 2040 or 2050. From a range of calculations from different analytical groups – the IEA or the EIA or independent groups and oil company scenarios – the lowest demand for oil appears to be 50 or 60 million b/d, instead of 100 million b/d: roughly half the consumption in 2019. Finding 50 million barrels of oil to produce per day still requires a lot of investment.

Natural gas liquids derived from oil for use in petrochemical feedstocks is one of the sources behind the growth of oil demand that will continue even if there is a rapid transition of cars to EVs where the electricity is produced from fuels other than gasoline and diesel. Jet fuel is another major economic area that won't go away. Air traffic is expected to grow and there is no technology in use so far to capture the CO_2, a point that Greta Thunberg has continually reiterated.

It is also possible in some countries that, as their economies develop, the easiest way to get electricity may be using oil. That is generally the case in a lot of places in remote locations; the easiest, fastest way to get electricity is to get a generator, a diesel generator even, and to use oil to produce electricity. If you look at India, for example, the per capita energy consumption is still extremely low. The economy and the population are growing. There is a moral case to be made that the people living in the slums in Mumbai and other cities in India deserve electricity for lighting, for cooking, and especially for refrigeration.

Emissions come from economic output

An OECD study on exported emissions[82] shows that the big emitters – China, India, Russia, Japan – are all big economies. The report tries to link, for example, how much of the fuel use in China is associated with the consumption of final goods in the US. If countries are using steel produced in China, they should take some of the responsibility for the carbon footprint of that steel.

The Norwegian SWF is no longer investing in coal. An interesting idea is whether it could put some investment into cleaner coal production and combustion in places like India and China; engaging rather than disengaging.

[82] OECD (2019), 'Carbon dioxide emissions embodied in international trade', https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (accessed 22 Feb. 2020).

Consider production techniques

In per capita CO_2 emissions, countries with high oil exports like Saudi Arabia and Norway are shown to be high emitters but that is because their populations are small as compared with Brazil, Mexico or Indonesia. Saudi Arabia, as demonstrated by another study,[83] has relatively little carbon intensity because it flares very little of its gas and does not use that much energy in the process of producing oil and gas. So the world might actually be better off if Saudi Arabia was exporting more oil and gas rather than less.

At the next COP negotiations China is likely to reiterate the fact that its per capita use of fossil fuels is very low. However, China needs to clean up; the country has a terrible air pollution problem and they're burning a tremendous amount of coal. They should be using more natural gas and they are trying to do that with gas pipelines from Russia and Kazakhstan, LNG from the US and Australia, and so on. You could almost argue that it would be better to stop burning coal and to burn oil to make their electricity. That's not a recommendation, but it is a fact that the emissions would be lower. But it is good that they are building a lot of renewables and nuclear power plants.

Oil and engine innovation

Either oil use will continue to go up because it is a really convenient fuel but its growth rate will be slower than in the past, or it peaks sometime relatively soon between now and 2030 as other non-carbon fuels come to the fore.

The auto industry seems to be bypassing the hybrid light-duty vehicle in favour of the all-electric model. The case for hybrid vehicles is still a strong one where you have a small gasoline engine that keeps the battery charged up.

The other thing that should not be discounted is the potential for improvements in the internal combustion engine itself. Automotive engineers have still not squeezed out all the horsepower they could get from an engine at higher efficiency. Saudi Aramco have been experimenting with a high compression gasoline engine. It is like a diesel engine but it runs on gasoline instead, so it is clean and the high compression leads to the higher efficiency, meaning less fuel per horsepower that you produce. In some places the internal combustion engines might even face a ban, but this may not actually achieve the desired result.

Cleaner outlook but demand growing

Saudi Arabia for its part has been trying to burn less oil and more natural gas to produce electricity. They have been instituting price reform for electricity and have introduced efficiency standards for things like air conditioners and electric motors that are intended to reduce the growth of how much electricity is needed. The IEA has done a very interesting study of the growth of air conditioning load in places like Asia and the Middle East.[84] The scale is large, and air conditioning might even become necessary in European cities in the summer months.

[83] Garthwaite, J. (2018), 'Stanford study finds stark differences in the carbon-intensity of global oil fields', Stanford News, 30 August 2018, https://news.stanford.edu/2018/08/30/measuring-crude-oils-carbon-footprint/ (accessed 22 Feb. 2020).
[84] IEA (2018), *The Future of Cooling, Opportunities for energy-efficient air conditioning*, May 2018, https://www.iea.org/reports/the-future-of-cooling (accessed 30 Mar. 2020).

