Technologies series

Carbon Capture, Utilisation, and Storage (CCUS)

A vital suite of methods and technologies to avoid a dangerous, high-temperature future.

The rubbish collectors of the future.*

What it is

The combustion of fossil fuels releases greenhouse gases, including carbon dioxide (CO_2), responsible for the warming of the atmosphere. Without effective carbon capture and either storage (CCS) or utilisation (CCUS), significant warming of the Earth will be difficult to avoid.[1]

How it works

CCUS technologies involve the capture of CO_2 from fuel combustion or industrial processes at source, or directly from the air, and its transport; and either its use as a resource to create products or services, or its permanent storage in deep underground geological formations.

Direct Air Capture (DAC) technologhies involve direct chemical absorption of CO_2 from the air, but are reckoned at present to be economically unfeasible.[2] Biological methods include:[3] restoration of peatlands; soil maintenance;[4] accelerated mineral weathering;[5] tree planting;[6] and bioenergy with CCS (BECCS).[7] CCUS technologies also provide the foundation for negative emissions. At present ~40m tons of CO_2 are captured each year – compared with global emissions of ~40Gt.

Applications

Given the long life of industrial infrastructure and the projected requirements of industrial products (steel, cement, chemicals), capturing emissions from these sources is vital.[8] CCUS is not simply a tool for reducing or reversing emissions. Although likely to be a small fraction of its use, products from captured CO_2 could further enable the circular economy.[9] These can be from:

- **Decarbonising Cement.** Both in its production and use if CO_2-cured cement is made.[10]
- **CO_2 Fuels.** These include methanol and methane and could enable easy transport of hard-to-utilise sources of renewable power. They are however expensive to produce.[11]
- **Enhanced Oil Recovery (EOR).** Perhaps ironically, pumping CO_2 into existing oil wells can lead to emission reductions from oil production and, supposedly 'CO_2-negative oil'.[12]
- **Chemicals.** Predominantly urea for fertilisers,[13] but polymers are a possibility.[14]

Implications and issues

These applications are potentially useful stepping stones to decarbonisation, but are in no way replacements for the significant amounts of CO_2 capture and storage that are required if the planet is to be kept below a 2°C global temperature increase.[15] Other issues remain:

- **Deployment and Scaling.** Worldwide, there are only 44 CCUS projects under development, and 21 in operation,[16] way fewer than required to avoid significant global heating.[17]
- **Assessing Cost.** Without CCUS, energy transition will be far more costly and complex,[18] but determining which metrics to assess,[19] and over what timeframe, is key.[20]
- **Investment.** The shock from SARS-CoV2 has caused many oil and gas companies to drop or postpone planned investments in CCUS.[21] Private equity is active,[22] but investment remains below what is required, due primarily to a lack of adequate carbon markets.[23]
- **Incentives.** Increased CCUS may reduce incentives to lower CO_2 emissions and switch to renewable energy, locking-in high emitting infrastructure.[24] Existing incentives are already 'abused' to enable greater emissions than 'permitted'.[25]
- **Monitoring.** Injecting CO_2 into existing oil wells may lead to leaks far from the injection site. Preventing these is essential.[26] This also applies to other forms of CCUS.[27]
- **100% CO_2 Capture.** While not currently the standard, capturing all released CO_2 from fossil fuel combustion, including errant releases, is possible.[28]
- **Policy.** Carbon credits and trading schemes are already in place and are being expanded,[29] but careful work is required to avoid abuse. Support for further innovation is necessary.[30]

With large-scale deployment of CCUS seemingly a requirement for almost all net-zero emission projections, investment into CCUS projects needs to accelerate rapidly, without diminishing investment in renewables to enable a successful energy transition.■

* Insomuch as children will want to be them, adults won't want to think about them, and civilisation will depend upon them.

[1] The International Panel on Climate Change (IPCC) recognises that carbon capture and sequestration will be required on a massive scale if catastrophic global temperature increases are to be avoided. While ambivalent about the specific approach, they suggest that it will be essential to sequester permanently ~10 billion tons of CO_2 per year by 2050, and double that each year by 2100. See: International Panel on Climate Change (IPCC), 2018. *IPCC Special Report Global Warming of 1.5 °C*. IPCC [online] Available at: <https://www.ipcc.ch/sr15> [Accessed 15 May 2021].

