General comments on Draft Climate Change Plan

Prof Stuart Haszeldine (witness), research Dr PA Brownsort, Dr V Scott

We welcome and support the continued climate change mitigation action ambition of the Scottish Government presented in the Draft Climate Change Plan (hereafter referred to as the "Plan"), and look forwards to further strengthening of ambition in the forthcoming new Climate Change Bill.

The new approach built around the TIMES model is instructive and essential in identifying connections between the key sectors and critical technologies, including Carbon Capture and Storage (CCS), which enable system-wide least cost decarbonisation. However, the Plan lacks detail in the assumptions and sensitivities of the TIMES output, and how these might influence the results. Here, we suggest the Plan should contrast the optimum scenario presented with a very few variant scenarios excluding or delaying the application of a technology, such as CCS, to better inform on the expected additional costs and re-balancing of emissions reductions across sectors. Such analysis is of particular importance for areas of action and technology deployment, which are not primarily the remit of the Scottish Government.

Here, the Plan places primary responsibility for the delivery of CCS to the UK, with the Scottish Government's delivery route to "seek to influence the UK Government's CCS strategy". Here, we note that RPP2 intended "demonstration of CCS at commercial scale by 2020", leading to 1600MW of CCS on gas power in the central scenario. Following the UK Government's unexpected 2015 decision to cancel the DECC CCS commercialisation programme, this timing cannot be realised. We suggest that it is perhaps risky for the Scottish Government to again rely on UK CCS delivery in the Plan, especially as publication of the BEIS UK Emissions Reduction Plan and CCS strategy remain delayed, and CCS does not feature in the recently published BEIS industrial strategy. Opportunities for Scotland-led CCS developments are outlined in subsequent sections.

Further, we note that the Plan places CCS deployment until 2032 predominantly into low-carbon and even negative carbon electricity generation, which is expected to be realised within a decade. Experience to date shows that CCS electricity generation has struggled to progress into reality in UK and European power markets. As explained above, this constitutes a substantial CCS delivery risk. In contrast, we suggest that there is perhaps relatively ignored Scottish potential for CCS in industry and in low-carbon heat in the Plan period, which the Scottish Government should consider (see sections below).

With respect to industrial emissions, the Plan relies on EU mechanisms, the EU ETS and Innovation Fund, to progress CCS development and deployment on industry. Brexit makes ongoing participation in the EU-ETS very uncertain, and we strongly recommend that the Scottish Government should consider and outline alternative strategies in the Plan. If the UK and Scotland exit the EU-ETS there is perhaps scope for faster decarbonisation, but this will require UK and or Scottish national policy mechanisms and facilitating funds.

For heat, conversion of natural gas networks to hydrogen appears to be a feasible option and relatively unintrusive at household level. Production of hydrogen in sufficient quantity would most likely be cost-effectively realised via steam methane reforming (SMR) of natural gas combined with CCS. A high-level assessment of heat transition to hydrogen is presented below.

Carbon Capture & Storage

Carbon Capture and Storage (CCS) is a suite of technologies that separates and concentrates carbon dioxide (CO_2) from wherever it is found and delivers it for safe, permanent storage deep underground in geological structures. CCS can capture CO_2 from natural air (direct air capture) but is more usually considered for capturing CO_2 emissions from combustion of carbon-based fuels or other industrial processes. More information from the Carbon Capture and Storage Association is linked.

The basic technologies have been in use in various industries for many decades, for instance, in natural gas purification, refining and fertiliser manufacture, but only in recent decades has there been an interest in capturing CO_2 to avoid emissions causing climate change.

