ESR NEWSLETTER
December 2020

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Special report Business and climate change — The Economist September 19th 2020

Technology

Green machines

A wave of innovation may help tackle climate change

"WE LOOKED for big industries that exist on inertia," recalls Kathy Hannun. She used to work at Google X, the tech giant's moon-shot division. Heating with fossil fuels was an example of an industry ripe for disruption. The distribution system is convoluted, argues Ms Hannun. Natural gas or fuel oil is taken from the ground, shipped across the world and piped into houses. But a huge amount of latent energy exists around us. In 2017 she founded Dandelion Energy, an attempt to harness that power by selling heat pumps, refrigerator-sized boxes that take heat from the air or the ground to warm a building. Orders grew fourfold in 2018 and 2019. Further expansion is likely. Last year 20m households purchased heat pumps. To stop the planet from overheating, the IEA reckons that number has to triple by 2030.

Yet that rate of growth may be optimistic without a push from regulators. Heat pumps face similar obstacles to other emissions-reducing measures. The upfront costs are large: some heat pumps cost over $15,000. And installation is disruptive, often taking days or weeks. Heat pumps are just the start: across the world entrepreneurs are busily inventing new technologies and tinkering with old ones. The opportunity is vast. The $1.2trn that the IEA says is needed for energy-system investment represents a 60% increase on current spending. But precisely which technologies and which firms flourish will depend to a large degree on getting the right pattern of regulation, subsidy and pricing.

This is best seen by considering four different places where greenery meets technological change. First comes the adaptation industry, which will thrive regardless, because of the physical risks linked to climate change. For the second, greater energy efficiency, to take off, something of a nudge from regulators will be required. The third, renewables, may need even more help, although prices have been tumbling. And the fourth, carbon removal, is nascent. It is still too expensive to remove a tonne of CO_2 from the air and store it safely; the industry must have a high carbon price if it is to be competitive.

Start with adaptation. Even with a sharp, sustained fall in emissions, the weather is certain to keep getting worse. So governments and companies alike will have to spend more on adaptive measures, such as seawalls. The Global Commission on Adaptation, an intergovernmental body, reckons that to avoid the worst consequences of climate change, $180bn of annual investment is needed for a decade.

Infrastructure firms have seen climate-related work pick up since the Paris agreement in 2015. AECOM, an engineering firm, is designing measures to stop floods engulfing Route 37, a coastal road in California, including raising it 150cm (five feet) off the ground. The payback for such measures is high. Often a dollar invested in adaptation yields ten dollars in avoided damage, says David Viner of Mott MacDonald, another engineering firm.

Farming is adapting too. Bayer and Syngenta, two agricultural firms, are developing more resilient crops. A strain of shorter, sturdier corn is being tested by Bayer in Mexico. It needs less water and is less likely to be flattened by a storm. Worse weather will call for more varieties of new seeds. Bayer has spent $100m on a high-tech greenhouse in Arizona. In an automated process, a laser slices off a tiny fragment from an individual seed. The slice's DNA is analysed while the rest is planted and grows normally. That allows researchers to track the genetic make-up of plants and find out which genes improve the likelihood of storm-survival. Along with other innovations, the process cuts the time when new seed varieties must be tested from two or three years to one.

Next come improvements in energy efficiency. In a scenario where the 2°C goal is met, greater efficiency could cut emissions by seven gigatonnes by 2040, about the same amount as renewables, according to the IEA. Up to a point, it makes economic sense as well. Analysts reckon that most companies can cut their emissions by 10-20% through greater energy efficiency and, in doing so, bring down their costs. That should be a boon for firms that pursue such goals—and those that sell them advice.

Schneider Electric, a French firm, is in the second group. Jean-Pascal Tricoire, its boss, says 70% of its revenue comes from green ▸▸

Falling

Electricity generation, global weighted-average cost
$ per kWh, 2018 prices

Sources: International Renewable Energy Agency; BloombergNEF

projects or energy-efficiency ones. Recently it ramped up a distribution centre for Lidl, a supermarket chain, in Finland. Rooftop solar panels, a microgrid and a smart energy-monitoring system were installed. Sensors cut wasted energy by switching off idle lights and machines. Excess heating from air-conditioning is stored for use when the weather cools. The system is so efficient that the surplus heat provides hot water for 500-odd homes nearby. Energy costs fell by 70%; carbon emissions by 40%.