[2] Direct Air Capture (DAC) technologies differ in chemistries, but all employ fundamentally similar mechanics, using powered intake of air through either liquid or solid filters to remove CO_2 from the air. They hold some attractive advantages over other capture technologies, including requiring a small footprint. And, being location-independent, they can make use of renewable energy overcapacity in areas, or be located adjacent to long-term CO_2 storage sites. However, they have not yet been demonstrated at scale, and unless the captured CO_2 is then stored, these will not lead to negative emissions. International Energy Agency, 2020. *Direct Air Capture*, IEA [online] Available at: <https://www.iea.org/reports/direct-air-capture> [Accessed 2 May 2021]. For a detailed breakdown of costs and engineering processes for Carbon Engineering's DAC plant see, Keith, D. W., 2018. A Process for Capturing CO2 from the Atmosphere. *Joule* [e-journal] https://doi.org/10.1016/j.joule.2018.05.006.

[3] Evidence is strongly supportive of "nature-based solutions" to pull CO_2 down from the atmosphere and protect biodiversity, although serious consideration must be given to land usage and mono-culturing. Maintaining biodiversity and adequate food security are of particular importance, and inability to maintain them alongside reductions in CO_2 emissions should be seen as a failure. See, Girardin, C. A. J., et al., 2021. Nature-based solutions can help cool the planet — if we act now. *Nature* [e-journal] https://doi.org/10.1038/d41586-021-01241-2

[4] Soil carbon sequestration is an attractive option, primarily because it uses the land most depleted in carbon stocks (a loss of 30-50% in topsoil), of which ~ 45% is under agricultural management, and does not require conversion of the land use to forests, for example. Estimates of the potential carbon sequestration potential range from 2–5Gt of CO_2 per year to compare, current global emissions are ~40Gt. See, Paustian, K., et al., 2019. Soil C Sequestration as a Biological Negative Emission Strategy. *Frontiers in Climate* [e-journal] https://doi.org/10.3389/fclim.2019.00008.

[5] Accelerated or enhanced mineral weathering refers to techniques that utilise the ability of the weather to break down, and eventually dissolve, mineral rocks. Through this process the exposed minerals react with carbonic acid present in rainwater, thereby removing CO_2. These carbonate compounds are eventually carried into the sea, where they reduce the acidity of the oceans and will store the carbon for long periods of time. In the context of geoengineering it is suggested that, in combination with crops, the crushing and spreading of either basalt or limestone can simultaneously enhance soil health and crop productivity. See: Beerling, D.J., et al. 2020. Potential for large-scale CO2 removal via enhanced rock weathering with croplands. *Nature* [e-journal] https://doi.org/10.1038/s41586-020-2448-9.

[6] Although the precise amount of CO_2 that expanded tree coverage could provide is under debate and is subject to climatic conditions (tropical, temperate, etc.), biodiversity, and previous land usage, it has considerable potential for carbon drawdown. Ensuring that other carbon sinks, such as peatland, are not used for tree planting, and ensuring a diverse, natural forest is planted to maximise soil uptake, is vital; as is ensuring the lasting survival of the planted trees. Conservative estimates suggest that large-scale afforestation could remove 40-100 gigatonnes of CO_2 over the 100 years it takes them to reach maturity. This represents approximately 10 years of anthropogenic emissions at current rates. See: Bastin, J-F., et al., 2019. Response to Comments on "The global tree restoration potential". *Science* [e-journal] https://doi.org/10.1126/science.aay8108, Friggens, N. L., et al., 2020. Tree planting in organic soils does not result in net carbon sequestration on decadal timescales. *Global Change Biology* [e-journal] https://doi.org/10.1111/gcb.15229, & Waring, B., 2020. Forests and Decarbonization – Roles of Natural and Planted Forests. *Frontiers in Forests & Global Change*, [e-journal] https://doi.org/10.3389/ffgc.2020.00058.

