Conquering carbon dioxide: What would it take to decarbonise the global economy?

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Lots of clean electricity and a revolutionary shift towards the lightest gas, writes Henry Tricks

FROM BEHIND the wheel of a self-driving electric Tesla model S, gliding amid the forests and fjords of Norway, the future of the planet looks pretty good. It almost feels as if you are on the road, hands-free, to a post-fossil-fuel future. Virtually all of Norway's electricity is emissions-free. It comes from hydropower delivered by cascading waterfalls, dams and rivers that run so close to the roads that you can almost run your fingers through them. There are so many fast-charging stations that you are unlikely to get stranded. Teslas have become so run-of-the-mill in Oslo that it is not unusual to see them spattered with mud, their seats matted with dog hair.

When your destination is Rjukan, three hours west of Oslo, which in the early 20th century was one of the world's biggest power plants, alternatives to fossil fuels look even more achievable. This is where one of the best potential zero-carbon options, hydrogen, was produced by hydroelectricity as far back as 1928. Cars powered by hydrogen fuel cells have now started to appear on Norway's streets, even though there may be much better uses of the gas than powering vehicles over short distances. A Hyundai Nexo, owned by Nel, a Norwegian hydrogen company that traces its roots back to Rjukan, carries a message on its rear window: "Thanks for the ride, dinosaurs! We'll take it from here." That could be the motto for the age of decarbonisation. Or it could be extreme hyperbole.

Alongside China, Norway has helped supercharge demand for electric vehicles, but it could afford to finance the tax breaks and other incentives because of the immense wealth it derives from oil and gas. Hydrocarbons produced by the state energy company, Equinor, generated 310m tonnes of greenhouse gases in 2017. That was almost as much as the total carbon dioxide (CO_2) belched out by Britain, a country with 12 times Norway's population.

Torn in much the same fashion between a desire to tackle global warming and a dependence on fossil fuels, the world is moving far too slowly to decarbonise its energy system. Acting on the promises made under the 2015 Paris agreement on climate change could see the world on a path to global warming of 3ºC above pre-industrial levels by the end of this century, rather than the 1.5-2ºC countries agreed to strive for. To stabilise global temperatures, humans must be putting no more CO_2 into the atmosphere than they are taking out by about mid-century.

Coming clean

Renewables are advancing, absorbing twice as much investment for power generation as coal, gas, oil and nuclear combined last year. Sales of electric vehicles (EVs) are also gaining momentum. According to Bloomberg New Energy Finance, a clean-energy consultancy, it took 17 months, from mid-2014 to 2016, for the global number of passenger EVs to rise from 1m to 2m. It took just six months this year for them to go from 3m to 4m.

Yet last year the global energy system still derived 85% of its oomph from fossil fuels, and the International Energy Agency (IEA), a forecaster, expects global CO_2 emissions to reach a new

record this year. In order to mitigate the impact of global warming and reduce the air pollution that does serious harm to physical and mental health around the world, the immediate task is to encourage the spread of zero-carbon ("clean") electricity and battery storage. By some estimates, power supply needs to increase fourfold over the next 30 years. To produce this electricity will require a huge increase in renewables, as well as nuclear power (more likely in the developing than developed world), as well as the use of fossil fuels with carbon capture and storage (CCS). And that is just what specialists call the "easy" part.

Decarbonising parts of the economy where electricity and lithium-ion batteries cannot be easily used, such as heavy transport, heating and industry, will be much harder. In 2014 (the latest year for which figures are available) these "hard-to-abate" sectors produced about 15bn tonnes of CO_2, or 41% of the total, compared with 13.6bn tonnes for the entire power sector (see chart). The biggest industrial emitters are cement, steel and chemicals.

In order to limit global warming to less than 2°C, total emissions from global energy use across industry alone will have to be 50-80% lower by 2050 than they are now, and as much as 75-90% lower if the rise in temperatures is to be capped at 1.5ºC, according to the Intergovernmental Panel on Climate Change (IPCC), a UN-backed body of experts. Even then, over the course of the century hundreds of billions of tonnes of CO_2 will need to be extracted from the atmosphere, in what are called "negative emissions".

It is an historic undertaking. In the 200 years from the start of the coal age to 1970, the burning of fossil fuels, flaring and cement-making produced 420bn tonnes of greenhouse gases, mostly CO_2, or about 1,200 times the weight of every person on the planet today. Between 1970 and 2011, the amount tripled to 1.3trn tonnes.