Most of the focus on CCS to date has been on large projects involving electricity generation at fossil fuel power stations, natural gas processing, oil refining, and other industrial processes. There is a small but growing number of large-scale integrated projects (that is, covering the full chain of capture, transport and permanent storage of CO_2) around the world. These large-scale projects are associated with high capital costs, partly because of their sheer scale and partly because these projects have often carried the costs of establishing new infrastructure for CO_2 transport and storage. Scotland has important experience of CCS projects; there have been four proposals for major CCS projects, two of which reached detailed design stage but were not supported by the UK Government. Scotland also owns huge CO_2 storage resources beneath the Central North Sea (30% of EU storage) with several sites ready for development at low cost; pipelines and legacy infrastructure are available from the oil and gas industry for access.

Crucially, CCS technologies can operate in different ways, in diverse sectors and at different scales. These are within the remit of Scottish Government to promote and support, starting with smaller projects, and opening up different opportunities for establishing CCS rapidly. Small projects can be used in ways that increase the effectiveness of other low-carbon actions that are worthwhile in their own right. This approach was set out in a recent briefing to Scottish Government from Scottish Carbon Capture & Storage, and is followed up below.

How can CCS support decarbonisation of the Scottish economy?

Use of natural gas in the Scottish energy system is likely to remain important for some time and may be unavoidable for some industrial processes requiring high-grade heat. CCS can decarbonise natural gas use in circumstances ranging from large industrial combined heat and power (CHP) schemes, through mid-scale CHP for institutions and businesses, and to gas-fuelled district heating schemes. At the mid to small scale, new technology being piloted using methane feed in molten carbonate fuel cells allows capture of CO_2 while generating additional electricity. This gives rise to a multiplier effect – more heat and power output while capturing the CO_2 from natural gas combustion.

The Scottish energy system includes an increasing degree of renewable electricity capacity, which is widely and rightly supported but does introduce issues of supply intermittency. Regional new-build of dispatchable, low-carbon electricity could use CCS on natural gas fuelled power plant to balance a renewables dominated system. New oxy-gas combustion technologies becoming available will capture CO_2 emissions directly in their process cycles, without additional capture plant, and have very high efficiencies.

There is currently high interest in the option of a wholesale change in the energy vector used for heat in Scotland from natural gas (methane) to hydrogen. Hydrogen could be delivered through the existing gas distribution network and has no CO_2 emission at the point of use. Production of hydrogen at the scale needed for this would be most cost-effective by SMR, which would be coupled with storage of by-product CO_2 (8-10 Mt /yr at full operation) in offshore reservoirs using CCS to give a low carbon system. Availability of "low-carbon" hydrogen on a bulk scale could lead to deep and rapid decarbonisation of domestic heat as well as heat for institutions, businesses and industry. Hydrogen availability would also create a fuel switch option for transport decarbonisation and replacement of diesel in fleets (taxis, delivery) and heavy truck transport through the use of hydrogen fuel cells – buses technology is being piloted currently in Aberdeen.

The draft Plan indicates that the "emission envelope" from electricity generation will need to be negative by the late 2020s. Most renewable electricity generation is close to zero carbon (although there are embedded emissions to consider in materials and construction) but to achieve "negative emissions" requires active management of CO_2 such as is achieved with CCS. Use of sustainable biomass fuels for electricity generation with capture and permanent storage of the CO_2 produced (Bioenergy with CCS – BECCS) could give significant "negative emissions" from the Scottish electricity system. However, the issues of biomass sustainability and whole life cycle carbon analysis need to be understood and considered carefully. Scotland has scope for greatly increased afforestation, which could create sustainable domestic biomass for fuel and storage of 10-20 Mt/yr CO_2. Conversion of use from marginal land to agroforestry is a multi-decade project. There are already a small number of large bioenergy units existing in Scotland, which may be suitable for small-scale flue gas take-off to demonstrate BECCS technology. Biomass can also be gasified to give hydrogen – this needs research to combine with CCS – and could lead to high efficiency "negative emissions" from use of hydrogen in the heat and transport sectors, as described above.

Use of other biologically derived fuels, notably methane from anaerobic digestion of organic waste and from landfill (bio-methane and landfill gas), when coupled with CCS can also lead to "negative emissions". The scale of contribution is likely to be smaller than possible from BECCS but the obstacles may also be fewer. Although not part of the energy system in Scotland, capture and storage of CO_2 from fermentation industries (brewing and distilling) also leads to “negative emissions”; in some other countries fermentation with CCS is used to give low-carbon bio-ethanol for transport fuel.

