Joint Action Plan for Smart CO_2 Transformation in Europe

CO_2 as a resource

Enabling European industry to become more resource efficient, sustainable, and eco-competitive.

SCOT

Smart CO_2 Transformation

Carbon dioxide (CO_2) utilisation is a broad term that covers a variety of innovative industrial processes that can transform carbon dioxide into a variety of value added products such as chemical products, synthetic fuels and mineralised wastes. The SCOT project has identified several areas of focus to accelerate the market uptake of CO_2 products, which are set out in this document.

SEVENTH FRAMEWORK PROGRAMME

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Foreword

By 2050, Europe needs to have decoupled its economic growth from its emissions of carbon dioxide (CO_2). This is a direct response to the compelling evidence from the increasing risks of climate change brought about by the anthropogenic emission of greenhouse gases, and CO_2 in particular. Moving from energy systems that are primarily reliant on fossil fuels to those which use greater amounts of lower-carbon sources is a broadly accepted policy choice of many Member States, although the exact technology choices and the speed of the transition vary e.g. Germany and the United Kingdom. In addition to its low-carbon energy transition, Europe requires new approaches to broaden its material base, away from fossil fuel sources. It needs to secure and create domestic jobs through economic growth by innovation in technologies, and the markets that they serve. CO_2 utilisation provides the potential to positively impact on these challenges.

Scientific and industrial progress has discovered solutions which allow CO_2 to become an increasingly important resource; this will lead to a future in which CO_2 is extensively utilised to make products. By accelerating development in the area of CO_2 utilisation, Europe can improve its industrial competitiveness whilst contributing to reducing its impact on the planet. However, for this to happen, there needs to be a clearer long-term strategy, which itself depends on a stable long-term research and industrial policy framework. CO_2 utilisation also provides a route for Europe to realise its ambition to move to a circular economy. Support for the circular economy comes from a high level, as evidenced by First Vice-President Frans Timmermans statement on the 15th of July 2015[1]:

"Europe should be a frontrunner on the circular economy. I believe passionately in this because the future of the European economy is not in competing on low wages; the future of the European economy is not in competing on wasting finite resources. The future of the European economy is in the circular economy, in reusing, in putting things back into the economic cycle. This means rethinking the way we design, produce, consume and dispose of products."

This document sets out a Joint Action Plan which will highlight the steps that can be taken to address the challenges highlighted in the SCOT project's Strategic European Research and Innovation Agenda.

1 https://storify.com/EU_Commission/circular-economy-chat-askfrans

Foreword

The SCOT documents are the product of extensive research and mapping of CO_2 utilisation throughout Europe aimed at understanding the current state of CO_2 utilisation. During this research process the following have been conducted:

- Over **300 interviews** with stakeholders from the CO_2 utilisation sector including academia, policy makers, technology developers and CO_2 emitters from industry
- **Over 10 workshops** at (inter)regional level to synthesise and discuss preliminary results
- A comprehensive **regional assessment** to map CO_2 utilisation actors, the existing funds allocated to CO_2 recycling projects and to produce regional SWOT/SOAR analysis
- A comprehensive **socio-economic analysis** to map major CO_2 emitters, energy infrastructures, and assess existing policy and regulations
- An elaborate desk research on three CO_2 transformation routes: mineralisation, power to fuels, and chemical building blocks
- Extensive review of intermediate results by an international and renowned panel of experts and Public Consultation

Executive Summary

CO_2 utilisation is beginning to create new opportunities for economic growth, and provide opportunities for greater innovation to boost Europe's competitiveness. In addition, CO_2 utilisation can also help to support Europe's decarbonisation and resource efficiency agendas, and provide a route for Europe to become less dependent on imports of fossil fuels.

To realise these aims, the sector needs to mature and develop. This document recommends **collaborative and concrete actions** which should be started **within the next five years** to accelerate the development and deployment of CO_2 derived products and processes within Europe. Each of these actions aims to tackle an aspect of the non-technical and technical challenges that hamper the market development of CO_2 utilisation identified throughout the SCOT project. The actions have been chosen through collaborative discussions with a wider group of CO_2 utilisation stakeholders, using the SCOT project's Strategic European Research and Innovation Agenda as a guide.

The SCOT project's Joint Actions

- **The creation and development of a European CO_2 Utilisation Association**
- **The creation of European Modular Pilot Plant and Verification Centres for CO_2 utilisation**
- **Continued or increased funding for fundamental CO_2 utilisation research (TRLs 1-4)**
- **Establishing a support programme for the most promising CO_2 utilisation technologies at the demonstration level**
- **Building capacity and raising awareness of the CO_2 utilisation sector**
- **Greater clarity of the impacts of wider European policies on the CO_2 utilisation sector**
- **Increased transparency and harmonisation in Life Cycle Analysis (LCA)**
- **Build a European CO_2 utilisation eco-system through a new Joint Technology Initiative**

Introduction

The aim of this Joint Action Plan (JAP) is to help the European commission, regions, the public sector, industry and academia to identify core actions that can be undertaken to accelerate the market development of the CO_2 utilisation sector through research and deployment of CO_2 utilisation technologies. The JAP is by description a Joint Action Plan and will therefore require investment of time and effort by the actors and stakeholders in the CO_2 utilisation community to help progress the actions identified. SCOT has gathered a network of regions and actors together, who are interested in the development of CO_2 utilisation technologies. This network has enabled the JAP to be a living document that has evolved throughout the research and analysis of the SCOT project.