[7] Bioenergy with Carbon Capture and Storage (BECCS) is regarded by many institutions as a lynchpin of most strategies to reduce CO_2 emissions to ensure temperature rises are kept below 2°C. The International Panel on Climate Change (IPCC) suggest that BECCS will be responsible for the sequestration of between 0.4 and 11.3 $GtCO_2$ per year. See: International Panel on Climate Change (IPCC), 2018. *Special Report On Climate Change And Land, Land–Climate interactions*. IPCC [online] Available at: <https://www.ipcc.ch/srccl/chapter/chapter-2> [Accessed 15 May 2021] & Hickman, L., 2016. *Timeline: How BECCS became climate change's 'saviour' technology*. CarbonBrief [online] Available at: <https://www.carbonbrief.org/beccs-the-story-of-climate-changes-saviour-technology> [Accessed 15 May 2021].

[8] This is also important with regard to electricity generation, where in Asia a continued expansion of coal-fired power is planned, and where the average age of a coal fired power plant is just 12 years. It remains to be seen whether the continually decreasing cost of renewables will undercut the economics of these plants. Evans, S., & Pearce, R., 2020. *Mapped: The world's coal power plants*. CarbonBrief [online] Available at: <https://www.carbonbrief.org/mapped-worlds-coal-power-plants> [Accessed 13 May 2021] and IEA, 2020. *The role of CCUS in low-carbon power systems*. IEA [online] Available at: <https://www.iea.org/reports/the-role-of-ccus-in-low-carbon-power-systems> [Accessed 13 May 2021].

[9] See Centi, G., 2020. Economics of CO2 Utilization: A Critical Analysis. *Frontiers in Energy Research* [e-journal] https://doi.org/10.3389/fenrg.2020.567986 & IEA, 2019. *Putting CO2 to Use*. IEA [online] Available at: <https://www.iea.org/reports/putting-co2-to-use> [Accessed 13 May 2021].

[10] It is inherently difficult to reduce the CO_2 emissions of cement production, as these are largely linked to the CO_2 released from the chemical reaction limestone undergoes when it is heated, rather than the heating itself. This means that simply decarbonising energy production will not reduce the process emissions sufficiently, and CCUS remains one of the most plausible options for reducing emissions in this sector. Various companies are developing carbon-negative cements, including CarbonCure and Solida. However, the construction industry is highly cost sensitive, and has strict safety regulations based on current, well-understood, materials. See: CarbonCure, 2021. *Innovative CO_2 Technology*. CarbonCure [online] Available at: <https://www.carboncure.com/technology> [Accessed 13 May 2021], Solida, 2021. *Solutions*. Soilda [online] Available at: < https://www.solidiatech.com/solutions.html> [Accessed 13 May 2021], and Cameron, J., & Llewellyn, P., 2021. *Cement*. Llewellyn Consulting.

[11] The expense of producing these fuels is due predominantly to their use of pure hydrogen (H_2), which at present is too high to make the process economical. It is envisaged that these fuels would be able to make use of renewable energy sources in locations that otherwise could not be used for domestic or current industrial use, for example much of Chile's available hydropower, or Australia's solar power. As a liquid fuel, methanol is

easy to transport, and could take advantage of existing infrastructure. However, the subsequent combustion of these fuels without carbon capture obviously leads to the release of more CO_2. Hence downstream carbon capture and storage would be required for carbon negative, rather than merely carbon neutral, fuels. See: González-Garay, A., 2019. Plant-to-planet analysis of CO2-based methanol processes. *Energy Environmental Science* [e-journal] https://doi.org/10.1039/C9EE01673B & Centi, G., et al., 2020. Economics of CO2 Utilization: A Critical Analysis. *Frontiers in Energy Research* [e-journal] https://doi.org/10.3389/fenrg.2020.567986.

[12] Enhanced Oil Recovery (EOR) is currently the largest source of CO_2 capture. However, it is not atmospheric CO_2 that is used but instead existing underground CO_2 reservoirs. To its favour, the oil reservoirs that EOR uses are much better understood than other geological proposals, and much of the infrastructure is already in place (together with some incentives, such as the USA's 45Q CO_2 sequestration subsidy and Europe's ETS). However, one pertinent consideration is the expanded production of oil that EOR would enable, leading to a huge expansion in oil production, by an industry which has demonstrated its ability to lobby and avoid regulatory oversight.