Many large industrial energy users are likely to continue with fossil fuels, primarily natural gas, for some time to come. Some may be able to convert to using hydrogen, if available at suitable scale. For others, CCS on existing gas-fuelled CHP or direct heating plant may be a practical route to reducing CO_2 emissions. A recent study by SCCS suggested CCS applied to major industrial emitters in Central Scotland could remove and store nearly 10% of Scotland’s current *total* CO_2 emissions.

These examples show that CCS is an appropriate technology group for decarbonising a number of different sectors of the Scottish energy system and the economy overall. CCS can support and increase the effectiveness of several decarbonisation actions being progressed or considered – district heating, CHP, bioenergy, biogas, intermittent renewable electricity, the hydrogen economy. CCS is essential to decarbonisation of heavy industry in Scotland, protecting jobs and the economy long-term. CCS is the only realistic method of achieving “negative emissions” from the energy system.

Scotland is uniquely well placed to develop CCS due to its huge and well-understood CO_2 storage resources, existing infrastructure that can be reused to reduce initial costs, and the right skills and experience needed to develop a new industry serving Scottish – and, potentially, European – CO_2 management needs. We strongly encourage the Scottish Government to continue and increase actions and support for the development of CCS across all appropriate sectors of the Scottish economy.

Hydrogen for heat: overview transition from 80% natural gas heating in Scotland to 80% low-carbon hydrogen heating in 15 years?

This is an initial scoping analysis based on questions asked in the EJFW Committee on 7 February 2017:

Meeting heat demand with hydrogen:

- Starting from total annual heat demand in Scotland of c. 80,000 GWh in 2014
- Peak delivery of 300 GWhr/day is needed (Draft Energy Strategy, Diagram 10), implying 12-20 GW of peak delivery (over 3 to 4 times the size of the anticipated renewable electricity fleet)
    - Assuming 10% demand reduction over 15 years (less than predicted)
    - Assuming 80% of this transitioned to hydrogen
    - Assuming 100% conversion efficiency of hydrogen in use for heat

- This requires 1.46 Mt/yr hydrogen to give 57,600 GWh per year
- This would require 2.9 Mt/yr methane to feed SMRs
- This would produce 8.0 Mt/yr of high-concentration CO_2 available for storage

Feasibility and cost:

- Using Port Arthur (operating SMR hydrogen production and CCS facility in Texas, US) capacity (c.172,000 t/yr from a pair of units) and declared CAPEX of USD 431 M, with exchange rate (£1=$1.25)
- Port Arthur is similar in size to BOC North Tees, the largest SMR in UK
- For Scottish demand, as above, this would need 8.5 x Port Arthur capacity = cost of c. £2.9 Bn
- Also need new CO_2 pipeline, Central to St. Fergus, at c. £320M (SCCS Clusters high-end estimate)
- And storage facility offshore – say £150 - 300 M (estimated)
- And conversion costs of gas distribution network – not well known in Scotland
- And costs of appliance conversion - £3,000 per household

All of the above could be funded as a programme under SGN's (rebrand of Scotia Gas Networks) regulated profits.

Delivery timescale:

- Say five years for study, design and piloting
- National UK Regulated Asset timeline to approve funding – 2022
- One SMR commissioned each year for 8 years
- Sequential conversion of gas network segments
- Parallel development of CO_2 transport and storage facilities
- Two final years to complete network and appliance conversions

Complete in 15 years – cf. 10 years for 1970s conversion of all UK to natural gas.

Thus, the substantial conversion of heating to hydrogen **is feasible** in the 15-year timescale being considered. But it is ambitious and would need rigorous planning. This would be a rapid progression, although can be staged along the timeline to discover and confirm designs and results from pilot test trials.