Because decarbonising transport is so pricey, the potential efficiency gains are big. The Energy Transitions Commission (ETC), a global body, estimates that 35-40% of energy use in transport could be profitably saved. Digitisation is one way forward. Scania says the average lorry is only 60% full. One study found that 45 trucks visited a single department store in Copenhagen every day, whereas four fully laden ones could have delivered the same load. The firm is now planning to use GPS-trackers to cut unnecessary journeys. Similar gains can be made at sea. Ships often sail full-steam to get to port, then queue for hours or days before they can moor. PortXchange, a data company, cuts fuel use by alerting boats to port queues in real time.

A renewable boom

The third area is renewables. In much of the world they are now cheaper than natural gas thanks to plummeting prices. More progress can be expected. Heliatek, a German firm, makes ultra-thin panels that can be printed onto flexible plastic. GE Renewable Energy, an engineering firm, is testing wind turbines as big as the Eiffel Tower. That is good news because a vast increase in renewable electricity will be needed. Adair Turner, chairman of the ETC, says decarbonising the economy will involve a threefold jump from 25 terawatt-hours today to 90 or so by 2050.

Because sunshine and wind are intermittent, better ways of storing energy are needed. Hydrogen and batteries are the frontrunners. Both have drawbacks. For a given volume, they store less energy than fossil fuels. Building the infrastructure to support them is a huge task, which requires much co-ordination (what low-carbon fuels should be available at petrol stations?). And even though the prices of both are falling, costs remain high.

One way to boost the amount of battery storage is through electric vehicles, which seem sure to spread. Because cars are parked 95% of the time, at any one moment a hefty amount of battery power is sitting idle. Enel X, the Italian utility's innovation arm, is experimenting at its headquarters in Rome. Electric vehicles belonging to a dozen or so employees are hooked up to the grid using special two-way charging points. They provide about one megawatt of electricity, which is enough to serve hundreds of homes. "Electric cars for us are batteries with wheels," says Eliano Russo, of Enel X.

Hydrogen is another form of storage. A recent report by BloombergNEF, a consultancy, finds that renewable hydrogen could cut up to 34% of global greenhouse-gas emissions from fossil fuels and industry. To do this would require $150bn in subsidies by 2030. That would bring prices down to a level competitive with natural gas in most of the world. Today most of the commercially produced stuff creates CO_2 as a by-product. However "green" hydrogen can be made by splitting water into hydrogen and oxygen with clean power. It could then be pumped into existing pipelines and power natural-gas boilers. It could be used to cut emissions from many industrial processes, such as making ammonia. Or it could be stored in fuel cells and used to power vehicles. China is pursuing this idea. It spent a reported $12bn on fuel-cell subsidies in 2018. The share price of PowerCell, a Swedish outfit that makes hydrogen fuel cells, has doubled in the past year. In the same period Canada's Ballard Power has seen its share price triple, while that of America's Plug Power has risen fivefold.

The fourth idea is carbon removal. Between 100bn and 11tn tonnes of CO_2 will have to be taken out of the atmosphere by 2100 if the 2°C goal is to be reached, according to a range of scenarios examined by the UN's Intergovernmental Panel on Climate Change. The median value was 730bn tonnes. If carbon removal costs around $100 per tonne of CO_2, an optimistic estimate for the foreseeable future, then annual global spending on carbon removals could easily reach $900bn in decades to come.

Many startups are trying to harness nature's own carbon sequestration. One is Indigo Ag. Last June it launched a platform to pay farmers for absorbing more CO_2 in their land. Soil is a natural store of carbon: the organic carbon into which plants transform the atmospheric CO_2 is stored there in abundance. Changes in agricultural techniques, such as reduced deep-ploughing, help keep carbon in the soil. Indigo Ag's first step is to measure the carbon content of soil. It uses an algorithm to crunch reams of data, from satellite imagery to information from tractor-based sensors, and generate estimates with 85% accuracy. Farmers who successfully use carbon-absorbing approaches will be paid for each additional tonne of CO_2 sequestered. The firm sells the offset, at around $15-20 per tonne, with a mark-up for its trouble.