The SCOT project consortium will undertake responsibility for the initial tasks outlined in the JAP to start a European Association for CO_2 utilisation, which then is envisaged to provide further leading roles in implementing further actions. Key organisations such as CO_2Chem, Dechema (CO_2NET), Greenwin, Axelera, Climate KIC and EnCORE, will be asked to contribute to certain actions due to the alignment of the actions with their organisations' priorities and ongoing operations. It is known that new Horizon 2020 projects such as CarbonNext[2] will respond and deliver parts of research actions highlighted in the JAP particularly around Life Cycle Analysis, techno-economic analysis and stakeholder engagement.

This JAP will be disseminated during the last months of the SCOT Project. Focus will be given to gaining the support of the relevant authorities and decision makers so that the JAP and Strategic European Research and Innovation Agenda (SERIA) can be taken forward.

This Joint Action Plan is the last of the three main documents produced by the SCOT project. The first is a Vision for the CO_2 utilisation sector in Europe, and the second is the Strategic European Research and Innovation Agenda that identifies many of the non-technical and technical challenges facing the sector. The Vision document explored why Europe should be interested in developing its CO_2 utilisation sector over the long-term, and the SERIA provided details on the major non-technical and technical challenges that the sector should focus on addressing, to accelerate the sector's market development. Both of these provided a firm basis for the recommended actions in this document; the Joint Action Plan

The main results of the SCOT project have identified the creation of the European CO_2 Utilisation Association and the European Modular Pilot Plant and Verification Centres for CO_2 Utilisation as key underpinning initiatives to accelerate the market development of the CO_2 utilisation sector in Europe. Given the complementary nature of all the actions, interaction between them is crucial: each action will complement and strengthen one another, ultimately accelerating the market development of the sector.

2 · This H2020 project is still in the grant agreement stage – 17/6/2016.

Introduction

Over the long-term, the actions could converge into a coordinated European initiative that promotes and develops a strong interconnected European CO_2 utilisation eco-system.

Each section of this document corresponds to an identifiable 'Joint Action' and together they form the Joint Action Plan as shown in Figure 1.

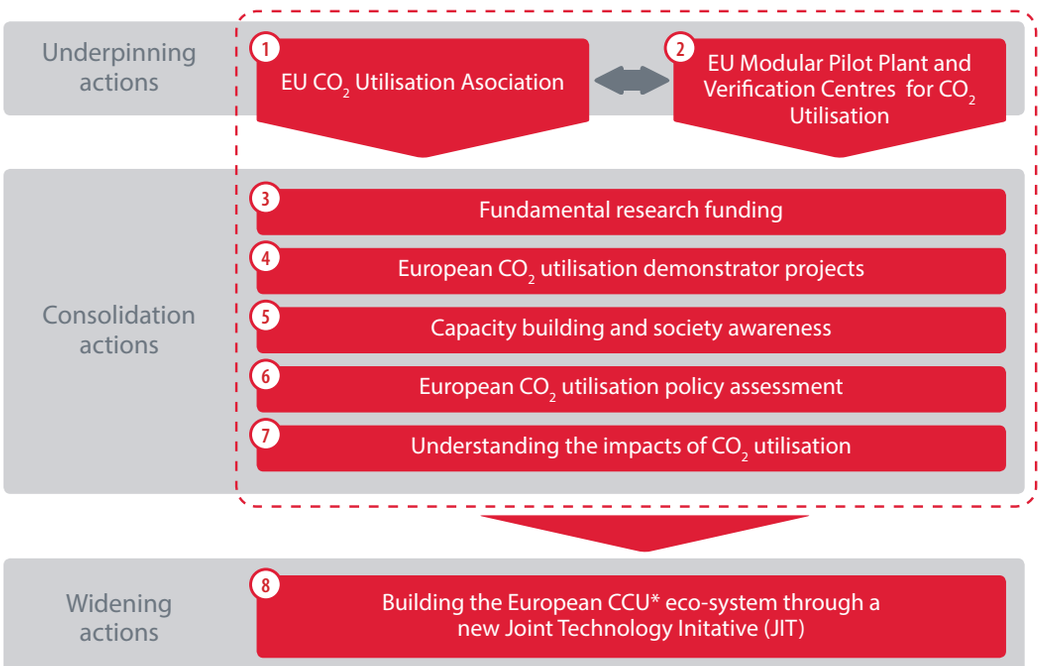


Figure 1 Joint Action Plan

**CO_2 utilisation is a term that covers the utilisation of the carbon dioxide molecule. It is often termed Carbon Capture and Utilisation (CCU), Carbon Dioxide Utilisation (CDU), or other similar variations. This report will use the terms CO_2 utilisation and CCU throughout, as both are commonly used interchangeably.*

What is CO_2 Utilisation?

