Supplementary Evidence: Climate Change Plan Update

2 February 2021, Prof. Stuart Haszeldine

Supplementary evidence submitted to the Scottish Parliament Economy, Energy and Fair Work Committee by Stuart Haszeldine, Director of SCCS, and Professor of Carbon Capture and Storage at the School of GeoSciences, University of Edinburgh.

This provides additional context and perspectives relating to : i) the viability of CCS; ii) The source materials for BECCS (Biomass CCS); iii) The role of hydrogen as an energy vector in Scotland and the need for massive inter-seasonal storage; iv) Calculating NetZero at and beyond 2045- combining Nature Based Solutions with technology solutions such as biochar and Direct Air Capture; v) Proposal to neutralise future oil production emissions with a mandatory Carbon Take Back Obligation.

1 Carbon capture and storage (CCS)

Carbon Capture and Storage (CCS) has operated for decades safely at industrial scale. For example CO2 transport to injection is a large USA and Canadian industry since 1972. The North Dakota gasification company has captured CO_2 from coal and pipelined 300km to injection since 2000. Additionally, CO_2 separation from hydrogen in oil refineries operates at QUEST (Alberta) and Port Arthur (Texas) - very similar to proposed "blue hydrogen" at St Fergus in Scotland. CO2 capture rates are typically cited as 95%, but can be designed to 99% if required on coal or gas power plant[1], for small additional costs of 1-7%. Several CCS operations in North America sell their CO_2 for Enhanced Oil Recovery. That is a business operation, not the CCS operation. There are no plans for CO_2-EOR operations in the North Sea. First projects in Scotland for CCS on power, industry, hydrogen or Air Capture will be grant co-funded with developers by Westminster BEIS. Minimal capital funding will be provided by Scottish Government. Scottish support for CCS or hydrogen (£5M and £180M) R&D, leads to job creation in Scotland if successful.

Co-benefits of CCS include creating a CCS and offshore installation supply chain, which is essential to maintain thousands of existing high value jobs. Pivoting offshore skills and engineering to build boreholes, pipes and installations for CCS, for hydrogen, and for wind will create many thousands of additional jobs - as in Norway[2]. Substantial air quality improvement - particularly if CCS is fitted to energy from waste[3]. Revenues to The Crown Estate Scotland through leasing of geological pore space. Development of DACCS rather than BECCS

[1] Towards Zero Emissions CCS in Power Plants. IEA GHG 2019-2
[2] Industrial opportunities and employment prospects in large-scale CO2 management in Norway SINTEF Report 2018:00450
[3] Health Effects due to Emissions from Energy from Waste Plant in London 2020 https://www.london.gov.uk/sites/default/files/gla_efw_study_final_may2020.pdf

reduces land use competition when providing NET - 1 Mt CO2/yr captured by BECCS is 140,000Ha forest, or captured from DACCS is 5Ha equipment. Transport and storage of CO_2 is persistently cited as most competitive UK value to create thousands of jobs compared to all energy industry opportunities[4].

" The long-term GDP boost associated with Government investment in 3 or 4 strategic CCS infrastructure hubs (costing up to a potential £1.75billion) could deliver a short-term wider economy gain of around £0.2million of cumulative GDP per £million spent. Crucially in the post-pandemic economic climate, this investment can lead to the almost immediate creation of between 1,700 and 3,850 new jobs per year over an assumed 6-year investment timeframe. This equates to an average of up to 1.6 jobs per year per £1million spent. However, the crucial outcome of this early investment will ultimately be the foundations set for the creation of a new large-scale CO_2 management industry that could help sustain and evolve potentially hundreds of thousands of jobs in UK manufacturing and fossil fuel industries"[5]

CO2 capture, pipeline and geological storage for the purpose of climate mitigation operates at Sleipner in the Norwegian North Sea since 1996, and Snøhvit in the Barents Sea since 2007 - at costs less than $50 per tonne CO_2. The Norwegian Northern Lights project will operate in 2024 to capture CO_2 from Brevik cement works and Fortum waste to energy plant at Oslo, and geologically store CO_2 at a new subsea site west of Bergen. Shipping tankers will collect CO2 from coastal industries around North Sea and Baltic countries, and transport to the same secure storage. A similar industry can grow in Scotland, where the Acorn CCS project, and Acorn hydrogen project, plan to operate in 2024. The St Fergus terminal can accept shipping of CO_2 from Scotland, British Isles and North Sea routes. Growing to 100 Million tonnes/yr can create hundreds of new offshore jobs in Scotland, within a new sector worth £ Billions per year, with a Scottish engineering and supply chain.