That may sound cheap, but it comes with risks. One is how securely the carbon is stored. A heavy storm could release some of it. An alternative source of negative emissions is machines or "direct-air capture" (DAC). Climeworks, a company based in Zurich, makes smart-car sized DAC machines which contain a fan drawing air through a filter, a bit like a sponge. Once saturated, the filter is heated and carbon is captured. Today it costs $600-800 per tonne of CO_2 removed. Two other firms pioneering DAC technology, Carbon Engineering and Global Thermostat, also have price points firms deem too high to be commercially viable. And the scale is still too small. But a new facility that Climeworks is planning will suck 4,000 tonnes of CO_2 out of the air each year, equivalent to the annual footprint of 600 Europeans.

That plant will be built with Carbfix, an Icelandic startup. Its researchers are trying to accelerate mineralisation, a natural process whereby CO_2 is transformed into rock, over hundreds of years. Captured from a geothermal power plant or through DAC, CO_2 is dissolved in water and injected into rock formations 500 metres underground. After two years, the carbon becomes rock and is stored in a stable form. Storage costs about $25 per tonne. The next step is to take the process offshore, storing carbon under the ocean. Seabeds are often made of deposits of basalt, the type of rock required. A pilot project will start in the next few years. If successful, it will create almost "limitless storage", says Edda Sif Aradottir, Carbfix's boss. The world may need it. ■

This material could be a game-changer for solar power

From an article by Adrian Lydon, CNN Business, October 14, 2020

A group of materials called perovskites are being used to create the next generation of solar panels, which could eventually be twice as efficient as current models, and flexible enough to wrap around entire buildings.

The first solar cell capable of powering everyday electrical equipment was made in the 1950s at Bell Labs in New Jersey. Back then the silicon-based panels were hugely expensive and converted just 6% of sunlight into electricity. Since then, costs have come down dramatically and today's silicon solar cells can turn up to 22% of sunlight into power. But they're nearly maxed out in terms of efficiency. Now, perovskites offer the potential for dramatic increases in power output, and they could ultimately replace silicon altogether.

Researchers at Oxford PV, a company spun out of the University of Oxford, made a major breakthrough in 2018. By coating silicon with perovskite they achieved 28% efficiency. The company believes it can eventually reach 40%, or higher.

Improved solar cell efficiency will enable installations to pump out more power with fewer panels, reducing costs, and the amount of land, labour and equipment needed to operate them.

Solar potential

Perovskite was discovered in 1839. Oxford PV uses a synthetic version, made from inexpensive materials that are abundant in the Earth's crust, while other companies use variations of the original mineral, collectively called perovskites.

As well as improved solar efficiency, they work better than silicon in the shade, on cloudy days or even indoors. Perovskites can be printed using an inkjet printer and can be as thin as wallpaper. Oxford PV hopes perovskite will eventually replace silicon entirely.

Oxford PV aims to begin producing cells made from perovskite on silicon early next year at a new purpose-built factory in Brandenburg, Germany. It estimates that panels made from the cells could save homeowners up to $1,000 on the purchase and installation of the average solar system.

Other companies working with perovskite include Warsaw-based Saule Technologies, which has secured funding of €10 million from Polish photovoltaics company Columbus Energy.

Last month, Saule Technologies' new factory in Warsaw began printing perovskite solar cells using inkjet printers. Early next year, it will start supplying Swedish construction company Skanska Group, which says it wants to be the first developer to attach printed solar cells to the façade of a building on a commercial scale.

Decent living for all does not have to cost the Earth

Source: University of Leeds, UK, Leeds Alumni News, October 2020

Global energy consumption in 2050 could be reduced to the levels of the 1960s and still provide a decent standard of living for a population three times larger, according to a new study. The study, led by the University, has estimated the energy resource needed for everyone to be provided decent living standards in 2050 – meaning all their basic human needs such as shelter, mobility, food and hygiene are met, while also having access to modern, high quality healthcare, education and information technology.