CO_2 utilisation is a broad term that covers a variety of established and innovative industrial processes that utilise CO_2 as a source of carbon, by transforming it into value added products such as chemical feedstocks, synthetic fuels or building materials. CO_2 utilisation can therefore be viewed as a range of novel or enhanced technology pathways that utilise CO_2. During the transformation, bonds between the carbon and oxygen atoms are broken and new bonds are formed with other reactants. Most reactions will also require an additional energy input, which must come from low-carbon energy sources to prevent the emission of further CO_2. The transformation of CO_2 occurs naturally e.g. photosynthesis and mineral carbonation, and much research has been devoted to studying and improving the speed, control, and efficiency of these processes. The SCOT project focuses on chemical routes for transforming the CO_2 molecule, the Bio-based Industries JTI[3] covers the biological transformation routes.

As the SCOT project focuses on CO_2 transformation technologies and processes (Figure 2), other related technologies such as those for capturing and transporting CO_2 for carbon capture and sequestration (CCS) are not discussed in detail. Direct physical uses of CO_2 without a transformative step are also outside the focus of the SCOT project e.g. enhanced oil recovery, using CO_2 as a solvent, or in carbonated drinks.

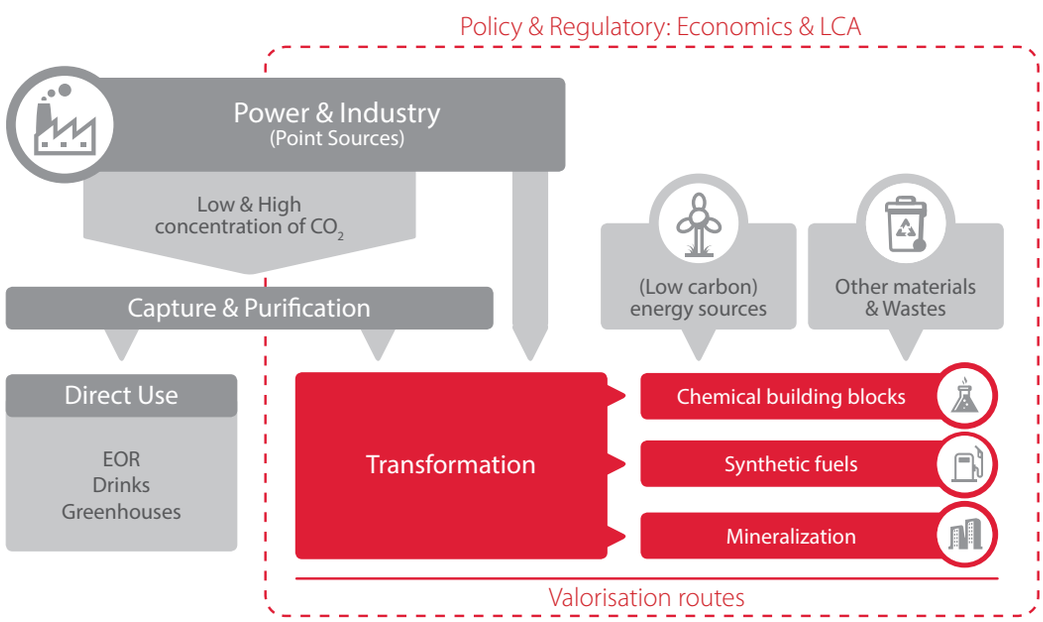


Figure 2
The SCOT
Global
Value
Chain

3 · http://www.bbi-europe.eu/

What is CO_2 Utilisation?

CO_2 can be transformed into a wide range of products from chemicals to fuels to building materials, from plastics to memory foams. The CO_2 is used as a carbon source replacing the carbon typically sourced from crude oil, natural gas or coal. Over 90% of organic chemicals are derived from fossil carbon and 5-10% of crude oil is used in the manufacture of these products; replacing this fossil carbon with carbon from CO_2 provides new sustainable process routes. Replacing the fossil fuels themselves with synthetic fuels for the purpose of large scale seasonal storage of energy could be a volume market, and this would require market changes to allow synthetic fuels to capture part of the market from conventional fossil fuels. Other inputs are also typically required to transform CO_2 into products. These can be in the form of energy such as heat or electricity as well as material inputs such as fly ash, hydrogen or epoxides. It is essential that any new CO_2 utilisation process has a lower carbon footprint over its total supply chain than equivalent products manufactured using fossil fuel routes. To achieve this, comprehensive Life Cycle Analysis (LCA) is required.