Further to this are considerations regarding the price of oil: recent plunges have prevented companies from recovering investment in CCUS. If CCUS is to make a significant dent in existing carbon emissions it will need to be consistently funded. Whether or not EOR can lead to 'CO_2 negative oil' is the subject of debate. Life-cycle analysis suggests that initial production is CO_2 negative, but it increases over time. See, Núñez-López, V., & Moskal, E., 2019. Potential of CO2-EOR for Near-Term Decarbonization. *Frontiers in Climate* [e-journal] https://doi.org/10.3389/fclim.2019.00005, McEwan, M., 2016. *EOR technology opens door to billions of barrels in residual oil zones*. Midland Reporter Telegram [online] Available at: <https://www.mrt.com/businessinsider/oilreport/article/EOR-technology-opens-door-to-billions-of-barrels-9973973.php> [Accessed 15 May 2021], Noël, J., 2018. *Carbon Capture and Release Oversight Failures in the Section 45Q Tax Credit for Enhanced Oil Recovery*. Clean Water Action/Clean Water Fund [online] Available at: <https://cleanwateraction.org/publications/carbon-capture-and-release> [Accessed 15 May 2021], & Núñez-López, V., et al., 2019. Environmental and Operational Performance of CO2-EOR as a CCUS Technology: A Cranfield Example with Dynamic LCA Considerations. *Energies* [e-journal] https://doi.org/10.3390/en12030448

[13] Urea production utilises 140 Mt CO_2 per year to produce 200 Mt of urea, of which the vast majority of CO_2 is released within days of applying to crops. It is the largest chemical pathway for CO_2 usage. The feasibility of producing carbon-neutral urea for fertiliser is outlined in the following: Driver, J.G., 2019. Blue Urea: Fertilizer With Reduced Environmental Impact. *Frontiers in Energy Research* [e-journal] https://doi.org/10.3389/fenrg.2019.00088, & Hepburn, C., J. et al. 2019. The technological and economic prospects for CO2 utilization and removal. *Nature* [e-journal] https://doi.org/10.1038/s41586-019-1681-6.

[14] Decoupling of the chemicals industry from fossil fuels is possible using CCUS, but would require vast amounts of renewable electricity. See Kätelhön, A., et al., 2019. Climate change mitigation potential of carbon capture and utilization in the chemical industry. *Proceedings of the National Academy of Sciences (PNAS)* [e-journal] https://doi.org/10.1073/pnas.1821029116.

[15] The Paris Agreement is a legally binding international treaty on climate change that has been signed by most countries, but not ratified by all. Its goal is to limit global warming to below 2°C, and preferably below 1.5°C, compared with pre-industrial levels. See: United Nations (UN), 2016. *The Paris Agreement*. UN [online] Available at: <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement> [Accessed 15 May 2021] & International Panel on Climate Change (IPCC), 2018. *IPCC Special Report Global Warming of 1.5 °C*. IPCC [online] Available at: <https://www.ipcc.ch/sr15> [Accessed 15 May 2021].

[16] Notable projects include: Norway's Northern Lights programme, which is a partnership of Equinor, Shell, and Total, and is a key component of Longship, the Norwegian government's integrated CCS project; and the UK's Drax power plant, which has been converted to run on biomass and, via BECCS, aims to become a carbon-negative power plant. There have been criticisms of Drax's reliance on imported biomass, reducing biodiversity in Estonia and Latvia, and its heavy reliance on subsidies. This has recently led to a court challenge from the EU. See: International Energy Association (IEA), 2021. *CCUS around the world.* IEA [online] Available at: <https://www.iea.org/reports/ccus-around-the-world> [Accessed 19 May 2021], Ibbetson, C., 2019. *European lawsuit threatens Drax power plant*. New Civil Engineer [online] Available at: <https://www.newcivilengineer.com/latest/european-lawsuit-threatens-drax-power-plant-06-03-2019/> [Accessed 21 May 2021], & Kuresoo, S., and Kerus, V., et al., 2020. *Hidden inside a wood pellet*. Estonian Fund for Nature (ELF) & Latvian Ornithological Society [online] Available at: <https://elfond.ee/biomassreport> [Accessed 21 May 2021].

[17] To meet the International Energy Agency's Sustainable Development Scenario, CCUS must account for reductions in CO_2 of 4 gigatons per year, rising to nearly 7 by the end of the century. See, International Energy Association (IEA), 2021. *CCUS in the transition to net-zero emissions*. IEA [online] Available at: <https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-in-the-transition-to-net-zero-emissions#abstract> [Accessed 19 May 2021] & International Energy Agency (IEA), 2021. *Sustainable Development Scenario*. IEA [online] Available at: <https://www.iea.org/reports/world-energy-model/sustainable-development-scenario> [Accessed 19 May 2021].

