Intelligence Gathering for Sustainable Manufacturing Campus

Report
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Prepared By: Mark Morrison	**Date:** 14.12.20
Approved By: Iain Weir	**Date:** 14.12.20

1 Introduction

Carbon capture and utilisation (CCU), the processes that convert industrially emitted or airborne carbon dioxide (CO_2) into chemicals, fuels and materials, is considered to have the potential to make a significant contribution to the mitigation of CO_2 emissions. It is estimated[1] that, in the long term, it could transform between 1 and 2 giga tonnes per annum of CO_2 (2.5 and 5% of global CO_2 emissions) into commercially viable products. CCU is, therefore, considered an attractive approach to support government commitments on greenhouse gas emissions and as a raw material for sustainable manufacturing.

2 Purpose of this Study

This study follows on from earlier work to investigate options for the development of a carbon capture and utilisation (CCU) value chain in Scotland, recognising that while there are opportunities there are also obstacles in doing so. One of the options identified during the previous study was a facility or hub to demonstrate CCU technologies. The purpose of this study was to define the scope and remit of such a CCU demonstrator through wide stakeholder consultation, to **ensure it matches industry needs**. This study had a Scotland-wide remit, covering all sectors with industrial CO_2 emissions, with a specific focus on how a sustainable manufacturing cluster in Grangemouth could be developed (part of the Falkirk and Grangemouth Growth Deal). It considered both large volume and niche opportunities.

The output from this study directly fed into a parallel study, delivered by Wood plc, that developed a high-level concept design for the CCU demonstrator hub as part of a sustainable manufacturing campus.

These two studies comprised the **first of three stages** to deliver a sustainable manufacturing campus:

Stage 1 – Concept design with key industry players' input

Stage 2 – Consideration, alongside stakeholders, of options identified in the concept design, appraisal of key locations with local partners and costing of viable options

Stage 3 – Identify funding options and set up partnership agreements to deliver plans for sustainable manufacturing campus

3 Study Design

The study was designed around a series of four workshops delivered at regular intervals between February and December 2020. The purpose of the workshops was to engage with key players in the CCU supply chain, discuss the scope and design of the hub and progressively refine these. Workshop discussions were further informed by consultations with individual stakeholders and smaller group discussions.

[1] Novel Carbon Capture and Utilisation Technologies, group of Chief Scientific Advisor, European Commission, May 2018, referencing The Changing Paradigm of CO_2 Utilisation, Aresta et al, Journal of CO_2 Utilisation, 3-4, 2013, 65-73

4 Stakeholder Engagement

Overall, this study engaged with 35 different organisations (in some cases multiple individuals within the same organisation) through a series of 4 large workshops, one focused workshop with emitters and technology providers and a number of one-to-one consultations. These stakeholders can be further defined as follows:

- 8 technology providers utilising electrochemical (6) and biotechnological (2) solutions, and located in Scotland (1), rest of UK (5) and rest of world (2)
- 7 industrial emitters all with sites in Scotland, 5 of which are multinational, representing chemicals, fuels, and food and drink sectors
- 10 academic and research and technology organisations, 6 within Scotland, 1 from elsewhere in the UK, and 3 in the rest of the world
- 11 other stakeholders, representing the public sector (4), industry associations (2) and other interested industries which could make use of technologies or the products they produce (5)

The engagement activities with these stakeholders are detailed below.

Activity	Dates	Brief Description	Numbers Engaged
Workshop 1	26.03.20	Introduced the study and concept behind the Hub. Discussed its scope in broad details.	33
One-to-one consultations	31.03.20 – 17.08.20	Discussed what the Hub should provide in more detail, in order to meet the needs of both emitters and technology providers. Also engaged with relevant centres in other global regions to identify lessons learned and opportunities to collaborate.	17
Focused workshop	25.05.20	Presented and discussed outcomes of the one-to-one consultations and how these were shaping the concept for the Hub. This allowed emitters and technology providers to have greater awareness of each other's needs and offers.	10
Workshop 2	23.06.20	Presented and discussed a refined Hub structure, based on output from the first workshop and further consultations. Also introduced the Wood plc study and its purpose.	29
Workshop 3	23.09.20	Presented a further refined model of the hub and used online polling (Mentimeter) to assess participants' reactions to the model. Wood plc provided further details of the developing concept design for the sustainable manufacturing campus.	28
Workshop 4	26.11.30	Presented the final model for the hub and discussed any outstanding aspects raised by stakeholders. Wood plc presented outcomes of the technical design study including graphics for the sustainable manufacturing campus.	28

Table 1: Stakeholder engagement activities

5 High-level Concept for the CCU Demonstration Hub

The stakeholder engagement activities defined a high-level concept for the CCU Demonstration Hub that was refined over a period of 8 months. In general, it was agreed that there was nothing like the proposed hub in the UK. Other facilities offer testing and development of carbon capture technologies (e.g. Imperial College, University of Sheffield and Doosan Babcock), and several academic facilities were developing and supporting the development of CCU technologies, but none bridged the gap between academic research and industrial application across a range of CO_2 emissions and technology platforms.