In the Middle East region a responsible producer is one that's considered reliable and capable of meeting demand at reasonable prices. However, capping emissions is also a key responsibility. The range of how much carbon is in the crude oil itself is small. Heavy oil has more carbon but the biggest thing that is controllable is how much fuel is used to produce the gas or the oil. Saudi Arabia is really good at that and Norway probably has a pretty good footprint. Stanford University did a study on the carbon footprint of various oil fields and Saudi Arabia's carbon footprint is at the bottom end of the range compared to other countries that produce oil. Norway carries out deep-water drilling, which raises the cost of its oil production but that doesn't necessarily increase how much energy has to be consumed to produce the barrel or the cubic metre. If your production techniques and refineries are in the upper quartile of producers then you're going to be more responsible about minimizing the emissions footprint.

Norway faces a squeeze on oil and gas

A presentation by the Norwegian energy company Equinor on some of the newer oil fields in the Barents Sea showed that there were plans to develop some of the oil there, although it was fairly expensive. The greatest impact on Norwegian oil demand is its production costs relative to its price in the marketplace. Within Norway itself there could be less demand for Norwegian oil if they increase EV deployment by using hydropower. There is also some surplus hydropower that they could use to produce hydrogen for vehicles including ferries and boats.

Natural gas in Norway would still be very interesting for Europe from the standpoint of reducing overall CO_2 emissions.

Given the low cost and abundance of reserves in Russia and its willingness to sell into Europe at competitive prices to keep that market, the transition away from natural gas may not happen in Europe very quickly, if at all.

The reliance on oil and gas in Norway, and in Europe, is not as significant as it is in the rest of the world and what they do there to reduce emissions could be seen as a harbinger of the transition that is likely to occur over time in other countries.

The third generation of aviation offers opportunities for new industries

Paul Stein is chief technology officer at Rolls-Royce
(Based on an interview)

Summary

The best perspective that Rolls-Royce can provide on the matter of decarbonization is on the axis of aviation. The world of aviation is changing; we are at the cusp of the third generation of aviation, driven by the parallel streams of addressing climate change and electrification. This opens up gaps for opportunities in technological innovation and in new industries such as sustainable aviation fuels, of which there are many types. Focusing on Norway, it has a geography leading to a distributed population that would benefit from short-range low- or no-emission aircraft, and is grasping that initiative.

Aviation's answer to climate change

Aviation is intrinsically a global industry, with each country's contribution being important. Aviation in itself is a positive thing, connecting people to one another and the world, and giving access to otherwise hard-to-reach areas. This is particularly the case with Norway's geography, with its fjords and islands. It is net CO_2 emissions that are bad for the environment and, as other industries are doing, we are putting our efforts into tackling that. Aviation at present accounts for 2 per cent of man-made global CO_2 emissions. It is possible to split out a strategy for getting there into three pathways.

The first focuses on fuel efficiency. We have been improving airframe engine combinations by around 1 per cent every year for the past 20 years, but we would like that trajectory to grow more steeply.

The second part of the strategy, which is more radical, is to significantly ramp up the availability of sustainable aviation fuels (SAF). These are fuels that have a net-zero carbon footprint, where no fossil is used in the fuel itself or in the creation of the fuel.

The third pathway is developing disruptive technologies – electrification and possibly the use of hydrogen.

Sustainable aviation fuels and Norway

In the context of Norway, the second pillar presents a better avenue than the first. SAF is a really exciting area, and one that does have significant opportunity for nations that either want to repurpose an oil and gas industry, or want to leap a generation and create a new industry that doesn't exist today.

The Norwegian Ministry of Climate and Environment has already announced a minimum requirement of 0.5 per cent content of advanced biofuel to be mixed with jet fuel sold from 2020.

Sustainable aviation fuels, or in fact any sustainable hydrocarbon, can be derived from three major feedstocks: biomass, organic waste or direct power to liquid. Biomass converts fast-growing plants into fuel by a chemical process. The CO_2 drawn in by them is then returned to the atmosphere.

Organic waste refers to black bag waste, which consists of most things disposed of from households except metals, including plastics, food, packaging and so on. There are a variety of processes around the world that can turn this waste into an aviation fuel. Direct power to liquid (PtL) produces what we refer to as a synthetic fuel. CO_2, a core element in the process, can be either directly captured from the

atmosphere or taken from seawater where it gets dissolved. The process has a high energy cost and so requires a lot of surplus hydropower or other renewable energy. You can use the CO_2 from a gas-fired power plant but the aim is to stop producing any historically buried CO_2.