2 BECCS

BECCS Biomass CCS can deliver in three forms;

1) Import of wood chips currently occurs, as a fuel claimed to have minimal or negative climate impact. The UNFCCC accounting rules mean that wood can be counted as a land use emission in the country of origin, not as UK electricity emission. Vast forest areas are cleared to feed large sized 3-4 Giga Watt sized power plant. No CO_2 is currently captured from wood biomass, industry scale CCS is 10 -15 years into the future. This is an example of deferring mitigation and CO_2 capture now, because of the promise of capture in the future.

[4] Energy Innovation Needs Assessment, 2019, Vivid Economics, for UK BEIS
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845652/energy-innovation-needs-assessment-overview-report.pdf
[5] Laying the foundations for a net zero society 2020, Bellona
https://network.bellona.org/content/uploads/sites/3/2020/07/Laying-the-Foundations-for-a-Net-Zero-Society_July2020.pdf

2) Biomass from annually harvested crop such as straw. Biomass from waste is also annually cycled and is readily available without additional harvesting. Our SCCS Negative Emissions report in 2018[6] **found 2.44Mt biogenic CO_2/yr for capture**, close to St Fergus pipeline.

3) Biomass on fermentation has been ignored in Scotland, but can be captured on a monthly cycle. Pure CO2 is inevitably emitted by brewing of beer, and by preparation for grain spirit or malt whisky. SCCS 2018 *(ibid)* found this to be **0.47 Mt CO_2/yr and can be captured at very low cost**. Anaerobic Digestion from dispersed sources - though mostly from landfill gas, provides an **additional 0.56 Mt CO_2/yr. Total biomass could be 3.6 Mt CO_2/yr NET**

3 Hydrogen and energy storage

A combination of low carbon chemical vectors and near-zero carbon electricity is anticipated to be a powerful combination for the Scottish all-energy whole system. It is not possible to immediately produce vast quantities of Green hydrogen - **an approximate quadrupling of wind generation will be needed** to provide electrolysis power, whereas the Offshore wind to hydrogen opportunity assessment 2020[7] states a possibility of green hydrogen at £2.3/kg delivered to shore by an extra 11GW of offshore wind. That could take at least 10-15 years. Consequently for Scotland 2030 targets of -75% emissions, blue hydrogen is the most certain source, requiring CCS to be operating.

Methane imports as LNG may be sources of blue hydrogen. This requires **substantial energy, often about 10% of the methane. That embedded energy** and its CO_2 emissions in should be labelled by a **numerical badging** to move beyond "green" or "Blue" or "grey", to label the grammes CO_2/kg hydrogen, like A+++ to G consumer ratings on white goods.

Storage of energy between seasons will be needed to guarantee hydrogen supply in winter, when demand can be 6x the entire electricity system. University of Edinburgh calculates that geological storage will be needed, as much as 15% of all annual energy. **Large grid scale hydrogen stores urgently need to be designed** onto the Scottish gas grid.[8]

4 Direct air capture

Direct Air Capture (DAC) is not yet adequately understood in Scotland. That can capture CO2 from normal air at 415ppm. Systems which can do this are now available at industrial scale TRL8 from Clime Works in Zurich, and Carbon Engineering in British Columbia. DAC could be installed and operate in 2022, but there is no CO_2 removal pipeline infrastructure and no business model to pay for CO_2 storage. One application of DAC could be to draw massive quantities of CO_2 from the atmosphere, to counteract the greenhouse effect. That is unlikely, because of massive tonnage and energy involved. Much more probable, is to use DAC as a

[6] SCCS 2018 Negative emission technology in Scotland. https://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2018_08_Negative_Emission_Technology_in_Scotland.pdf
[7] Offshore wind to green hydrogen opportunity assessment 2020 Scottish Government. https://www.gov.scot/publications/scottish-offshore-wind-green-hydrogen-opportunity-assessment/
[8] Scafidi, J., Wilkinson, M., Gilfillan, S., Heinemann, N. & Haszeldine, R. S., 2021 Quantitative assessment of the hydrogen storage capacity of the UKCS. International journal of hydrogen energy.