5.1 Overall Vision for the Hub

The initial workshop, consultations and focused workshop indicated that the hub:

1. Would not be a true industrial 'demonstrator' (i.e. capable of capturing and utilising hundreds to thousands of tonnes of CO_2 per day), rather, it would be a flexible pilot plant, operating in the range of a few tonnes per day
2. Must be technology agnostic
3. Must be used to 'demonstrate' CCU technologies that are high TRL (7+) and commercially relevant to the emitters, i.e. demonstrate the whole process chain – from CO_2 source to a final product
4. Must be capable of delivering different emission compositions, to provide confidence to emitters that deployed technologies will work with industrially relevant emissions
5. Must offer continuous process runs of at least 1000h, to provide confidence to emitters that deployed technologies will work in industrially relevant conditions
6. Should connect with existing infrastructure and capability, including the Research Centre for Carbon Solutions (RCCS), the Industrial Decarbonisation Research and Innovation Centre (IDRIC), Scottish Carbon Capture and Storage (SCCS), the Industrial Biotechnology Innovation Centre (IBioIC) and the James Hutton Institute (JHI), and link to Forth Valley College for relevant skills and training opportunities
7. Should embed state-of-the-art, industry 4.0 capabilities, such as augmented and virtual reality and real-time access to trial data. This would enable it to be as "future proof" as possible and be differentiated from other facilities

These observations and aspirations were further refined through consultation but did not fundamentally change. Figure 1 (overleaf) shows how a utilisation technology could be positioned within the hub and its performance evaluated. Further, it is proposed that the facility will be defined so that several utilisation technologies could be demonstrated at the same time.