Norway has seized the initiative with SAF. Quantafuel is a Norwegian company that has developed biomass to liquid (BtL) technology on residues from the Norwegian forestry industry. It struck an agreement to sell this sustainable aviation fuel from its pilot plant to the Norwegian state-owned company Avinor, which operates most of the civil airports in Norway. At the same time, Quantafuel has been developing technology to convert plastic waste into fuel. It opened its first European plant in northern Denmark in autumn 2019. Its pilot plant located in Sonora, Mexico, makes 800 litres of synthetic diesel from every 1,000 kg of plastic waste.

All of these routes offer a potential solution. PtL could present a particularly good path for Norway, assuming that a spare hydropower station with all the costs written off is available, with an economic way to capture CO_2.

Most importantly, there are three principle requirements: it has got to be sustainable, i.e. it does not involve digging up fossil fuels, it is scalable to meet the huge volumes needed for aviation and it has to be compatible – able to be blended with today's fuels and eventually run at 100 per cent in airframe engines.

Electrification

Electrification is already having an impact on our markets, customers and the products we are developing. The move to a more electrical world will be gradual, but ultimately revolutionary, and key to the third generation in aviation. Rolls-Royce has a very special relationship with Norway in this area because we have a key electrical technology business in Trondheim. This used to be a company called Smart Motor – a leading company in making electrical systems for wind farms and the marine industry. We partnered with them to repurpose the business in order to meet the challenging electrical machine requirements of electrical aviation. It is a world-class centre in rotating machines, motors and generators.

At the moment, electrification in aviation will apply to short-range aircraft, those travelling under 1,000 miles. Extremely short-range aircraft, urban air mobility (UAM), and medium-range aircraft, could be transformational and start to connect cities and reduce congestion in them. This will allow a platform for regional aviation from between 200 and 1,000 miles with an aircraft that uses significantly less fuel, and is far less noisy than existing aircraft, with fewer emissions. For both ranges it will be possible to use pure electric propulsion with a powerful battery, or a hybrid electric solution with a battery, an electric motor, and a gas turbine to supply the electric power rather than the thrust.

There is another world of aircraft that are also being developed, including our demonstrator aircraft that we are developing alongside Airbus – called E-Fan X. This is to show that regional hybrid-electric technologies can apply and provide major emission benefits for regional aviation. Norway is producing one of the key components in the E-Fan X programme. This is a very complex programme taking place across a cluster of expert centres around the world; one in Norway, the others in the US, the UK, France, Germany and Singapore.

Last year Rolls-Royce and the Norwegian airline Widerøe, the largest regional airline in Scandinavia, launched a joint research programme on zero-emissions aviation. The programme is part of the airline's ambition to replace and electrify its regional fleet of 30+ planes by 2030. It supports the Norwegian government's goals for emission-free domestic aviation by 2040.

Norway has a particularly special interest in developing this technology because of its unique geography. In the past, it has spent large amounts of money on very deep tunnelling to connect up a significant fraction of its westerly coastline with roads. A zero-emission aircraft, or an aircraft capable of running on sustainable fuels, would be an ideal solution for the country. By laying down 500-metre [very short] runways, Norway would be able to unlock part of its geography, which borders on being inaccessible today.

Hydrogen

The jury is still out on hydrogen as an aviation fuel; however, Norway has been leading the way in terms of using it as a fuel in the marine and automotive industries. It will be a struggle to make the economics of it work as an aviation fuel, to make the distribution systems work and to displace other means of achieving net-zero carbon. But, there are two areas where hydrogen does seem to offer unique benefits. One is in energy storage, where with surplus wind, solar or hydropower, creating and using hydrogen offers a good solution. The second is in countries that have a supply of natural gas to houses. Decarbonizing domestic heating is quite a challenge when it uses piped gas, so many countries including the UK are introducing a hydrogen blend into natural gas to reduce the net CO_2 footprint.

Decarbonization across the economy

Norway has ambitious national climate targets: to reduce GHG emissions by at least 40 per cent by 2030 and to be a low-emission society by 2050.

