Promethean Particles®

Commercialisation, Exploitation, Dissemination – Stakeholder Analysis

CCUS Innovation 2.0

Key Knowledge Deliverable 6.6

May 2025

Key Knowledge Deliverable Cover Sheet

This Key Knowledge Deliverable (KKD) has been produced by Promethean Particles Ltd. as part of the Department for Energy Security and Net Zero £1bn Net Zero Innovation Portfolio (NZIP) - CCUS Innovation 2.0 programme. The document is reflective of the status of the project at the time of writing. The material presented could have been subject to change as the project matured. These documents should not be considered a full representation of the final project.

Market analysis to identify the key players in the CCUS value chain, including technology adopters, end-users, and competitors. Final output will be a report on the analysis and results.

Description of project

The project will involve the design and fabrication of a prototype carbon capture unit that utilises Metal Organic Frameworks (MOFs) as the novel solid sorbent, which will be installed onto Drax's CCUS Incubation Site. The installed unit will be operated to demonstrate the effective separation of CO2 from Drax's industrial flue gas stream, with the sorbent adsorbing and desorbing over several cycles to demonstrate a capture capacity of 0.5-1tCO2/day. The use of this high-performance sorbent category will enable more energy-efficient CO2 capture – through reduced regeneration energy penalty – while overcoming several undesirable aspects of solvent-based CO2 scrubbing, such as zero waste production, zero aerosol emissions and a smaller site footprint. The demonstration of such a prototype unit, which utilises novel sorbent materials that are currently held back due to misconceived lack of scale and cost viability, is expected to significantly de-risk the innovation and - in turn - pave the way for adoption in a range of point source carbon-emitting processes and industries. A Lifecycle Assessment (LCA) and Technoeconomic Analysis (TEA) will also be conducted within this project, based on the data collected from test trials at Drax, and compared to alternative sorbent technologies where corresponding data is known or publicly available. This will validate the innovation of the novel solid sorbents and allow a strong business case to be built, for commercialisation and exploitation beyond the project timeframe.

Description of KKD D6.6 – Stakeholder Analysis

Within WP6, one of the aims is to promote the scope, aims and achievements of the MONET project to external audiences. While the technical work packages (WPs 1-4) focus on developing Metal-Organic Framework (MOF)-based Carbon Capture, Utilisation and Storage (CCUS), WP5 investigates the lifecycle and technoeconomic impact of the technology. WP6 runs in parallel to these WPs and targets the communication of project activities to external stakeholders, thereby increasing the likelihood of successfully exploitation and commercialisation beyond the project duration.

As part of the market analysis work in WP6, this deliverable report D6.6 identifies the various stakeholders relevant to a MOF-based CCUS value chain – from system integrators and end-users, through to regulatory bodies and trade associations. The report captures some key metrics of certain stakeholder groups, and discusses the relevance of these. As MOF-based CCUS is an emerging technology, the findings set out in this report lay the foundations for a path to commercialisation.

KKDs to be released in full:

D6.4 - Marketing Material Creation

D6.5 - Conference Presentations and Trade-Show Exhibitions

KKDs to be released after redaction:

D3.2 - Control and Safety System Manufacturing

D3.4 - Build of Capture Rig

D4.1 - Installation of Capture Rig

D4.3 - Rig Operation and Decommissioning

D5.1 - CAPEX Technoeconomic Analysis (TEA)

D5.2 - OPEX TEA

D5.3 - Life Cycle Analysis (LCA)

D6.6 - Stakeholder Analysis

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Introduction

Within the MONET project, the Technology Readiness Level (TRL) of MOF-based carbon capture and storage (CCS) will progress beyond its current status of TRL5. Aside from the technical development of the technology itself, the success of the project is reliant on the effective communication of project aims to external stakeholders, and the dissemination of project results.

As part of the Stakeholder Analysis activities, the Promethean team has identified various groups of external stakeholders – each of whom is expected to have an interest in the project progress and outcomes, but potentially for different reasons. The team has grouped these stakeholders into categories and captured relevant information about each of them that is thought to impact how they should be viewed or considered for dissemination and future commercialisation activity. Engagement with almost all of these stakeholders has been initiated in some form, all with the aim of laying the foundations for successful commercial deployment of the MONET technology during and beyond the project lifetime.

This Deliverable report summarises the stakeholder analysis work conducted and provides an overview of the stakeholder categories and the information captured. Where information is commercially sensitive, particularly where non-disclosure agreements (NDAs) are in place, details have been redacted or omitted.