[18] See, Baylin-Stern, A., & Berghout, N., 2021. *Is Carbon Capture Too Expensive?* IEA [online] Available at: <https://www.iea.org/commentaries/is-carbon-capture-too-expensive> [Accessed 15 May 2021].

[19] Developing frameworks to assess the potential costs and benefits of technologies at early stages of readiness and in as yet unproven markets is incredibly difficult. Systematic techno-economic (TEA) and life cycle assessment (LCA) tools, and international standards including ISO 27912–ISO 27919 have been developed, and these clarify the scoping and evaluation of CO_2 capture systems, But further work is required. See: Zimmermann, A.W., et al., 2020. Techno-Economic Assessment Guidelines for CO2 Utilization. *Frontiers in Energy Research* [e-journal] https://doi.org/10.3389/fenrg.2020.00005, von der Assen, N.V. (2015), F*rom Life-Cycle Assessment towards Life-Cycle Design of Carbon Dioxide Capture and Utilization*. University of Aachen [online] Available at: <http://publications.rwth-aachen.de/record/570980/files/570980.pdf> [Accessed 15 May 2021], & ISO, 2016. *ISO/TR 27912:2016*. ISO [online] Available at: <https://www.iso.org/standard/64233.html> [Accessed 16 May 2021].

[20] The length of time the CO_2 remains sequestered and the likelihood of its release are key considerations. However, in the context of avoiding significant global warming, it can be argued that it is less important that a given amount of CO_2 is stored for a given amount of time – more important is the amount of fossil fuel usage that can be avoided, allowing for a switch to a renewable energy system. See: Centi, G., et al., 2020. Economics of CO2 Utilization: A Critical Analysis. *Frontiers in Energy Research* [e-journal] https://doi.org/10.3389/fenrg.2020.567986, Schlögl, R., et al., 2018. *Novel carbon capture and utilisation technologies*. Science Advice for Policy by European Academies (SAPEA) [online] Available at:

<https://www.sapea.info/topics/carboncaptureandutilisation> [Accessed 16 May 2021], & Hepburn, C., et al., 2019. The technological and economic prospects for CO2 utilization and removal. *Nature* [e-journal] https://doi.org/10.1038/s41586-019-16_81-6

[21] See Gould, T., & Atkinson, N., et al., 2020. *The global oil industry is experiencing a shock like no other in its history*. IEA [online] Available at: <https://www.iea.org/articles/the-global-oil-industry-is-experiencing-shock-like-no-other-in-its-history> [Accessed 15 May 2021].

[22] See Kerber, R., 2021. *Investors BlackRock, Vanguard join net zero effort*. Reuters [online] Available at: <https://www.reuters.com/business/sustainable-business/investors-blackrock-vanguard-join-net-zero-effort-2021-03-29> [Accessed 13 May 2021], BusinessWire, 2021. *Valero and BlackRock Partner with Navigator to Announce Large-Scale Carbon Capture and Storage Project*. BusinessWire [online] Available at: <https://www.businesswire.com/news/home/20210316005599/en/Valero-and-BlackRock-Partner-with-Navigator-to-Announce-Large-Scale-Carbon-Capture-and-Storage-Project> [Accessed 13 May 2021] & Carbon Infrastructure Partners (CIP), 2021. *Leading Oil & Gas Investment Firm Embraces Carbon Capture & Storage*. PR Newswire [online] Available at: <https://www.prnewswire.com/news-releases/leading-oil--gas-investment-firm-embraces-carbon-capture--storage-301280374.html> [Accessed 13 May 2021].

[23] Attempts to address this include Nori, which enables businesses to purchase "carbon removal certificates" from verified farmers using blockchain-issued tokens. This can be thought of as essentially a "carbon coin" cryptocurrency. In order for it to succeed the validation of carbon sequestration is important, as is the support of policies for carbon removal. See Nori, 2021. Reach Your Business Climate Goals Faster. Nori [online] Available at: <https://nori.com/for-business> [Accessed 12 July 2021] & Baylin-Stern, A., & Berghout, N., 2021. *Is Carbon Capture Too Expensive?* IEA [online] Available at: <https://www.iea.org/commentaries/is-carbon-capture-too-expensive> [Accessed 15 May 2021].