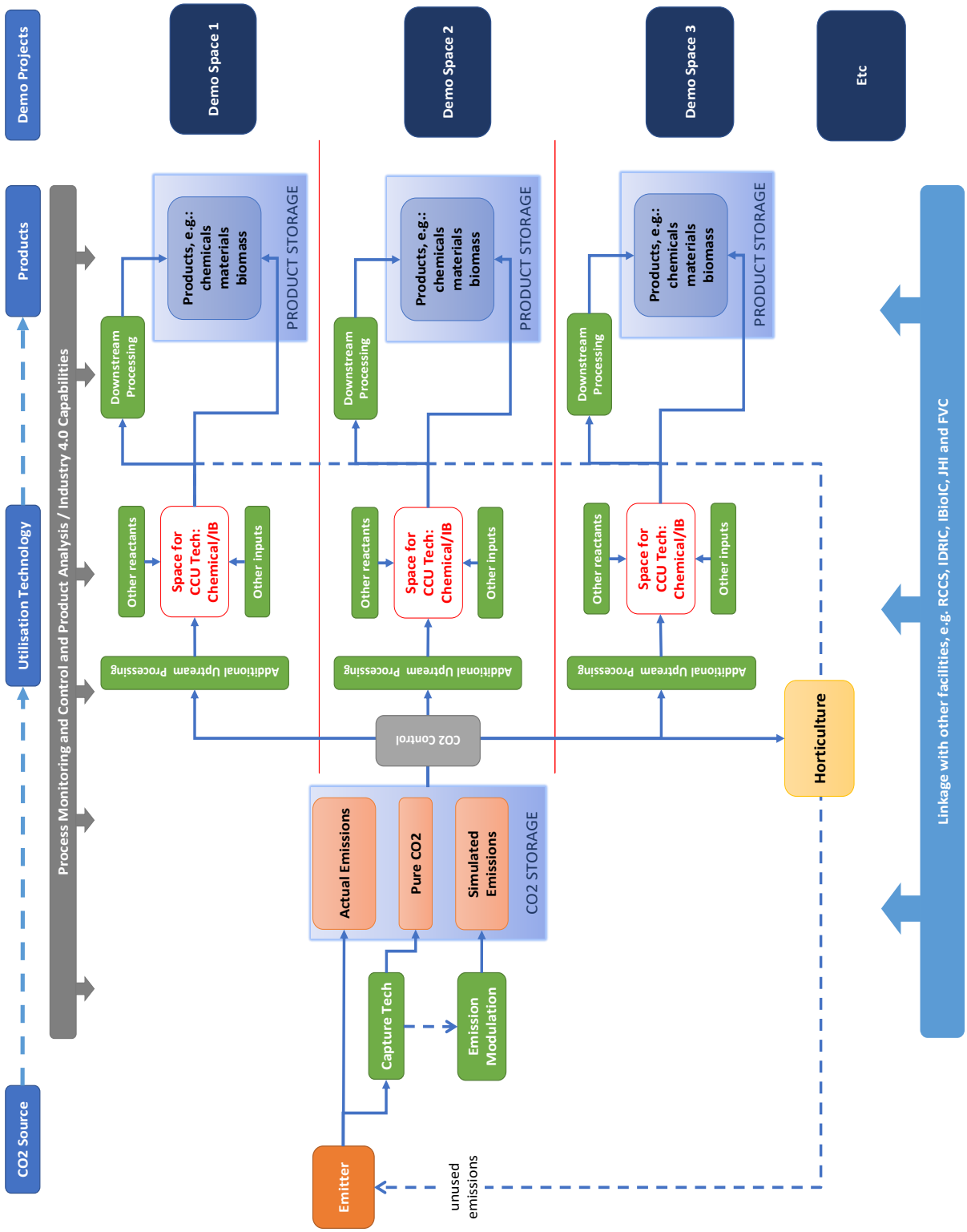

Figure 1: High-level concept for the CCU Demonstration Hub

The different aspects and features of the hub are described in more detail below.

5.2 CO_2 Emissions

The CO_2 source or sources should come directly from a flue stack and be routed to a number of different 'locations' within the facility for use by different CCU technologies. This may require blowers and pipes to move the CO_2 and/or some of the CCU technology could be located next to the emission stack. If necessary, the emissions could be cleaned (through a capture technology) and/or modulated to different CO_2 concentrations, pressures, temperatures, moisture content and/or with other chemicals (e.g. SO_x or NO_x) to represent emission compositions from a variety of industrial processes, e.g. chemicals, petrochemicals, steel, cement, power generation, etc. In this way the Hub would be capable of demonstrating the utility of a number of different technologies to a number of different industrial emitters. It was noted that a variety of emission compositions are available in Grangemouth and that there is strong support from emitters in Grangemouth for the hub, including allowing access to their flue stacks.

There would also be a requirement for CO_2 storage upstream of the utilisation technologies to enable provision to multiple demonstrators at the same time and to accommodate processes that need to run 24/7 within defined parameters (e.g. pressure, temperature). There would also be systems to recirculate unused emissions, divert to alternative utilisation technologies (e.g. horticulture) or vent through the original flue stack.

5.3 CCU Technology

These could be based on a chemical or industrial biotechnology conversion platform, or alternatively could be a horticulture-based platform (converting CO_2 into plant biomass). Most CCU technologies will operate with a range of emissions with a range of CO_2 concentrations and tolerate the presence of other gases. At this scale, these technologies are typically housed in one or two shipping containers or skid-mounted (for easier transport and siting). They may also require additional space for ancillary equipment, and to store both raw materials (required to convert CO_2 into the final product, such as mineral salts, hydrogen, or culture media for industrial biotechnology processes) and products. Storage facilities may be at ambient temperature or refrigerated dependent on the nature of the raw material or product. Each will have utility requirements such as 3-phase electricity, water, heat, cooling, waste treatment and drainage. In addition, some may require other services including high pressure steam and caustic cleaning. A source of sustainable electricity was considered essential to the hub, in the short term this could be delivered through a contract with a relevant supplier, in the long term through a standalone facility in the campus or through linking with one of the other initiatives across Falkirk Council area to provide sustainable electricity.

5.4 Process Control and Analytical Capabilities

While each demonstrator unit would have its own process controls, the Hub itself must be able to manage and monitor common upstream and downstream processes including CO_2 parameters (such as concentration, flow rate, pressure, temperature, moisture content, etc), preventing cross-contamination between demonstrators and be capable of independently starting and stopping individual demonstrators without affecting others.