With the stakeholder analysis work complete, an intended outcome is for the marketing materials created to promote MOF-based CCS (and reported in Deliverable 6.4) to be used most appropriately, to deliver a message that resonates with each target audience.

Project Stakeholders

End-Users (CO_2 Emitters)

The first group of stakeholders identified in this report is the potential end-users of the MONET technology, the organisations emitting CO_2 who are seeking a carbon-removals process. The companies listed in table 1 below have already engaged with Promethean and shown interest in MOF-based carbon capture; their company names have not been given here due to non-disclosure agreements (NDAs) being in place to restrict the sharing of their identity and the nature of discussions.

Nevertheless, the industry that each company is working in is provided below. All of these involve point-source emissions, i.e. CO_2 emissions result from an industrial process. Distinguishing the industry is important here as, from a technical perspective, the composition of the relevant flue gas, and available site infrastructure, will differ. These will therefore

determine how directly relevant the outcomes of the MONET project will be to each end-user. For instance, flue gas will be tested within the MONET project, where biomass is the fuel source. In this case, the CO2 concentration, and type and concentration of contaminants, are likely to be quite different to flue gas emitted from anaerobic digestion processes, where MOF-based CCS is of interest for biogas upgrading. Segregating these industries is the first step to understanding if and how each end-users requirements may differ.

Beyond technical requirements, identifying the end-user's industry is important as there may be differing levels of Government incentives available, or societal pressures, for each industry to implement CCS. This is likely to influence the company's motivations, impacting the pace at which MOF-based CCS could be implemented.

The location of operations for each end-user is given below. This can be important as, again, local Governments may have incentives or policies in place affecting the likelihood and speed of CCS technologies being developed and deployed.

Also described in Table 1 below is the Scale of Emissions, with definitions for the three groupings used. This categorisation is captured here as it impacts the overall size of the opportunity (and therefore potential demand for MOFs from Promethean's manufacturing processes), and may influence the timescale for deployment. For instance, decision makers for the decarbonisation of larger scale emission processes are likely to be more risk-averse, and require more proof points at intermediate scales before committing to a new technology. On the other hand, smaller emission processes are likely to present fewer engineering challenges and are therefore easier to retrofit a CCS process onto.

Table 1: Scale of emissions associated with various industries at certain locations

Organisation ID (Anonymised)	Industry	Location	Scale of Emissions*
1	Power Generation	Global	Large
2	Power Generation	Global	Large
3	Steel Manufacture	UK	Large
4	Chemical Manufacture	Global	Medium
5	Ceramics Manufacture	Global	Large

6	Cement Manufacture	Global	Large
7	Data Centre Management	Ireland	Medium
8	Chemical Manufacture	Turkey / UK	Small
9	Waste to Energy / Anaerobic Digestion (AD)	UK	Small
10	Oil & Gas	Middle East	Large

Note: Emissions Scale: Large = >1MT, Medium = >1MT, Small = <200KT

Engineering Companies

It is pertinent to note that Promethean is a producer of MOFs, an ingredient in carbon capture systems, and the company's mission is to be a large-volume manufacturer and supplier of MOFs. Therefore collaborating with organisations who are positioned to develop carbon capture systems, using MOFs as the sorbent, is crucial for the deployment of MOF-based CCS. These 'system integrators', downstream to Promethean in the value chain, have been identified as EPC (engineering, procurement, and construction) companies, who have process design and unit fabrication capabilities.

A selection of EPC companies who have already engaged in discussions with Promethean are given in table 2 below; however, their company names have not been given due to NDAs being in place.

The Focus Industry of each company (i.e. the industry where they currently operate, or are intending to operate in) is described below. This information has been captured here as it could align with particular end-users described in section 2.1, and could therefore form a logical collaboration.

The Location of the engineering firm is given for the same reasoning, alignment with certain end-users could prove beneficial. Also, as described for the end-users, there may be Government incentives or policies impacting the motivations and pace at which these engineering companies could deploy new CCS technologies.

Table 2 below also captures whether or not each company is already working on CCS projects. This is relevant because an existing track record of CCS demonstration units, and an appreciation of general process requirements and current challenges, will provide distinct advantages. Moreover, this likely reflects the company's motivation for working on CCS projects beyond pilot-scale trials.