CO_2 is invisible and odourless, so it is harder to visualise the effects of all of this than for more tangible scourges like sulphur and nitrogen oxides, which cause acid rain. Yet the quantities belched out are staggering. The steel and cement industries each produce more CO_2 than any country except China and the United States. For every tonne of cement produced, almost three-quarters of a tonne of CO_2 seeps into the atmosphere. Cars and trucks are an even bigger burden on the climate; and knowing how much you produce when you fly can ruin the joy of taking off in an aeroplane. This report focuses on energy-related emissions, not greenhouse gases emitted by agriculture, forestry and other land use. The latter account for about a quarter of total emissions.

Where were you while we were getting hydrogen?

Steven Davis of the University of California, Irvine, has led a team of researchers in mapping out what a net-zero-emissions energy system would look like, using a set of already available technologies that he describes as "fairly simple and finite". Besides electricity and batteries, they include hydrogen and ammonia, biofuels, synthetic fuels, CCS, and removal of carbon from the atmosphere. They can have many end uses. Hydrogen could have a role in light and heavy transport, heating, steelmaking and synthetic fuels for jet aircraft. CCS could be used in heating and cement-making.

Each of them has its pros and cons. There are obstacles to making, moving and using hydrogen on a large scale. Biofuels such as ethanol are already blended with hydrocarbons in fuels in places such as Brazil and America, but energy crops compete with the food industry for land, and their cultivation also produces greenhouse gases. Emission-free synthetic fuels rely on lots of hydrogen and carbon monoxide to produce surrogate hydrocarbons, so their development hinges on low-cost supplies of those two gases. CCS, as Mr Davis puts it, elicits a "collective groan" from environmentalists, who see it as life support for the fossil-fuel industry. But it is hard to imagine decarbonisation of industries like cement without capturing the CO_2 emitted in flue gases.

Some are much closer to commercialisation than others. Those working on decarbonising the energy system have an approximate time frame for their endeavours. They say 2025-35 could see the emergence of battery and hydrogen-powered long-distance lorries, and hydrogen-fuelled residential heating. In the 2030s, synthetic hydrocarbons may be developed for ships and planes. In the 2040s, CCS and hydrogen could be applied at vast scale in industry. By the 2050s there would be full-scale carbon removal, either by massive reforestation or direct capture from the air.

All this may seem pie in the sky if you live in Africa, or another impoverished region, where the main priority is to satisfy existing energy demand. It will hinge crucially on what government mandates and tax incentives are in place to encourage the shift.

Still, this report will argue that the obstacles to decarbonisation of the energy sector are not insurmountable. What is more, they could bring economic benefits. The IPCC estimates that, between 2016 and 2035, the annual cost of keeping the rise in temperature to 1.5ºC would be about $2.4trn, or roughly 2.5% of world GDP. Last year total energy investment was $1.6trn, mostly in coal, oil and gas. Adair Turner, chairman of the Energy Transitions Commission (ETC), a global body, says the additional cost per year of running the hard-to-abate industries with net-zero emissions would be $1.2trn in 2050. "You can be absolutely terrified [by the amount]. But if you could go back to building railways in 1850, I'm willing to bet you would also terrify yourself."

Moreover, none of the technologies involved is new; and, unlike fossil fuels, the more they are used, the more their costs fall, providing an incentive to use them across as many industries as possible. Hydrogen could be the most promising, because it is the best complement to mass electrification and could also be used in heavy transport, heating and industry.

In a report, the ETC says that to achieve net-zero CO_2 emissions, global hydrogen production needs to rise from about 60m tonnes a year today to 500m-700m tonnes by mid-century, even without assuming there will be many hydrogen fuel-cell cars. That sounds ambitious but the interest in hydrogen is growing fast. Membership of the Hydrogen Council, a forum made up of global chemical, car and oil companies started in 2017, has quadrupled in 18 months. Francis O'Sullivan, head of research at the MIT Energy Initiative, says: "Battery storage may feel like a headline act in the transition. But ultimately it will play second fiddle to hydrogen."

To make the hydrogen cleanly, most of it will have to come from electrolysis of water, which today accounts for only 5% of hydrogen production (the rest comes from "steam reforming" of

fossil fuels). That will require vast quantities of low-cost, zero-carbon electricity. Making that available, along with batteries to electrify cars, is one of the most pressing priorities in the coming decade.