This process control should be designed with industry 4.0 capability to provide augmented reality that will allow users to monitor and control processes and access real-time data remotely.

Additional capabilities would allow technology providers to monitor and analyse specific inputs and product streams and adjust process parameters accordingly.

5.5 Technical Support

Most technology providers are micro SMEs, which makes it challenging to provide staff for the periods of time to deliver demonstration projects (at least 6 weeks, and in some cases as much as 1 year). Thus, there would be a requirement for onsite technical staff to be provided by the hub to run demonstration projects. In addition, expert advice would benefit technology providers in terms of supporting applications for regulatory permits for demonstrator projects and, in at least some cases, for life-cycle analysis to demonstrate that their technology has a reduced carbon footprint and/or specific sustainability attributes.

Some of these aspects could be delivered through close partnership with the wider research community represented by IBioIC, RCCS, IDRIC, SCCS and JHI, for example analytical capabilities and expertise regarding specific platforms. Others could be delivered through a core complement of technical staff (as is the case in other pilot-scale facilities, e.g. Bio Base Europe).

5.6 Other Aspects

Health and safety oversight would be essential for the hub, in particular zoning for different technologies (e.g. some will require use of hydrogen) and ensuring that the hub itself is fully compliant with blast resistance requirements for the Grangemouth site.

In addition, office and meeting room facilities would be required – to support the management of projects and client engagement.

It was also felt that the hub should offer grow-on space and support for companies that may wish to establish a presence in Grangemouth, e.g. to work with further clients and make further use of the hub for that purpose.

Finally, it was clear from the consultation that supportive Government policy was needed – providing clarity on future fiscal and regulatory policies to underpin viable business cases for the adoption of CCU.

5.7 Out of Scope

Demonstrating novel carbon capture technologies was discussed as being relevant to the hub's operation. However, this was discounted for the following reasons:

1. All of the technology developers consulted could use unadulterated emissions, or with limited cleaning required and were keen to point this out. This is also more attractive to emitters, avoiding the need for additional equipment on their flues
2. There are a number of public and private facilities available in the UK, specifically for the development of capture technologies, including Imperial College, University of Sheffield and Doosan Babcock
3. The additional cost to implement capabilities to test different capture technologies

6 Conclusions

6.1 On the High-level Design for the Hub

The concept for the hub as presented above was considered by the majority of stakeholders consulted to meet with their overall expectations. Of 19 stakeholders responding to polling:

- 15 thought it was covering the main aspects
- 1 thought it was not covering the main aspects
- 2 thought significant aspects were missing
- 3 thought it was missing minor aspects
- 8 strongly disagreed with the statement 'that there was nothing to add'

Figure 2: How close is this high-level design to your expectations? (19 respondents)

This is therefore a good basis to progress to Stage 2, however there will need to be further refinement to ensure that, while not every aspect may be built into the facility from the start, it remains sufficiently flexible to accommodate additional capabilities at later dates, should the need arise. In this context, there will also be a need to consider practical aspects such as available funding and space.

6.2 On other Output from the Study Process

The study had to be adapted to work within restrictions resulting from the COVID-19 pandemic. Overall, this worked extremely well, with strong engagement from emitters, technology providers and relevant stakeholders throughout the ten months of this study. Participants were afforded multiple opportunities and mechanisms to contribute to study conclusions through the one-to-one discussions, a focused workshop and the larger workshops that combined traditional Q&A and verbal discussion, with online chat and polling tools. Overall, this iterative process established a trusted forum for discussion and captured wider and possibly more direct feedback on the evolving hub concept allowing it to be progressively built and refined. It also highlighted to public sector agencies the range of opportunities that were being presented by technology developers and were of interest to emitters. The fact that each participant knew who else was in the audience and understood their interests built trust and transparency and a sense of common purpose. Stakeholders were generally positive about this open forum approach and the opportunity to input at various points. In effect this generated a far greater understanding of individuals' positions and their requirements vis-à-vis CCU technologies than might otherwise have been the case.

There is ample evidence of bi-lateral discussions, including during the workshops where individuals discussed what would be required to make something happen, given the specifics of a site's emissions and individual CCU technology requirements, and offers to assist. In some cases, it is clear from

confidential discussions with emitters and technology providers, that NDAs have been signed allowing more detailed bi-lateral discussions and opportunities to progress, that can be directly linked back to presentations and meetings at the initial Living Lab event in January, and the subsequent workshops. More widely there is a sense of commitment to make the hub work, should suitable support be available.