If a nation state has signed up to a net-zero carbon trajectory by 2050 then it must approach and execute it in a structured way. It needs to look at all the sections of CO_2 emitters that it has in its country – road transport, industry, home, rail, air and sea – and then demand from those industries, strategies to get to those targets by 2050. It then needs to set those requirements into a mechanism by which it puts governance around it. In maritime and aviation, however, this will have to be done as part of a global strategy because planes and ships take off or sail from one place to another place.

The picture gets more complicated when you start looking at supply chains and carbon trading, and the effects of globalization, which is why it is important to connect up with all the supply chains and put measures in place to account for the carbon.

The countries that will cut CO_2 the quickest are the ones that will take each sector independently, and then look at what the trajectory is for net-zero carbon for that sector. For example, the cement industry faces a huge challenge, but people are already starting to develop new chemistries for cement with a far lower CO_2 footprint.

In aviation, there is not a single solution to low-carbon air travel. As outlined here, a combination of improved engine and aircraft efficiency, new technologies and designs, changes to infrastructure (action at airports and in route planning), and sustainable fuels is required to get there. To succeed, a significant portion of that work will require commitment from, and partnership with, suppliers, customers, governments and countries such as Norway.

We might not have all the answers at the moment, but at Rolls-Royce, we are determined to be part of the solution.

Net-zero is achievable by 2050

Lord Adair Turner, chairman of the Energy Transitions Committee
(Based on an interview)

Summary

To avert catastrophic climate change it is crucial to transition to net-zero emissions. We are clearly not on that path at the moment but the goal is technically and economically feasible, and we can be fairly confident of getting there by 2050. As the net-zero target gets teeth, the survival rate for fossil fuels depends on the scope of CCS. Hydrogen will play a major role in the zero-carbon economy. Norway's role will be crucial whichever way this technology develops.

The Energy Transitions Commission (ETC)[85] has produced an illustrative scenario on reaching net-zero.[86] This has oil down 80 per cent from current levels, coal as good as gone, and gas on a global level down by 10 per cent.[87] So gas is the one that survives, and declines more slowly than other elements of the fossil fuel mix. But forecasts for Europe's future gas demand given by oil and gas companies based on gas as a transitional fuel are overstated. Gas will need to decline as the urgency of the energy transition becomes clearer and we will see gas beginning its decline by 2050.

As the net-zero target gets teeth, the survival rate for fossil fuels depends entirely on the scope of CCS. If you are more sceptical about the central role of CCS, then this requires coal to be almost eliminated, oil to be reduced by 70–80 per cent and gas to be no higher than it is at the moment and to have begun its decline. Gas in the power system can be combined with CCS to make it zero carbon. In the residential heat environment, gas can't be made zero carbon. Many countries realize that to get to net-zero, some mix of electrification, biogas or hydrogen is needed.

Hydrogen's role

Hydrogen will play a very major role in the zero-carbon economy. Not so much in cars, which will be primarily battery electric, but in other carriers – short-distance aviation, short-distance shipping and long-distance shipping. Hydrogen can be turned into ammonia by binding with nitrogen, and used as an engine fuel.

Hydrogen is gaining traction as an energy input to large sectors of the economy. Take steel-making: SSAB, the Swedish company, is now committed to switching to hydrogen. Hydrogen in petrochemicals is being looked at. Hydrogen in domestic heating is a possibility in places that already have gas distribution grids. Hydrogen can be an agent in the balancing mechanism within the power system, made from surplus electricity when wind power is in excess of requirements and turned back into electricity when we need it. Add up all those together and the total amount of hydrogen in the economy could go from 63 million tonnes a year today to more than 600 million tonnes by mid-century.

[85] The Energy Transitions Commission (ETC) – a coalition of business, finance and civil society leaders from across the spectrum of energy producing and using industries – supports the objective of limiting global warming ideally to 1.5°C and, at the very least, to well below 2°C.
[86] Energy Transitions Commission (2018), *Mission Possible*. In the illustrative decarbonized power mix, Exhibit 6.2, p. 111, global power demand is 89 per cent met by direct zero-carbon electricity generation (solar, wind, hydro, geothermal, nuclear), with some level of back-up from abated fossil fuels (7 per cent) and biomass (4 per cent), and by a balanced hydrogen production mix – 50 per cent from electrolysis, 47.5 per cent from SMR plus carbon capture, and 2.5 per cent from biomethane reforming. The report states that these illustrative pathways provide a useful indication of the scale at which different technologies should be developed, and of the possible final energy mix and primary energy mix by mid-century.
[87] Ibid.