1 European CO_2 Utilisation Association

The establishment of a European CO_2 Utilisation Association, based in Brussels, is viewed as one of the highest priorities in the Joint Action Plan. The primary aim of the Association should be to provide an increased level of advocacy for the CO_2 utilisation community; to voice the interest of its members and continually and consistently raise the profile of CO_2 utilisation in aiding Europe to meet a number of its wider policy objectives. This will also continue the momentum created by the SCOT project for the CO_2 utilisation sector, as the SCOT project formally finishes at the end of September 2016.

CONTEXT

The creation of the SCOT project's Vision and the SERIA documents identified a number of non-technical challenges that could hamper the uptake of CO_2 utilisation technologies in Europe. Some of these are local and regional in nature, but many could be helped by discussion at a pan-European level. The SCOT project believes that the majority of these non-technical challenges, which are related to policy frameworks, or societal uptake, can be better addressed by coordination through a CO_2 Utilisation Association that has strong links with industry, policy makers and other stakeholders. The creation of an Association would provide an advocacy role for the sector, for the continued policy focus on research, demonstration and commercialisation of CO_2 utilisation technologies within Europe.

The association would focus on CO_2 utilisation, and will be complementary to the Zero Emissions Platform (ZEP)[4] that is focussed on Carbon Capture and CO_2 storage (CCS). The European CO_2 Utilisation Association would seek to collaborate with ZEP on specific issues when this is of benefit to both groups e.g. issues related to CO_2 capture or feasibility studies that link the two areas. The Association, for instance, will not have Enhanced Oil Recovery using CO_2 in its scope, as this is better suited to promotion under ZEP, even though it is often described as a CO_2 utilisation process.

Whilst the SCOT project's remit was to focus on the chemical transformations of CO_2, the Association should include the direct uses of CO_2 too (where the CO_2 molecule is not transformed), such as supercritical solvents and also bio-based CO_2 utilisation routes.

4 · http://www.zeroemissionsplatform.eu/ (online) accessed April 2016

In order to expand the CO_2 utilisation network the Association would work in partnership with existing CO_2 utilisation communities of interest e.g. CO_2Chem[5], ClubCO_2, CO_2Net, SusChem, linked industry associations such as CEFIC, and Technology Platforms with a growing interest in CO_2 utilisation, such as the European Steel Technology Platform. The aim is to make CO_2 utilisation more and more visible and to ensure that different actors connect to each other to help accelerate the commercialisation of CO_2 utilisation products and processes. Members would include for example: technology developers, Academic institutes, Research Institutes, Regional Agencies, Member State agencies, Non-Governmental organisations, and other wider stakeholders.

KEY OBJECTIVES

The Association's main objectives are to:

Be an advocate for supporting further development and deployment of CO_2 utilisation in Europe

- Provide an increased level of advocacy for the CO_2 utilisation community and continue to raise the profile of CO_2 utilisation strategically in aiding Europe to meet a number of its wider policy objectives. Reducing fossil fuel and chemical products import dependency, and transitioning to a more circular economy are two examples of policy interest.
- Participating in and contributing to the agenda setting and design of new funding mechanisms, to ensure CO_2 utilisation interests are reflected
- Leading and contributing to relevant events and conferences, by interacting with national and international organisations to ensure the growth and promotion of the Association and its members' interests
- Responding and actively participating to European policy initiatives by creating specific policy briefing papers and strategic funding papers
- Mobilising industry and other stakeholders within Europe to work in partnership and deliver on agreed priorities
- Establish and foster links / interactions with CO_2 utilisation sector groups outside Europe

Be a repository and source of information for the European CO_2 utilisation community

- Continuing to gather data to expand the SCOT database of CO_2 utilisation projects
- Being repository for regional, national and European reports regarding CO_2 utilisation and associated initiatives
- Providing regular communication/advocacy reports on the latest developments from Brussels likely to affect the CO_2 utilisation community
- Providing information about upcoming funding calls and feedback from previous funding calls

Making sure its members have opportunities to interact and collaborate with each other

- Convening working groups on specific issues, bringing together the expertise of our members
- Creating a stronger link between various stakeholder groups including academia, industry, policymakers, Non-Governmental Organisations and the wider public

5 · As a UK funded project, CO_2Chem currently links 183 UK-based and 137 European-based organisations together; engagement with this community would be key to success of the new association.

- Providing a members directory and assisting in partner matching for funding calls
- Providing a neutral platform for association members to have discussions on various areas of common interest
- Promoting synergies with other initiatives that are linked to the development of CO_2 utilisation (e.g. bio-based economy, carbon capture and storage, innovative value chains, certification bodies, development of the circular economy, deployment of hydrogen supply chains, etc.)