MOFs offer technical advantages over incumbent solvent CCS sorbents when it comes to regeneration requirements; these ultimately impact the required footprint of the CCS system. Therefore MOF-based CCS is thought to lend itself to modular systems, making it easier for end-users to integrate at existing sites. Whether these EPC companies are already developing modular CCS systems has been captured here, as it shows potential alignment in strategy with Promethean's technology.

Table 2: Anonymised survey of companies engaged with Promethean Particles

Organisation ID (Anonymised)	Focus Industry	Location	Modular CCS System Developers?	Existing CCS Projects?
11	Broad Coverage	Global	Yes	Yes
12	Energy Transition	UK	Yes	Yes
13	Energy Transition	Europe	Yes	No
14	Oil & Gas / Cement	Global	Yes	Yes
15	Commercial CHP	Europe	No	Yes
16	Commercial CHP	UK / Ireland	No	Yes
17	Energy Transition	Global	Yes	Yes
18	Waste to Energy / AD	UK / Ireland	Yes	No
19	Oil & Gas Upstream	UK / USA	Yes	No
20	Oil & Gas / Power Generation	Global	Yes	Yes
21	CCS Implementation	Scandinavia	Yes	Yes
22	Energy Transition	Global	No	Yes

23	Energy Transition	UK	Yes	Yes

Definitions of acronyms: AD = Anaerobic Digestion, CHP = Combined Heat Power

CO2 Utilisers

As carbon capture technologies develop, and their implementation grows, important questions arise around the fate of the captured gas. For a capture technology to succeed, there needs to be a viable plan for the CO2 beyond capture.

Our lives and economies are reliant on chemicals and products derived from fossil fuels – from petrol to drive vehicles, to solvents required for several chemical processes, to polyurethanes used in everyday products such as clothing. If the CO2 gas we capture can be processed into these useful products, there would be a decreased reliance and use of fossil fuels, thereby further reducing CO2 emissions.

This approach towards a circular economy, is what is targeted by CO2 Utilisation companies – organisations with novel, emerging technologies to process captured CO2 into useful, valuable products. Table 3 below highlights just a few of these organisations, which Promethean has already engaged with.

Table 3: Organisations that are engaged with utilising captured CO2

Organisation ID (Anonymised)	CO2 Utilisation Path	Location	Focus Industry
24	Deep sequestration in concrete	UK	Construction
25	Surfactant & polymer production	UK	Chemical Manufacturing
26	Methanol / oxalic acid production	Netherlands	Chemical Manufacturing
27	Limestone production	Global	CASE Industries

As carbon capture and CO2 utilisation are emerging markets, and value chains are not yet defined or established, it is important to ensure technologies can match up. With this in mind, Promethean will continue to engage with these companies, with the aim that MOF-based CCS being developed within MONET will result in captured gas that can be used in their downstream processes.

CO2 Off-Takers

While the processing of captured CO2 into valuable products should be the goal if targeting a circular economy, it should also be recognised that most CO2 utilisation technologies are currently in development. Therefore, some technical and commercial barriers remain before these processes can be deployed at any meaningful scale.

If carbon capture technologies continue to develop at pace, and at the scale required on a global scale, then alternative means of processing or storing the captured gas are needed. Fortunately, there is some existing infrastructure for processing and transporting/distributing CO2.

Beyond these more traditional means of CO2 distribution, there are companies specialising in the transport and sequestration of captured CO2, and it is anticipated that they will play a vital role in supporting the development of carbon capture technologies through downstream gas processing, see Table 4.

Table 4: Summary of off-takers of CO2

Organisation ID (Anonymised)	Relevant Offering
28	CO2 distribution through standard applications
29	CO2 distribution through standard applications
30	Transportation & Storage
31	CO2 pre-sequestration treatment services

Broader CCS Value Chain

The organisations categorised here do not fall into any of the aforementioned classes of stakeholders, based on the information gathered so far by Promethean. However, it is apparent that they have an interest in MOF-based CCS, and in the outcomes of Project MONET. These are currently comprised of consultancy firms, research organisations and foreign trade bodies, with whom Promethean has held discussions. It is anticipated that the technical results and proof points from MONET will be of interest to this group, as they have a network of contacts (including end-users) who would be interested in implementing MOF-based CCS.