So what about natural gas? Hydrogen could either replace natural gas or it could create a permanent demand for it. Most likely, it will get rid of natural gas: if we want a carbon-free economy we cannot continue in the long run with burning natural gas in residential homes. Furthermore, the problem of methane leakages is becoming increasingly apparent and methane is a very powerful GHG. That implies over the long-term that natural gas grids, which feed homes, will either be removed entirely and we will go to electric heating or hydrogen will be used.

Across the world now there are companies starting to put hydrogen in the natural gas grids, or are planning to. Engie in France announced that it intends to put about a 10 per cent mix of hydrogen into the gas grid. SNAM, the Italian national grid company, has already started mixing in 5 per cent and is committed to incorporating increasing amounts of hydrogen, either mixed with natural gas or produced from renewable energy. Many experts are talking about gas grids in 2050 that will not be transporting any methane but will be taking hydrogen. That will be both at long-distance transmission from where it is produced to where it is needed in industrial forms but also in local distribution networks. The city of Leeds in the UK is experimenting with turning the whole gas grid over to hydrogen. The use of methane at a distributed level will have to go and be replaced by hydrogen.

However, hydrogen may continue to be produced using methane. There are essentially two ways that we can make hydrogen in a zero-carbon fashion. One is from electrolysis with renewable electricity. Some people call that 'green' hydrogen but it is only really green when we are making it from renewable electricity. The other way is from steam methane reforming where you start with methane (CH_4) and you turn it into hydrogen. You can put CCS on the back of a steam methane reformer (SMR) and therefore make hydrogen zero-carbon. Some people call that 'blue' hydrogen. The SMR plants are typically large production plants, located next to other industrial facilities so that the methane goes directly into production processes next door but the CO_2 still needs capturing. In our ETC report on the future of hydrogen, we did not take a view between the electrolysis route and the steam methane reforming/CCS route.

Norway's role

Norway was the historical centre of electrolysis. Back around 1945, most ammonia fertilizer in the world was made by hydrogen from electrolysis and most of it was produced in Norway. That is why a company like Norway's Yara is a leading fertilizer company and a Norwegian company like Nel is a leading company in electrolyser manufacture.

It later became so cheap to use methane instead, that all of those electrolyser plants were closed and that business disappeared. However, there is a historical lineage of it in Norway and of course Norway is a good place to do electrolysis because it has very cheap renewable electricity in its abundant hydropower. It also has lots of natural gas. The world will need huge amounts of hydrogen. Depending on how different technologies develop, it might be cheaper to make hydrogen by electrolysis based on renewable electricity. It might in some circumstances be cheapest to make it using natural gas and SMR. Norway has both in abundance so whichever route we take to hydrogen production, Norway starts with the natural resource for each route.

It would be good for Europe if it relies as much as possible on Norwegian gas rather than Russian gas. US gas doesn't have much significance for Europe, as in Europe there will always be an advantage for piped gas rather than shipped LNG. Russia will find the energy transition a challenge and that will be somewhat of a drag anchor to global and European agreements.

Even being a responsible gas producer, however, does not justify opening more reserves. The world does not need more gas. The world has lots of gas. Our ETC's focus is on what has to happen to achieve zero carbon, which requires a significant reduction of the role of gas.

Internal combustion engine's future

The ICE will likely be totally phased out by 2050. There will be a very strong tipping point in about four to five years' time when the fall in the cost of batteries will make light-duty electric vehicles competitive upfront. At the moment there is an initial premium upfront but then you save on the cost of fuel. Once the upfront cost is cheaper, which will possibly happen in 2024, there will be a much higher take-off of EV demand than in any of the standard models. It may be constrained initially by insufficient investment in charging infrastructure.

Constraints with battery weight preclude such an advance in uptake in trucks, as is the case for shipping and aviation. These forms of heavy-duty transport will almost certainly account for a rising proportion of emissions over the next 20–30 years. There is scope for significant energy efficiency in these forms of transport and there will be a steady process towards electrification of trucks during the 2020s. One prediction is that by the end of the 2020s, almost all new short-distance distribution vehicles will be battery electric, as will all buses. Long-distance trucks that travel 600–700 km/day will hold out a little longer, but by 2040 most likely there will be a flow replacing them with hydrogen trucks, if not earlier. So by 2050, if we're serious about net-zero, all vehicles need to be electric, either battery electric or fuel cell electric, but it will take us 30 years to do that.