Providing education and training to enhance the knowledge base of a wide group of stakeholders

- Coordinating member-only webinar series for knowledge transfer and capacity building
- Creating educational and promotional materials to increase the public and wider stakeholder awareness of the benefits of CO_2 utilisation
- Promoting access to courses and professional development opportunities provided by the association or its members

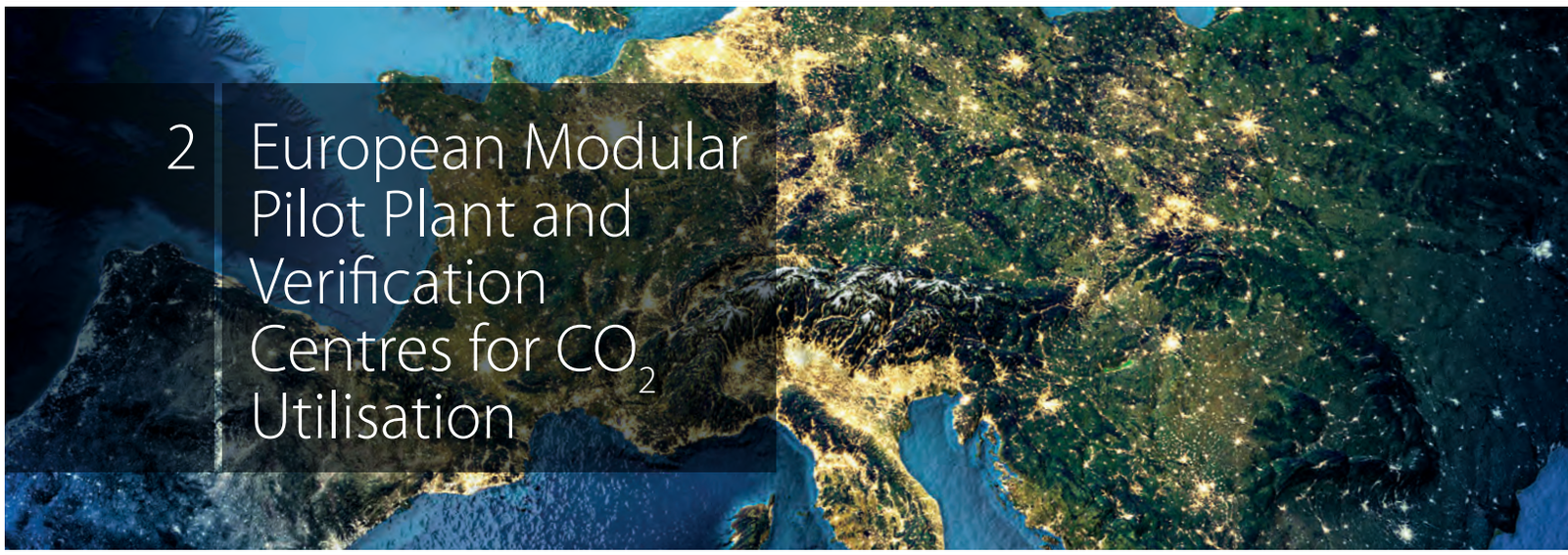
EXPECTED IMPACTS

- Greater visibility for CO_2 utilisation in EU Commission and Member States
- Increased levels of networking leading to more coordinated approaches to funding, and increased collaboration
- Stakeholders have an increased knowledge of European developments in the CO_2 utilisation sector
- Acceleration of the market development of CO_2 utilisation products leading to reduced import dependency, diversified supply chains and potential export opportunities of know-how as well as products

NEXT STEPS

The SCOT project is seeking to provide the seed corn funds to create and start the CO_2 Utilisation Association. This would allow some initial scoping work to be undertaken to progress several Actions in this Joint Action Plan. Additional funding will also be sought from Regional and Member State public bodies in the first few years.

Task	Timeframe	Responsibility
Create a detailed business plan for prospective funders	2016	SCOT
Produce a membership pack in which membership benefits are outlined	2016	SCOT
Approach regional authorities for initial funding contributions and submit proposals where relevant	2016	SCOT
Create the Association and register it as a legal entity	2016	SCOT
Invite organisations to join	2016	SCOT
Approach other organisations to form a consortium to apply for SC5-07-2017	2016	CO_2 Utilisation Association
Create job descriptions for staff and start the recruitment process	2016	SCOT
Develop the Association website	2016	SCOT then CO_2 Utilisation Association



2 European Modular Pilot Plant and Verification Centres for CO_2 Utilisation

The creation of a number of European Modular Pilot Plant and Verification Centres for CO_2 utilisation will enable industry and academia to test out various processes and technologies at industrially meaningful plant scales. This joint action is focussed on bridging the gap between lab scale and demonstrator scale facilities. The locations of the facilities would be decided in the future, but likely to be best supported in CO_2 utilisation cluster regions that have an active industrial and academic community. The potential to create specialist centres built around specific industrial feedstocks would also be a determining factor in the choice of location e.g. steel, petrochemicals, cement, power generation. These European facilities would therefore create shared infrastructure with access to process gas stream inputs such as cement flue gas, power sector flue gas, and hydrogen with an ability to test, verify and certify processes and products.