means to capture CO_2 at a fixed maximum price. That would enable trading within Scotland, so that a refinery able to capture 80% of its own CO_2 at $50-$150 / ton CO_2 could purchase CO_2 for storage from DAC to capture CO_2 from air, equivalent to the 20% un-captured by their own efforts. Thus DAC can be used to create a maximum price of CO_2 to fully decarbonise industrial centres.

5 Nature based solutions

Planting trees is proposed by environmental groups as a method of CO_2 storage instead of CCS. Trees are often environmentally desirable, but are insufficiently durable to create long timespan storage. The annual tonnage of CO_2 in Scotland stored by trees is insufficient to produce enough Negative Emissions for Scotland and can not arithmetically balance to Net Zero. Present forest cover in Scotland is replanted at 10,000Ha/yr, and planned to increase to 15,000Ha/yr. Commercial softwoods have a crop rotation of about 50yr, and on average store 7t CO_2/Ha /yr[9]. This fits well with the 2018 report of emissions, where 7 Mt/yr CO_2 is claimed as NET due to forestry. **However this is not yet true**. The trees may indeed have grown, but there is no method of long duration storage of that biomass carbon, which needs to be **removed and stored for 10,000 years for climate recovery**[10]. Current Scottish forestry is another example of mitigation deterrence and does not provide long duration CO_2 storage. A long duration store or use needs to be created for Scottish wood and other biomass. That could be biochar - charcoal made locally from wood biomass and emplaced into agricultural soils and infrastructure; or BECCS combustion in local river catchment scale 50MW power plant with CO_2 sent to geological storage. Alternative uses - such as building with wood provide only temporary storage.

6 Carbon Take Back Obligation

This proposal closes the missing link in the cycle of fossil carbon, from extraction, sale, use, emission - to storage. The Oil and Gas Authority predicts a potential 10 Bbbl of oil to be produced before 2050, around Shetland and the Central and North North Sea. This will face **increasing difficulties of social licence to operate**. It remains an open question if Scotland will be liable for those Scope 3 CO_2 emissions from combustion of the products - a **linear average 140Mt CO2/yr until 2050**. There is currently no method to enable payment for capture of CO_2, or transport and storage of CO_2. The Climate Change Plan update seems to rely on payment from the Government - this is OK to start projects but not sustainable in an enduring regime up to and beyond 2050. An alternative method simply changes the Obligation, from consumers to producers. Thus **fossil fuel or biofuel producers or importers are given a Carbon Take Back Obligation (CTBO)**[11] to store each tonne CO_2e by the Government. A percentage of that tonne is mandated starting small at 1% in 2024,

[9] Scotland's Forestry Strategy 2019–2029 https://www.gov.scot/publications/scotlands-forestry-strategy-20192029/pages/6
[10] Haszeldine, R.S., Flude, S., Johnson, G. and Scott, V., 2018. Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2119), p.20160447.
[11] CTBO 2021 project website https://carbontakeback.org/

rising to 10% in 2030, and 100% or greater in 2045. The holder of the Obligation has to purchase storage of an equivalent CO_2 tonnage, within Scotland or UK. Verification of that storage produces a Certificate of Storage, which cancels the Obligation. This is simple to operate, and creates a market for storage which exactly balances extraction - ensuring Net Zero. In Scotland, such a market could for example create a need to capture Negative emissions from fermentation, or use Scottish biomass feedstock to BECCS as Negative emissions from forestry.

In general terms a CTBO is similar to Extended Producer Responsibility schemes which already exist in Europe and the UK - for white goods, cars, tyres, and specified wastes. A CTBO provides criteria for the conditions under which fossil energy can still be brought to market. That requires explicit consideration of who provides sufficient CCS capacity. A CTBO will ensure that the polluter not only pays but also cleans up. With a simple carbon tax on emissions as commonly operated, the polluter pays to be allowed to pollute. With a CTBO payments are used to clean up. External costs are included in the gas, oil, and biomass price.