Capturing prosperity from CO_2 and waste

Executive Summary

Utilisation of CO_2 using emerging biologically based methods, such as biorefineries, to capture and turn CO_2 into useful products is an alternative route to Carbon Capture and Storage where CO_2 is captured and then stored underground. In many respects, NI is an ideal location to best exploit the potential of alternative carbon capture, utilisation and storage technologies, reducing the economic risks of carbon taxes, carbon capture and storage costs and offering the potential of negative emissions. The region has a strong agricultural heritage with resources such as waste biomass and nutrient streams which can support such endeavours. Additionally, the land has extensive basalt deposits and there are many waste heat sources from industry and the public sector that could be effectively exploited to enable effective use of captured CO_2.

NI does not have a preponderance of high CO_2 emitters but mainly moderate (<100,000 t CO_2) to low scale emitters (<1,000 t CO_2). Many of these utilise natural gas for heat generation and so could be converted to biomethane as recent work on fully decarbonising the NI gas grid has shown. Switching to a biogenic fuel, such as biomethane, allows many of these installations to come close to net-zero emissions. Coupling a biomethane powered furnace (for example) to carbon capture and utilisation potentially enables atmospheric Carbon Dioxide Removal (CDR) where the end product stores all or part of the biogenic carbon long-term. Beneficially, this will create jobs in a new industry across the region that could deliver raw materials for our animal feed industry, provide biogenic fuels and chemicals as well as producing food that is currently imported. Where we can successfully combine maturing technologies in CO_2 capture, biogenic uses for CO_2 together with the use of surplus nutrients from agriculture then this will both prevent carbon emissions to the atmosphere and the release of excess nutrients that cause pollution of land, rivers, and lakes.

This report looked at the opportunities in NI based on enhanced biogenic methods for utilising CO_2 either directly from exhaust gas streams or captured, purified and shipped to point of use. Two main biogenic routes are explored:

1. Biorefineries: Algal and bacterial based biorefinery technologies can utilise CO_2 emissions from industry and liquid digestate from anaerobic digestion (AD) of farm wastes to produce products such as biogenic fuels, omega-3 fatty acids, proteins and lipids for use in fish and animal feeds.
2. Vertical farming: Using CO_2 to increase yields in greenhouse crops has been a common practice for decades. More recent innovations have seen the introduction of vertical farms with artificial lighting and other innovations to increase yields and hence uptake of CO_2. The second part of this report estimated the potential economic value and environmental impact of vertical farming and aquaponics and their carbon sequestration potential compared to other biological carbon sinks.

The results for a biorefinery based model to produce e-methane in the report showed the potential economic viability with a e-methane price of £0.12/kWh assuming co-location with a CO_2 source, electrolyser (electricity at £50/MWh), and sale of co-products such as oxygen. The ultimate breakeven price of the e-methane is highly dependent on the input electricity price for the electrolyser and price achieved for oxygen.

There are many other products from biorefinery systems that would be a good fit to the local economy. Another example of the economic potential for NI is production of protein or higher value additives for feed production. The agri-food sector in NI imports 389 kt of soya beans as a

protein source for animal feed at a cost of c£109m each year. Displacement of expensive imported soya by locally sourced feed would not only improve support for the local economy but also save considerable carbon emissions due to shipping across the world.

It is also worth noting that combining AD and biorefinery approaches including processing of digestate to biochar or other carbon products can make a substantial difference to NI agriculture's carbon footprint. NI is already one of the most carbon efficient locations for protein production in the world. Further reducing greenhouse gas emissions from the sector would improve competitiveness and prevent displacement in local markets by protein produced from areas of the world that have lower production costs but are much less carbon efficient.

Aquaponics and vertical farming are rapidly developing technologies that are commercially viable and attracting increasing investment. In a vertical farm, multiple layers of crops are stacked on shelves generally in a hydroponic or aeroponic system to supply water and nutrients to plant roots in the absence of soil. Complimentary to vertical farming, aquaponics combines aquaculture (fish farming) with hydroponics into a system where the input of plant nutrients is provided via the food supplied to the fish and the requirement for artificial fertilisers and pesticides is minimal. Combining aquaculture with vertical farming creates a system that is more efficient in resource utilisation, compared to conventional crop farming. However, they require some additional resources above conventional agriculture such as the electricity needed for the lighting used by vertical farms.

Vertical farming and aquaponics are easily combined into an agricultural production system with minimal needs for chemical inputs. As a closed system, they prevent the release of environmental pollutants and protect plants from pests and disease in an environment controlled to achieve optimum growth rates. Switching from conventional, open arable farming to enclosed vertical farming reduces the total amount of land needed for crop production, reduces the growing cycle, and can remove the need for imports of out of season produce, reducing food miles and carbon footprints. Vertical farming also has a productivity up to 516 times greater per unit area than conventional agricultural techniques, depending on the system configuration. Potentially up to 6000 tonnes of CO_2 per hectare of vertical farm could be saved using this technology and environmentally sensitive land and waterways protected from excess nutrients.

Key recommendations:

The prospects for biorefinery based methods look promising and justify further steps:

1. E-methane production looks to be a good fit with Northern Ireland's ambitions to decarbonise the gas grid and could economically utilise local sources of CO_2. Support for the following steps should be taken forward in sequence:
   1.1. A pilot scale trial to assess technology and costs.
   1.2. A full design study and market support assessment should be undertaken.
   1.3. Support for a demonstration plant at suitable size and scale for CO_2 sources in Northern Ireland.
2. Further detailed investigations of alternate biorefinery systems which could use waste streams to produce products of direct use to Northern Ireland's economic sectors should be performed. Suggestions for these include:
   2.1. Other e-fuels such as e-methanol or Dimethyl ether (DME).
   2.2. Animal feed additives.
3. Seaweed aquaculture is also worth exploring although NI's territorial waters are limited there is potential for both carbon sequestration and for absorption of excess nutrients ultimately from run-off from land but delivered by river systems to the sea.

Vertical farming is a growing industry but exploiting the potential for carbon sequestration and for using other waste streams such as oxygen, heat and nutrients have not been explored beyond the desk-based study in this report. Future work should include:

4. A pilot scale investigation to verify the modelling, business models and confirm economic viability in this report.
5. Work with retailers in NI to determine the most viable crops and the food miles/carbon saved by growing locally.

The potential for growing crops such as hemp in a vertical farm where CO_2 can be turned into durable products to sequester carbon for the long-term.