[24] It is debateable whether continuing to build fossil fuel infrastructure and investing in CCUS will offer better energy returns on investment than will increasing investment into renewables and storage. Especially given the success in massively scaling renewable energy production over the past 10 years, compared with the dismal pipeline of CCUS projects. See: Sgouridis, S., et al., 2019. Comparative net energy analysis of renewable electricity and carbon capture and storage. *Nature Energy* [e-journal] https://doi.org/10.1038/s41560-019-0365-7 & Fattouh, B., Poudineh, R., & West, R., 2018. *The rise of renewables and energy transition: what adaptation strategy for oil companies and oil-exporting countries?* Oxford Institute of Energy Studies [online] Available at: < https://www.oxfordenergy.org/publications/rise-renewables-energy-transition-adaptation-strategy-oil-companies-oil-exporting-countries> [Accessed 15 May 2021].

[25] A pertinent example is California's carbon credit policies, which are being considered as a blueprint for the rest of the US. These have been demonstrated to fail in reflecting genuine climate benefits. The carbon offset programme involved inaccurate averages of forest cover, resulting in around 1/3 of the offsets being over-credited, equalling ~$410 million and ~30 million tCO_2e. See, Badgely, G., 2021. *Systematic over-crediting of forest offsets*. Carbon Plan [online] Available at: <https://carbonplan.org/research/forest-offsets-explainer> [Accessed 15 May 2021], & Song, L., & Temple, J., 2021. *The Climate Solution Actually Adding Millions of Tons of CO2 Into the Atmosphere*. ProPublica & MIT Technology Review [online] Available at: <https://www.propublica.org/article/the-climate-solution-actually-adding-millions-of-tons-of-co2-into-the-atmosphere> [Accessed 15 May 2021].

[26] Successful monitoring of CO_2 storage in undersea rock formations has been successfully demonstrated in real-world conditions in tests from the EU-funded STEM-CSS. See, *Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEM-CSS), 2020. Research Highlights*. STEM-CSS [online] Available at: <https://www.stemm-ccs.eu/sites/stemm-ccs/files/documents/STEMM-CCS_research_highlights_r.pdf> [Accessed 29 April 2021] & Kelemen, P., 2019. An Overview of the Status and Challenges of CO2 Storage in Minerals and Geological Formations. *Frontiers in Climate* [e-journal] https://doi.org/10.3389/fclim.2019.00009.

[27] For example, this applies to afforestation (planting forests) and maintaining forests, ensuring that they do not burn, such that the CO_2 recorded as having been locked in is indeed truly sequestered. For this reason, it has been suggested that soil sequestration may be preferable, essentially because the sequestered emissions are stable over a longer period.

[28] See, IEAGHG, 2019. *2019-02 Towards Zero Emissions*. IEA Greenhouse Gas R&D Programme [online] Available at: <https://ieaghg.org/publications/technical-reports/reports-list/9-technical-reports/951-2019-02-towards-zero-emissions> [Accessed 29 April 2021].

[29] The two most prominent policies are the recently amended US 45Q tax credit and the EU carbon emission trading scheme (ETS). The recent expansion of the 45Q tax credit for carbon capture and storage is significant. The credits rise from $35/tonne CO_2 in enhanced oil recovery (EOR) to $50/tonne CO_2 stored, and apply to a wide range of industrial facilities down to those producing 100,000 tonnes of CO_2 per year, and to applications that use more than 25,000 tonnes CO_2. See: Ochu, E., 2021. *Proposed 45Q Tax Credit Reform Could Give a Big Boost to Carbon Capture Projects*. Columbia Climate School [online] Available at: <https://news.climate.columbia.edu/2021/05/06/proposed-45q-tax-credit-reform-boost-carbon-capture-projects> [Accessed 21 May 2021] and European Commission, 2021. *EU Emissions Trading System (EU ETS)*. European Commission [online] Available at < https://ec.europa.eu/clima/policies/ets_en> [Accessed 21 May 2021].

[30] See: Climate Change Committee, 2019. *Net Zero – The UK's contribution to stopping global warming*. Climate Change Committee [online] Available at: <https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming> [Accessed 15 May 2021].