7 Recommendations

Moving forward it is clear that engagement with stakeholders must be maintained. Primarily this should be through networking organisations such as NECCUS that provide a regular forum for interested stakeholders to be informed of developments and opportunities and also to feedback to Government.

In addition, it is clear that many of the technology providers are already in a position to undertake small scale demonstration projects with suitable financial support; so there is an opportunity to make use of existing Scottish, UK and perhaps EU funding programmes to establish a demonstration 'footprint' at Grangemouth. This could be through supporting individual projects, building limited connectors to flue stacks and other infrastructure (such as hard-standing and storage) that could be re-used for subsequent projects and eventually subsumed within the hub, which realistically will not be operational until late 2022 at the earliest. Support could be provided through existing Scottish Enterprise, Scottish Development International and Enterprise Europe Network mechanisms to link technology providers, emitters and research capabilities in Scotland to drive these opportunities forward. This also signals to a range of stakeholders the intent in Grangemouth to support CCU opportunities and is a logical step on the path to the sustainable manufacturing campus and building a sustainable manufacturing industry in Scotland, through transitioning existing industry and attracting innovative companies to establish in Scotland. In addition, the Scottish Government's 2020-21 Programme for Government includes £60 million to support the decarbonisation of industrial and manufacturing sectors, as well as stated intent to '*continue to support and invest in the development of CCUS projects in Scotland and commission a suite of research projects for CCUS*' and to develop a '*Carbon Capture and Utilisation Challenge Fund*'.

Table 2 summarises this plan of activities:

Activity	Timing	Brief Description
NECCUS webinars and newsletters	Monthly	NECCUS organises monthly webinars and issues a monthly newsletter for interested and relevant stakeholders. This provides an ideal forum for the public sector to keep the wider community apprised of campus developments and to highlight funding and collaboration opportunities.
Engagement with other facilities	As required	Both NORCE and the National Carbon Capture Center have signalled their desire to remain engaged with developments at Grangemouth and to explore opportunities for collaboration and mutual learning. This could be cemented through: • MoU to cooperate on future developments • Joining the existing global network of carbon capture test centres • Funded projects making use of different capabilities/facilities offered in Scotland and at these centres • Regular programme of events to keep each other up to date with developments – which could include site visits and information exchanges
SNZR Phase 2	As required	Phase 2 of SNZR will investigate options to decarbonise in specific industrial settings through discussion with emitters and others. This may provide opportunities to connect emitters and technology providers and others (such as researchers) that could be provided with some analysis to support specific collaborations outside of SNZR.
SE funding programmes	As required	Specific thematic funding programmes could provide the incentive for technology providers and emitters to engage in demonstration projects. These could be adapted from existing R&D schemes.
Database and/ or forum	Ongoing	A dedicated database and/or forum, supported by the public sector, could allow interested actors to be informed of each other's capabilities and requirements. This could be extended further afield through EEN for example, to attract other European partners.

Table 2: Options for ongoing stakeholder engagement

Appendix A - Organisations Consulted

- ABB
- Argent Energy
- Bouygues Energies
- CalaChem
- Carbon8 Systems
- Carbon Capture Machine
- Deep Branch Biotechnology
- Diageo
- Doosan Babcock
- Drochaid Research
- DSM
- Forth Ports
- Fraunhofer ICT
- Forth Valley College
- GreenSkill Environmental Technology
- GSK
- Heriot Watt University (Research Centre for Carbon Solutions, RCCS, and Industrial Decarbonisation Research and Innovation Centre, IDRIC)
- Industrial Biotechnology Innovation Centre (IBioIC)
- INEOS
- Ingenza
- Innovate UK
- Innovation Norway
- James Hutton Institute (JHI)
- Knowledge Transfer Network (KTN)
- Liquid Wind
- National Carbon Research Center
- NECCUS
- NiTech Solutions
- NORCE – Risavika Gas Centre
- Opus12
- Petroineos
- Scottish Carbon Capture and Storage (SCCS)
- Scottish Government
- Scotch Whisky Research Institute (SWRI)
- University of South Wales

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Scottish Enterprise

Falkirk Council

optimat

Business Growth | Economic Development | Technology Commercialisation

Head Office:

Optimat Limited

Torus Building, Rankine Avenue,

Scottish Enterprise Technology Park,

East Kilbride

G75 0QF, United Kingdom

Tel: +44 (0)1355 272 800

Email: resource@optimat.co.uk

Web: www.optimat.co.uk