Oil will have a steeper decline than many of the companies are anticipating, and my commission posits it down by 70 per cent or 80 per cent by 2050. As many of the oil companies say, only a small amount of oil demand is light-duty vehicles. Therefore there is a transition away from oil in trucking; and in the petrochemical complex, the impacts are not dramatic. In five years or so, oil demand will be tempered by the switch to electric power in light-duty vehicles. Thereafter we will have some stability and the expectation is that by 2030, oil demand will be roughly where we are at the moment. Then we will have an accelerated decline as the impact of electrification extends into the heavy-duty truck segment and as we begin to find new ways to cut oil demand in petrochemicals.

A small but significant impact

The move away from oil and gas in Norway and Europe is clearly not as important as the need to transition in other parts of the world, which have much bigger populations. By definition Norway has a population that is about 1/250th of China.

But the fact that Europe is committed to zero carbon and is driving towards a zero-carbon economy is very important because it convinces Chinese and Indian policymakers that it is doable, that it is possible to be a rich, developed, zero-carbon economy. As we achieve that there will be both a demonstration effect and an enabling effect through driving forward the technologies. An economic bloc like Europe heading towards a zero-carbon economy will help proliferate new technologies. So although on one level Norway is a minute bit of the world, about 1/1000th of the global population, Norway and the rest of Europe will have a non-trivial impact on whether the rest of the world heads towards a zero-carbon economy as well.

About the Editors

Germana Canzi

Germana is a freelance writer and consultant. She started her career as a journalist at Euromoney, Petroleum Argus and Dow Jones Newswires, before writing for the *Wall Street Journal*. She later worked for NGOs and think-tanks, devising and managing a variety of UK and international research projects, including a high-profile report to support the establishment of the 2009 UK Climate Change Act. She has also worked as a communication consultant to help various organizations boost global media coverage of the Paris Agreement and related issues, such as climate-related risks to the financial system. She holds an MSc from the London School of Economics and a Magna Cum Laude first degree in Political Science from Milan State University.

Amanda Burton

Amanda Burton does freelance work on energy and climate change developments. She has 20 years' experience in the sector, starting with reporting on the energy markets first for Petroleum Argus and subsequently Heren Energy. After a freelance assignment on energy developments in India, she took an MSc in Environmental Technology from Imperial College. She has since worked on investment opportunities in renewable energy for the European Wind Energy Association, as a policy officer and as a senior research analyst for Energy Intelligence Group and was later a research manager for Interfax Global Energy Services.

About the Interviewees

Rainer Baake

Rainer Baake is an expert on energy and climate issues from Germany. An economist by training, he has served for almost 20 years as state secretary for various state and federal governments in Germany. Rainer Baake is one of the key architects of the German 'Energiewende'. In between government positions he has been the national director of an environmental organization and the founding director of the Berlin based think-tank Agora Energiewende. During his career, Rainer Baake has made a significant contribution to the international policy debate on energy transition and climate change. Rainer Baake previously worked as a community organizer in Chicago.

Fatih Birol

Dr Fatih Birol has served as executive director of the IEA since September 2015. He was re-elected in January 2018 for a second four-year term, which began in September 2019. Prior to his nomination as executive director, Dr Birol spent over 20 years at the IEA, rising through the ranks to the position of chief economist responsible for the flagship *World Energy Outlook* publication. Before the IEA, Dr Birol worked at the Organisation of the Petroleum Exporting Countries (OPEC) in Vienna. He earned a BSc degree in power engineering from the Technical University of Istanbul and received an MSc and PhD in energy economics from the Technical University of Vienna.

Mark Campanele

Mark Campanele is the founder of the Carbon Tracker Initiative and conceived the 'unburnable carbon' capital markets thesis. Mark is responsible for management strategy, board matters and developing their capital markets framework analysis. Their goal is to align capital markets with natural ecological limits to growth. Mark has 25 years' experience in sustainable financial markets working for major institutional asset management companies. He co-founded some of the first responsible investment funds at Jupiter Asset Management in 1989 with the Ecology Funds, NPI with Global Care, the AMP Capital Sustainable Future Funds, and Henderson Global Investor's Industries of the Future Funds.