The findings, published in in the journal Global Environmental Change, reveal that decent living standards could be provided to the entire global population of 10 billion that is expected to be reached by 2050, for less than 40% of today's global energy. This is roughly 25% of that forecast by the International Energy Agency if current trends continue. This level of global energy consumption is roughly the same as that during the 1960s, when the population was only three billion.

The authors emphasise that achieving this would require sweeping changes in current consumption, widespread deployment of advanced technologies, and the elimination of mass global inequalities. However, not only do the findings show that the energy required to provide a decent living could likely be met entirely by clean sources, but it also offers a firm rebuttal to reactive claims that reducing global consumption to sustainable levels requires an end to modern comforts and a 'return to the dark ages'.

The study calculated minimum final energy requirements, both direct and indirect, to provide decent living standards. Final energy is that delivered to the consumer's door, for example, heating, electricity or the petrol that goes into a car, rather than the energy embedded in fuels themselves – much of which is lost at power stations in the case of fossil fuels.

The team built a final energy-model, which builds upon a list of basic material needs that underpin human well-being previously developed by Narasimha Rao and Jihoon Min.

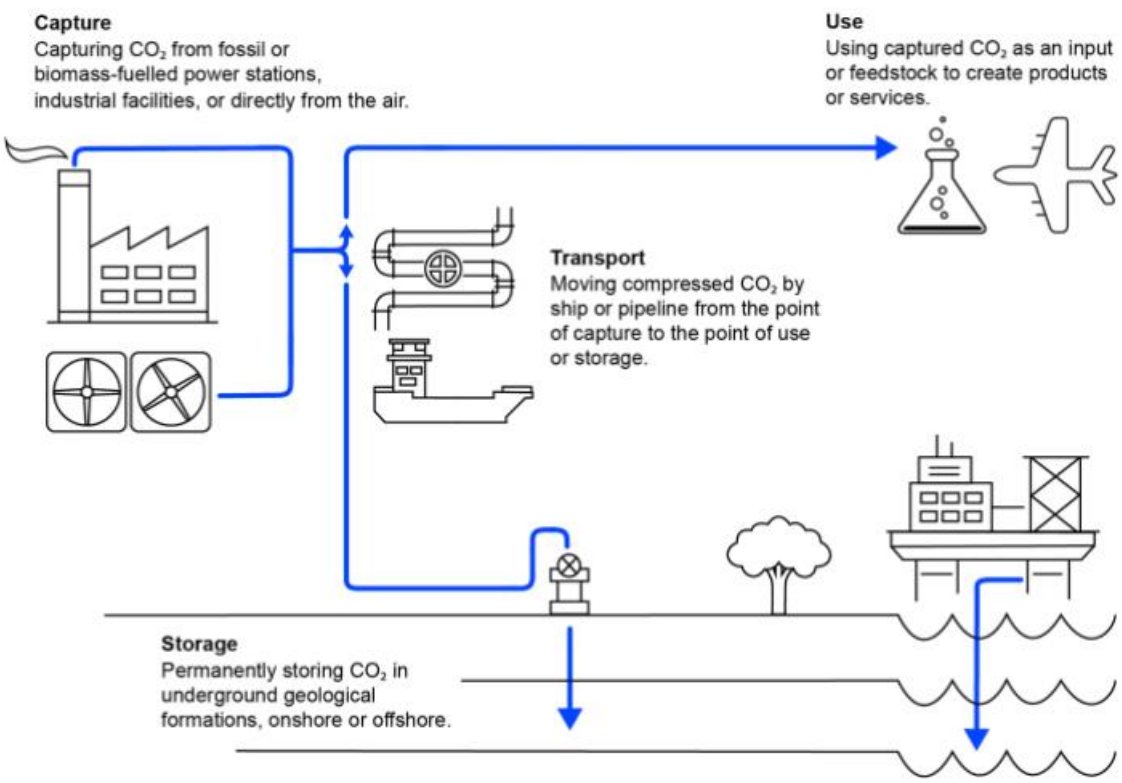
The study compared current final energy consumption across 119 countries to the estimates of final energy needed for decent living and found the vast majority of countries are living in significant surplus. In countries that are today's highest per-capita consumers, energy cuts of nearly 95% are possible while still providing decent living standards to all.