CONTEXT

The SCOT project has received significant feedback on the challenges of the translation of CO_2 utilisation research from the early stages at the bench/lab scale through to the pilot scale (TRL3-6). This is typical of other sectors too, and is commonly termed the 'Valley of Death' where promising projects falter due to the funding requirements necessary to scale up and de-risk technologies i.e. to validate whether bench scale processes are viable even at a pilot scale. The CO_2 utilisation sector has a particular set of requirements that are costly to implement at a pilot scale level, when access to actual process gas feedstocks would be advantageous. Therefore, having a number of shared facilities that have undertaken the complex and lengthy tasks of connecting to process gas streams will help accelerate CO_2 utilisation development. Figure 3 shows where the shared Modular Pilot Plants are positioned in the pathway of scaling up to commercialisation. A shared facility also allows the funding risk to be broadened and spread between public and private funders, and allows technology developers to concentrate on innovating technologies rather than on the burden of high risk financial investments on R&D facilities. The European Marine Energy Centre[6] and the European Carbon Dioxide Capture and Storage Laboratory Infrastructure[7] (ECCSEL) are a couple of examples of shared infrastructure that would provide valuable lessons in the development of the Modular Pilot Plant and Verification centres. The area of Intellectual Property (IP) protection and confidentiality is a

6 · www.emec.org.uk
7 · www.eccsel.org

major challenge for shared facilities, which would have to be fully addressed to build trust, and attract users and wider support from the community. The experience of other sectors could provide useful guidance on how best to approach this. This is a crucial area to resolve, as without a robust system to protect IP in a shared facility, many technology developers simply would not accept the risk to use the facility, regardless of the benefits.

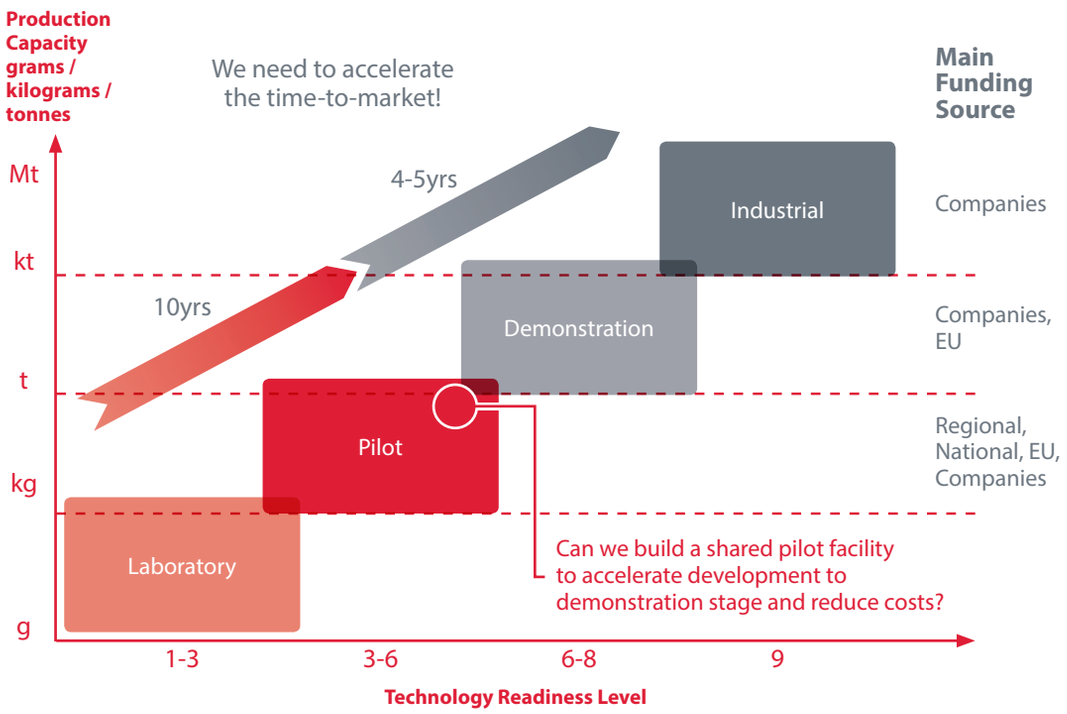


Figure 3 Scale up of processes from research laboratory to demonstration scale

Technical and innovation challenges for the CO_2 utilisation sector can broadly be thought of as a focus on trying to do more with less (energy or materials). Speeding up reactions, with less need to replace equipment and materials, with less waste or by-products, in a more environmental manner, or with less costly materials. Innovation in reactor design, process intensification, and separation techniques are also likely to prove fruitful areas for development in overcoming the low equilibrium yields of many potential products from CO_2. All of these areas would benefit from access to a pilot scale facility that provides connections to actual process gas streams rather than synthetic gas streams. The lack of access to process gas streams was seen as a major weakness in the sector's existing range of facilities, which would be also be addressed by the Modular Pilot Plants. Other process inputs like electricity and heat, would be able to be controlled in a precise and repeatable manner, and the design of the facilities would aim to be flexible and modular to provide a range of options and a degree of scalability to technology developers. This will allow technologies to be tested under a range of potentially dynamic conditions, which will help to drive innovation and also crucially help to de-risk various technologies too.