Philip Cunningham

Philip Cunningham graduated in chemical engineering from the University of Manchester in 1991. After work at a local engineering firm he joined Amoco in 1997, which became a career with BP in engineering and operational roles in the UK, Far East, and Central Asia. Phil returned to Southeast Asia in 2010 with technical and managerial roles for Premier Oil before joining Maersk Oil to support their COO and executive office in Copenhagen in 2014. He became managing director for Maersk Oil Kazakhstan for 4 years after that, transferring to Stavanger in 2019 to head Total's Norway business after Total acquired Maersk Oil.

Dominic Emery

Dr Dominic Emery was appointed chief of staff for BP in February 2020. Prior to this he was vice president responsible for long-term planning and strategic activities for the company. He has worked for BP since 1986, leading gas and power business development in the UK and northern Europe and

running power and utility assets at BP sites. He was chief development officer for the alternative energy business, with responsibility for BP's corporate venture capital investments and is a member of the board of the Extractive Industries Transparency Initiative.

Tomas Kåberger

Dr Tomas Kåberger is affiliate professor at Chalmers University of Technology in Göteborg and serves as executive board chairman of the Renewable Energy Institute in Tokyo and a senior adviser to GEIDCO in Beijing. He is a member of the Swedish Climate Policy Council and on the board of the energy company Vattenfall. He is a member of the Royal Swedish Academy of Engineering Sciences and The Swedish Association of Energy Economists. He has served as a member of the government energy commission launching the re-regulated electricity market in Sweden and as director-general of the Swedish Energy Agency.

Zoë Knight

Zoë Knight is a managing director and group head of the HSBC Centre of Sustainable Finance. She joined HSBC in 2010 and previously led the Climate Change Centre of Excellence within Global Research, having been an investment analyst at global financial institutions since 1997. For 10 years she focused on equity strategy, before focusing on socially responsible investing. Zoë is a commissioner on the Energy Transition Commission and is a member of the WEF Global Future Council on Energy. She also sits on the Board of the World Energy Council UK and holds a BSc (Hons) in economics from the University of Bath.

Michael Liebreich

Michael Liebreich is chairman and CEO of Liebreich Associates, through which he provides advisory services and speaks on clean energy and transportation, smart infrastructure, technology, climate finance and sustainable development. He founded and is senior contributor to BloombergNEF and a visiting professor at Imperial College's Energy Futures Lab. He is also a senior adviser to Sustainable Development Capital Ltd and a member of Equinor's International Advisory Group.

Andris Piebalgs

Andris Piebalgs is a professor at the Florence School of Regulation in the European University Institute. His work now focuses on the decarbonization challenges in the energy sector. He is the chairman of the Board of Appeal of ACER. Before coming to FSR Andris Piebalgs was EU commissioner for Energy and EU commissioner for development. He is a key figure in the formation of the EU's renewable energy and energy efficiency policies and made a crucial impact in the creation of the European energy market. He has been a prominent Latvian politician and diplomat, and was instrumental in Latvia's accession to the EU.

Kristian Ruby

Kristian Ruby is a widely recognized expert with a strong communication profile and extensive experience in political affairs. He joined Eurelectric from Wind Europe, where he served as chief policy officer and was in charge of development and implementation of the political strategy. Prior to this, Ruby worked as a journalist and served seven years as a public servant in the Danish Ministries of Environment, and Climate and Energy and in the European Commission in the cabinet of the former climate action chief, Connie Hedegaard. Kristian holds a master's degree in history and international development.

Pierre Schellekens

Pierre Schellekens was deputy head of cabinet for Energy and Climate Change Commissioner Arias Canete. Before this he was the head of communication unit – DG AGRI and the head of the EU Commission representation in Sweden between 2009 and 2014. He joined the European Commission in 1996 and has most recently been working in DG Maritime Affairs, as head of unit for maritime policy in the Baltic and North Sea. Prior to this, Mr Schellekens was the deputy head of cabinet of the Commissioner for Environment Stavros Dimas from 2004 to 2008. This comprised general coordination of environmental files, and responsibility for climate change (international negotiations and the climate and energy package) as well as contacts with Council and the European Parliament. During the first part of 2004, Mr Schellekens was a member of the cabinet of Margot Wallström, then responsible for environment.