Further information: The paper Providing "Decent Living with Minimum Energy: A Global Scenario" was published in *Global Environmental Change* on 29 September 2020. For additional information contact University of Leeds press officer a.harrison@leeds.ac.uk.

Carbon Capture, Usage and Storage

The International Energy Agency (IEA) *Energy Technology Perspectives 2020* report highlights the central role that CCUS must play as one of four key pillars of global energy transitions alongside renewables-based electrification, bioenergy and hydrogen (IEA, 2020a). CCUS can reduce emissions from large stationary sources, essentially power stations and large industrial plants, in a variety of ways, as well as generate negative emissions, by combining it with bioenergy (BECCS) or through direct air capture (DAC). Carbon removal technologies will almost certainly be required due to the practical and technical difficulties in eliminating emissions in certain sectors, including some types of industry (notably steel, chemicals and cement), aviation, road freight and maritime shipping.

Another key attraction of CO_2 capture technology is that it can be retrofitted to existing plants, many of which were built recently and could operate for decades to come. CCUS can also provide a least-cost pathway for producing low-carbon hydrogen based on natural gas or coal in countries with low-cost resources. Captured CO_2 can be used in a number of ways, including to produce clean aviation fuels.



CCUS technologies can provide a means of removing CO_2 from the atmosphere, i.e. “negative emissions”, to offset emissions from sectors where reaching zero emissions may not be not economically or technically feasible. Bioenergy with carbon capture and storage (CCS), or BECCS, involves capturing and

permanently storing CO_2 from processes where biomass (which extracts CO_2 from the atmosphere as it grows) is burned to generate energy. A power station fuelled with biomass and equipped with CCUS is a type of BECCS technology. DAC involves the capture of CO_2 directly from ambient air (as opposed to a point source). The CO_2 can be used, for example as a CO_2 feedstock in synthetic fuels, or it can be permanently stored to achieve negative emissions. These technology-based approaches for carbon removal can complement and supplement nature-based solutions, such as afforestation and reforestation.

Tackling emissions from today's power stations and industrial plants will need to be central to the global clean energy transition. Those assets could generate more than 600 $GtCO_2$– almost two decades' worth of current annual emissions – if they were to operate as they currently do until the end of their technical lives. Together with the committed emissions from other sectors, this would leave virtually no room for any emissions-generating assets in any sector to meet climate goals – an inconceivable prospect as populations and economies around the world continue to grow.

Coal-fired power generation presents a particular challenge. The global coal fleet accounted for almost one-third of global CO_2 emissions in 2019, and 60% of the fleet could still be operating in 2050. Most of the fleet is in the People's Republic of China (hereafter, "China"), where the average plant age is less than 13 years, and in other emerging Asian economies where the average plant age is less than 20 years. Similarly, 40% of current primary steel-making assets could still be operating in 2050 unless retired early.

CCUS is the only alternative to retiring existing power and industrial plants early or repurposing them to operate at lower rates of capacity utilisation or with alternative fuels. Retrofitting CO_2 capture equipment can enable the continued operation of existing plants, as well as associated infrastructure and supply chains, but with significantly reduced emissions. In the power sector, this can contribute to energy security objectives by supporting greater diversity in generation options and the integration of growing shares of variable renewables with flexible dispatchable power. Retrofitting facilities with CCUS can also help to preserve employment and economic prosperity in regions that rely on emissions-intensive industry, while avoiding the economic and social disruption of early retirements.

Meeting net-zero goals requires tackling emissions across all energy sectors, including those that are sometimes labelled as "hard to abate". This includes heavy industry, which accounts for almost 20% of global CO_2 emissions, as well as long-distance modes of transport, including aviation, road freight and maritime shipping. In these sectors, alternatives to fossil fuels are either prohibitively expensive, such as electricity to generate extreme heat, or impractical, such as electric-powered aircraft or tankers.