The chemical industry has evolved a design paradigm primarily oriented towards large scale production and continuous use of its assets. Chemical plants that are designed for more flexible use (typically smaller production scales, lower capex with potentially lower efficiency) are likely to become more common as the plant flexibility becomes a more important driver for process design. Flexibility will become more important in order to take advantage of increased periods of lower cost energy driven by the increased amounts of variable renewable energy generation.

This type of dynamic operation would be able to be tested at the Modular Pilot Plant and Verification Centres.

Through discussions with the CO_2 utilisation community it is clear that facilities already exist in several partner regions which are used to test specific technologies with various synthetic gas stream inputs. These are a mixture of private and public research facilities. The sharing of these facilities under bilateral contractual agreements is a possibility with many facilities open to discussion about this type of access. The locations of the facilities would be decided in the future, but likely to be best supported in a CO_2 utilisation cluster region that has an active industrial and academic community.

An additional function of the facilities will be to verify certain technology elements of the CO_2 value chain, which will provide a level of evidence to help inform policy and further technology development.

KEY OBJECTIVES

The strategic goal of the European Modular Pilot Plant and Verification Centres is to accelerate the development of CO_2 utilisation technologies by sharing the organisational and financial risks of pilot scale facilities. This technology innovation will itself accelerate the commercialisation of CO_2 utilisation products The centres will:

- Provide a controlled environment (1) to test, optimise and verify CO_2 utilisation process flows, catalysts and reactor developments, (2) to verify the performance of CO_2 utilisation processes under dynamic input conditions, and (3) to validate the type of services that CO_2 utilisation processes may provide e.g. to provide balancing services to electrical grid operators through adjustment of the electrical demand of the process
- Allow the harmonisation of accelerated testing programmes specifically focussed on CO_2 utilisation technologies
- Allow the de-risking of CO_2 utilisation technologies by allowing a better understanding of the costs and performance characteristics under various controllable and repeatable input and process conditions. This would also help to improve knowledge of the potential or room for improvement of various technologies too
- Allow industry and academia to better understand and validate business models, which will help build the evidence base for policy makers
- Create a hub for CO_2 utilisation innovation by offering access to state of the art facilities (lab space, modular plant and testing facilities)
- Enhance the synergy between the different actors of CO_2 value chains
- Enhance the visibility of CO_2 utilisation in Europe, benefitting public perception
- Allow independent verification and certification of technical performance of various technologies - which could be crucial to securing recognition under different regulatory regimes
- Improve the comparison of different processes and process routes by means of life cycle analysis implemented on data from industrially meaningful scale plants

EXPECTED IMPACTS

- Accelerate lab scale discoveries through to demonstration scale investments
- Significant reductions in costs and effort to take a process from lab scale through to pilot plant scale due to shared funding of facilities
- A shared use of infrastructure and equipment rather than creating individual facilities for each process or technology developer leading to efficient use of financial resources
- Increase in the number and type of processes that can be trialled at pilot scale due to reduced risks and costs
- Provision of a physical hub or hubs for Europe to scale up CO_2 processes
- Increase investment in CO_2 utilisation middle TRL research (TRL3-6) leading to the prioritisation of process and technology development
- Increased amounts of verified industrially meaningful empirical data for technology development and policy makers (where available)

NEXT STEPS

Task	Timeframe	Responsibility
Set up a working group specifically for development of Modular Pilot Plants Action	Autumn 2016	SCOT transferring to working group
Review similar facilities for other sectors within Europe / Globally to identify best practices e.g. ECCSEL, European Marine Energy Centre.	Spring 2017 onward	Working group
Investigation of possible financial support at regional, Member State and EU level	Ongoing	Working group & Commission
Identification of facility sizes, aims, costs and potential revenue streams coupled with the identification of potential locations through engagement with various stakeholders	Spring 2017 onward	Working group
Develop roadmap for creation of facilities	Spring / Summer 2017 onward	Working group

3 Fundamental research funding

Continued or even increased funding for fundamental CO_2 utilisation research (TRLs 1-4) from regional, national or Pan-European sources is important to the long-term progress of the CO_2 utilisation sector. Underpinning scientific research is generally not a high priority for private sector funding, as the timeframes to a return on the investment are much longer than more applied research targeted at higher TRL levels. For Europe to make a transition to a future where CO_2 is used more and more as a carbon source, breakthroughs in several areas would be helpful inter alia discoveries in CO_2 catalytic science, discoveries in CO_2 reaction kinetics, discoveries in novel CO_2 reaction pathways and reactor designs, and discoveries in separation techniques.