Jesse Scott

Jesse Scott is a specialist in clean energy policy. She is senior adviser at think-tank and policy institute Agora Energiewende in Berlin. During 2015–17 she worked at the IEA where she was project leader of the agency's flagship 2017 report *Digitalization & Energy* and worked closely with Executive Director Fatih Birol. Jesse has over 15 years' experience leading major European Union policy campaigns and multi-actor coalitions in Brussels, including for the reform of the EU ETS carbon market, which turned around the failing EU carbon price from €2 in 2011. She was previously deputy secretary general at the EU natural gas sector association Eurogas, head of environment at the EU electricity sector association Eurelectric, head of Brussels office for environment NGO E3G, and worked at law firm White & Case LLP and as adviser to the Italian prime minister and to the Polish foreign minister.

Adam Sieminski

Adam Sieminski is president of the King Abdullah Petroleum Studies and Research Center (KAPSARC), an independent, non-profit, research think-tank located in Riyadh. Prior to joining KAPSARC in 2018, Mr Sieminski held the Schlesinger chair at the Center for Strategic and International Studies (CSIS). Sieminski served as administrator of the US Energy Information Administration (EIA) in 2012–16. He was previously Deutsche Bank's chief energy economist and integrated oil company analyst. He is a member of the International Association for Energy Economics (IAEE), a senior fellow of the US Association for Energy Economics (USAEE). He holds the Chartered Financial Analyst (CFA) designation and earned both an undergraduate degree in civil engineering and a master's degree in public administration from Cornell University.

Paul Stein

Paul Stein was appointed to the Rolls-Royce Executive Leadership Team as chief technology officer in April 2017, accountable for the company's technology investment and for ensuring close alignment with business strategy, to maintain a competitive edge. He joined Rolls-Royce in 2010 as chief scientific officer and for two years concurrently acted as the engineering and technology director for the company's nuclear business. Immediately prior to joining Rolls-Royce Paul was director-general, science and technology, at the UK Ministry of Defence. Paul holds an electrical and electronic engineering degree from King's College, London. He is a fellow of the Royal Academy of Engineering, the Royal Aeronautical Society and the Institution of Engineering and Technology.

Lord Adair Turner

Lord Turner chairs the Energy Transitions Commission, a global coalition working out pathways to limit global warming to below 2˚C by 2040. He chaired the Institute for New Economic Thinking where he remains a senior fellow. He is chairman of insurer group Chubb Europe, and on the Advisory Board of Shanghai Envision Energy group. Among his public policy roles, he chaired the UK's Financial Services Authority (2008–13); was director-general of the Confederation of British Industry (1995–2000); chaired the Low Pay Commission (2002–06); the Pensions Commission (2003–06); and the Climate Change Committee (2008–12). He became an independent member of the House of Lords in 2006. He writes regularly for Project Syndicate, and in 2015 published *Between Debt and the Devil* (Princeton).

About the Authors

Antony Froggatt

Antony Froggatt joined Chatham House in 2007 and is a senior research fellow in the Energy, Environment and Resources Programme. He studied energy and environmental policy at the University of Westminster and the Science Policy Research Unit at Sussex University and is currently an associate member of the Energy Policy Group at Exeter University. At Chatham House, he specializes in global electricity policy and the public understanding of climate change. He has worked as an independent consultant for 20 years with environmental groups, academics and public bodies in Europe and Asia. His most recent research projects were on the energy and climate policy implications of Brexit and on the technological and policy transformation of the power sector.

Paul Stevens

Paul Stevens is a Distinguished Fellow at Chatham House and is now Professor Emeritus at the University of Dundee. He is also a Distinguished Fellow at the Institute of Energy Economics Japan. He was the recipient of the 2009 OPEC Award for services to the international oil industry. He has taught at various universities including the American University of Beirut, in Lebanon (1973–79); the University of Surrey (1979–93); and the Centre for Energy, Petroleum and Mineral Law and Policy at the University of Dundee (1993–2008). He has degrees from the University of Cambridge and the School of Oriental and African Studies.

Siân Bradley

Siân Bradley is a senior research fellow in the Energy, Environment and Resources (EER) Programme at Chatham House, where she works on climate change and energy transition. Her research focuses on climate risk and low-carbon transition in resource-driven economies, the realignment of development assistance with the Paris Agreement, and global energy and resource trade and governance. Prior to joining Chatham House in 2014, she worked as an analyst for a risk consultancy firm, advising companies and international organizations on environmental, social and governance (ESG) issues. She holds an MSc in international relations from the London School of Economics (LSE).

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The Royal Institute of International Affairs
Chatham House
10 St James's Square, London SW1Y 4LE
T +44 (0)20 7957 5700 F +44 (0)20 7957 5710
contact@chathamhouse.org www.chathamhouse.org

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