In practice, some sectors will simply not be able to achieve net-zero emissions without CCUS. Cement production is a prime example: it generates significant

process emissions, as it involves heating limestone (calcium carbonate) to break it down into calcium oxide and CO_2. These process emissions – which are not associated with fossil fuel use – account for around two-thirds of the 2.4 Gt of emissions from global cement production and more than 4% of all energy sector emissions. With no demonstrated alternative way of producing cement, capturing and permanently storing these CO_2 emissions is effectively the only option.

CCUS is also among a limited number of options that can decarbonise long-distance transport, including aviation. A supply of CO_2 is needed to produce synthetic hydrocarbon fuels, which alongside biofuels are the only practical alternative to fossil fuels for long-haul flights due to energy density requirements. Limitations on the availability of sustainable biomass mean that these synthetic fuels will be needed for net-zero emissions; the CO_2 would need to come from bioenergy production or the air to be carbon-neutral.

Hydrogen is a versatile energy carrier that can support the decarbonisation of a range of sectors, including transport, industry, power and buildings (IEA, 2019a). CCUS can facilitate the production of clean hydrogen from natural gas or coal, which are the sources of practically all hydrogen production today, and provide an opportunity to bring low-carbon hydrogen into new markets in the near term at least cost.

Liveable streets': how cities are prioritising people over parking

From an article by Derek Robertson in Rotterdam, Guardian Upside,12 Oct 2020

In Rotterdam's terrace scheme which ended on 1 November, wooden decks replaced parking. At the start of the year, Rotterdam's Witte de Withstraat was a car-choked thoroughfare. During the scheme, cars were banned after 4pm, locals strolled leisurely down the middle of the road and special wooden terraces replaced parking spaces. It's not just bars and restaurants that benefited. MAMA, a contemporary art gallery, installed seating and speakers so passers-by could watch the video installations displayed in their huge windows.

The scheme is part of a phenomenon that has swept the world's cities amid the coronavirus pandemic: parking spots reclaimed for pedestrians. In Rotterdam, the programme allowed businesses to take over the parking spaces directly in front of their building, without a permit. Proprietors could lay their own decks but the municipality provided decks free of charge. The decks were made from reclaimed and repurposed wood. The authorities handled installation and removal. 1,000 were installed across the city.

The reallocation of urban space has become one of Covid-19's most tangible effects on the built environment. Cities are being forced to innovate and the car is bearing the brunt. Car-free days and restrictions in city centre driving are nothing new but councils are looking beyond simple traffic bans to more fundamental redevelopment. They are also introducing ideas that challenge decades of orthodoxy in urban planning and design.

Oakland, California, converted many neighbourhood streets into pop-up “slow streets”, closed to car traffic. In London, the mayor, Sadiq Khan, introduced Streetspace for London, including temporary cycle lanes and wider footpaths. In Paris, the plan is for 650 new kilometres of pop-up “corona cycleways”, and the removal of 72% of on-street parking.

Parking spaces have proved the perfect way to reclaim the required land. Many people are working remotely and inner cities have had huge drops in visitor numbers. American cities have been particularly aggressive in this regard. Portland, Oregon, was one of the first to seize on parking spaces with its Come Thru Market. The initiative connects black and minority ethnic farmers with customers through local parking lots in disadvantaged neighbourhoods. Las Vegas has erected tented shelters and “cooling centres” in unused parking lots for homeless people to take refuge and access services.

The pandemic has allowed many of these initiatives to be implemented with a minimum of fuss; the Rotterdam scheme was up and running in two weeks.

Uncertainty about the future of Covid-19 aside, some predict the most profound changes may not be about tweaks to existing infrastructure but the possibilities in districts yet to be built. China has recently accelerated plans for a huge, car-free district in Shenzen, “designed for and about people”.

It remains to be seen whether there is enough momentum from ordinary people to demand existing city neighbourhoods permanently reject cars.

Ross Rutherford

ESR Newsletter Editor

8 December 2020