Table 5: Overview of companies associated with the CCS Value Chain

Organisation ID (Anonymised)	Value Chain Role	Focus Industry
32	AD Consultancy / Service Provider	Energy to Waste
33	Innovation Demonstrator	Steel / Cement / Ceramics
34	Innovation Demonstrator	
35	CCUS Consultancy	CCS Implementation
36	Technology Showcasing / Regional Implementation	Energy Transition
37	Technology Showcasing / Regional Implementation	Energy Transition
38	Technology Showcasing / Regional Implementation	Energy Transition
39	Technology Showcasing / Regional Implementation	Energy Transition

Trade or Professional Bodies

Here, we consider trade associations and other advocacy groups who are thought to have an interest in at least one aspect of the MONET project. Below is a non-exhaustive list of the organisations that Promethean has had some form of interaction with to-date, and an overview of why they have been considered a project stakeholder.

UK Carbon Capture and Storage Research Centre (UKCCSRC)

The UKCCSRC part-funded a precursory R&D project to MONET, titled PICASSO (Pilot Scale Carbon Capture using Solid Sorbents). This project was led by The University of Nottingham, with support from Promethean – thus, Promethean has prior links with the UKCCSRC.

The Research Centre brings together ideas and research on a range of CCS technologies, and aims to promote these for technological advancement towards commercial deployment. As such, the organisation naturally has an interest in project MONET and its outcomes. In turn, project dissemination activity should and will be aimed at this group.

Carbon Capture and Storage Association (CCSA)

The CCSA is the lead European association accelerating the commercial deployment of CCUS. The organisation operates through advocacy and collaboration, with its membership base comprised of technology developers, end-users and policy makers. This means the CCSA is well placed to support the advancement of emerging CCS technologies, such as MONET. Promethean has prior engagement with the group and will look to establish stronger working links in order to promote the benefits of MOF-based CCS to their members, and to engage with advocacy groups, thereby giving MONET the best chances of expedited, successful deployment.

Chemical Industries Association (CIA)

Members of the CIA include manufacturers, formulators and developers of chemical technologies; all of these are likely to emit carbon either directly or through their supply chains. Through its membership to the CIA, Promethean understands the pressures facing the chemical industry to decarbonise, and the appetite for viable CCUS technologies. Therefore continued engagement with the CIA can bring benefits on two fronts – increased commercial opportunities for MOF-based CCS technology with end-users, and support for Promethean as a chemical manufacturer of MOFs.

Nanotechnology Industries Association (NIA)

The NIA is a trade body promoting the commercial adoption of nanotechnology and advanced materials. Promethean has a history of links with the NIA and has already established a strong working relationship.

As Project MONET involves the development of MOFs, a class of novel advanced materials, in an industrial application, the NIA will be able to provide support. By connecting with the NIA's network of members, Promethean is accessing support to comply with all relevant regulations as MOF production is upscaled for commercial use.

Regulatory Bodies

For any new product, service, or technology to be successfully commercialised, regulatory compliance is essential. Here, the key regulatory bodies – relevant to the MONET project and activities – are listed. Any prior interaction between Promethean/MONET and the organisation is given, along with the expected types of regulations to affect the project and future technology deployment.

Environment Agency (EA)

Within the MONET project, there is a requirement to ensure that the installation and operation of the prototype CCS rig at the flue gas test site complies with all relevant regulations, e.g. air and water emissions.

Health and Safety Executive (HSE)

There are two aspects of regulatory/legal compliance enforced by the HSE that is relevant to the MONET project and technology.

First is compliance with health and safety law, specifically the Health and Safety at Work Act 1974. During the manufacture of MOFs, Promethean ensure that safe working practices are implemented for operators and the local area. This involves using a combination of mechanical means, documented procedures, and personal protective equipment (PPE) to minimise or mitigate health and safety risks.

The second aspect relates to UK REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulatory compliance. While the UK was in the European Union, REACH regulations were monitored by the European Chemicals Agency (ECHA). However, since the UK left the EU, REACH regulations have been mirrored in the UK and are now enacted by the HSE. Promethean is, and will continue to, monitor the REACH regulatory landscape and work with the HSE as required to ensure compliance.

European Chemicals Agency (ECHA)

As alluded to in Section 2.7.2, ECHA continues to enforce REACH regulations within the EU, and monitors compliance. Where MOFs are being manufactured in - or imported into - the EU, REACH compliance is required, and registrations should be submitted to ECHA for approval.

As MOF-based CCS develops, it is anticipated that the technology will be deployed in the EU, and Promethean will be exporting MOFs into the economic zone. There may be potential for Promethean to be manufacturing within the EU in the future too, meaning REACH compliance is a must. With this in mind, Promethean are already scoping out the regulatory landscape and will comply with relevant regulations to ensure MOFs and MOF-based CCS can be exploited in the EU.

Export Control – Department of International Trade (DIT)

As carbon capture is required on a global scale, it is expected that demand for MOF sorbents will extend beyond the UK domestic market as MOF-based CCS technology advances. Therefore, export compliance is essential.

Financial Investors

MOF-based CCS is an emerging technology that requires financial investment in order to develop the technology, and to deploy commercially. While Government funding (such as that from the Department of Energy Security and Net Zero under the CCUS 2.0 competition) can be used to de-risk the nascent technology, it is recognised that private investment will also be needed. In this section, a selection of financial investors have been identified, all of whom are or may be interested in backing MOF-based CCS.

Firstly, venture capital (VC) firms are a highly relevant group of investors to startups with innovative technologies anticipating rapid growth. There are VC firms who seek to invest in technologies specifically tackling carbon emissions, or the so called ‘Clean Tech’ sector. The MONET technology could also be relevant to ‘Deeptech’ investors; these are typically venture capitalists investing in advanced materials or manufacturing, robotics, aerospace, artificial intelligence, the Internet of Things (IoT) and virtual reality, as examples.

Beyond VC, there are corporate investors who have, and are continuing to, invest into carbon removal technologies. Many of these are specifically viewing MOF-based CCS as a credible next-generation technology, and the potential for MOFs to be applied in other applications within the energy transition.

These sets of private investors have been identified as potential routes to fund Promethean, and its work in developing MOF-based CCS, to advance and commercially deploy the technology beyond Project MONET.

Conclusion

To summarise this stakeholder analysis report, project MONET’s success relied not only on demonstrating the effectiveness of MOF-based carbon capture, but also on effective stakeholder engagement and communication. Stakeholder analysis was a critical component of the project as communication with relevant audiences paves the way to achieving Promethean’s strategic goal of becoming the world leader in the manufacture and supply of MOFs. Showcasing Promethean’s MOF manufacturing capabilities, and positioning MOF-based CCUS, to CO2 emitters potentially requiring industrial quantities of MOF is an important aspect to technological and commercial advancement.

This activity on stakeholder analysis also allowed Promethean to fully understand the requirements of various CO2 emitters, utilisers and off-takers and therefore guide application development and deployment. A deeper understanding of regulation and legislation surrounding the deployment of MOF-based technology, both in the UK and globally, has allowed Promethean to anticipate regulatory challenges and to develop a strategy to overcome them. Finally, a more comprehensive understanding of the financial landscape surrounding MOFs and CCUS will enable Promethean to seek investment from appropriate partners in the future to assist in advancing the technology described in project MONET to a real-world commercial product.

A diverse range of stakeholders were engaged across the CCUS value chain including:

- CO2 emitters with varying technical needs and regulatory environments. Promethean engaged with a variety of emitters to understand their requirements and current understanding and utilisation, if any, of CCUS.

- Engineering companies (EPCs) who could potentially integrate MOFs into CCUS systems. Engaging with stakeholders from this category ensured that Promethean's MOF production strategy was technically aligned with companies developing modular CCUS systems.
- CO2 utilisers and off-takers who will store captured CO2. Input from those interested in storage and downstream processing allowed Promethean to better understand how MOF-based CCUS can align with their operational needs and contribute to a circular economy.
- Consultancies, trade bodies, and research organisations who influence adoption of CCUS technology and policy. Interacting with stakeholders in these areas allowed Promethean to align its technology with the requirements of those actively involved in the CCUS space i.e. industry needs. Furthermore, engaging with trade bodies has helped foster, amongst potential end-users, a better understanding and acceptance that MOF-based CCUS is a credible pathway to decarbonisation.
- Regulatory agencies ensuring compliance for safe and legal deployment (HSE, REACH, ECHA, DIT). Interactions with regulatory bodies is a vital component for any potential product launch and Promethean's engagements in this area will help ensure safe and compliant launch of its MOF products for global CCUS markets in the future.
- Financial investors critical for scaling the technology beyond public funding. While government funding has helped to de-risk this emerging technology it is vital that additional investment from other sources e.g. private investment, venture capital, be identified. Promethean has identified potential sources of future investment to advance and commercially deploy the technology developed under project MONET.

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