CONTEXT

Fundamental scientific discoveries are the basis of innovation and the foundation for disruptive technologies. The ability to exploit CO_2 as a carbon resource will be helped by a greater understanding of the reaction pathways that enable the production of more sustainable chemicals, fuels, feedstocks, and materials. Using CO_2 as a feedstock will allow Member States to consider a reduced need for fossil resources, and, in particular, could help the transition of the chemical industry towards greater sustainability and being a major part of the circular economy. In addition, the integration of renewable energy sources in chemical production through CO_2 utilisation processes could establish the chemical sector as a major producer of clean technologies, alongside its traditional outputs of chemicals feedstocks and fuels.

The SCOT project suggests that the following areas are considered for increased fundamental research, but also recommends that this is not viewed as an exhaustive list. Additional areas should continue to be funded and also be able to become a focus for increased funding too.

- **CO_2 catalytic science**
- **CO_2 reaction kinetics**
- **Novel CO_2 reaction pathways**
- **Novel reactor designs**
- **CO_2 capture techniques including direct air capture**
- **CO_2 product process separation techniques**
- **Direct utilisation paths from impure gas sources (cement, power generation, etc.) in a single process without needing a prior CO_2 separation and purification step**

KEY OBJECTIVES

- Development of novel homogeneous and heterogeneous chemical catalysts and catalysis processes to optimise activity and selectivity under a range of input gas conditions, including dilute and impure streams while also reducing the energy demand
- Development of novel reactor designs
- Development of novel methods of product separation from reactants
- Development of reactive capture and conversion of CO_2 to products in a single process to reduce OPEX and CAPEX costs
- Development of novel photochemical catalysts
- Development of novel photoelectrochemical catalysts
- Development of materials and methods for direct capture of CO_2 from the atmosphere to provide lower cost and with greater energy efficiencies

EXPECTED IMPACTS

- Continued or enhanced National and Regional research funding for fundamental CO_2 utilisation
- Increased levels of fundamental scientific knowledge leading to breakthroughs for the CO_2 utilisation sector
- A breakthrough in the underpinning scientific knowledge in the areas listed would lead to improvements and perhaps entirely new methods for utilising CO_2
- Allow CO_2 utilisation derived fuels, chemicals, and materials to close the cost gap to alternative sustainable products

NEXT STEPS

Task	Timeframe	Responsibility
Management of map of CO_2 Utilisation sector	Ongoing	SCOT, TU Berlin, University of Sheffield
Increase networking and partnering opportunities	Ongoing	CO_2Chem, Dechema, Axelera, CO_2Forum, CO_2 Utilisation Association
Lobbying for funding increases	Ongoing	Stakeholders, CO_2 Utilisation Association, CO_2Chem, SusChem
Identification of key opportunities for applied fundamental research	Ongoing	Stakeholders, CO_2 Utilisation Association

4 European CO_2 utilisation demonstrator projects

Establishing a support programme for the demonstration of the most promising CO_2 utilisation technologies is vital to accelerate CO_2 utilisation market deployment. Demonstration level projects would be led by the private sector but co-funded from public sources, as is common with other innovative areas. It is strongly recommended that CO_2 utilisation projects are included in the NER 400 Innovation Fund.

CONTEXT

The Modular Pilot Plant and Verification Centres will provide a method to tackle the initial technical scale-up challenges from lab scale to pilot scale. Beyond this, demonstration facilities are then required to further scale up CO_2 processes towards commercial industrial deployment (Figure 3). The private sector would take the lead on the choice of technologies to scale up to demonstrator levels, and where these should be located, but co-funding from public sources will also be required in a similar way to CCS and renewable energy demonstrator projects.

Due to the scale required for demonstrator projects, it is typical for partnerships to be formed between the private and public sector to share the burden of technological risks and of funding. CO_2 utilisation technologies have not been specifically included in the New Entrants' Reserve (NER). The NER is a Member State demonstration programme which seeks to establish the leading CCS technologies (pre-combustion, post-combustion, oxyfuel, and industrial applications) and renewable energy technologies (bioenergy, concentrated solar power, photovoltaics, geothermal, wind, ocean, hydropower, and smart grids). The SCOT project strongly recommends that CO_2 Utilisation demonstration projects are included in the next demonstration funding programme, the NER 400 Innovation Fund. This would provide a significant potential source of funding to CO_2 utilisation demonstration projects to accelerate the market development of CO_2 utilisation products and processes within Europe. As NER400 is planned for the timeframe 2021-2030, a series of structured calls for CO_2 utilisation scale-up may be a suitable additional mechanism during the period to 2021. Funding under industrial ecology or eco-efficient industry programmes may also be suitable for CO_2 technology demonstrator.

KEY OBJECTIVES

The aim is to build a world leading European CO_2 utilisation ecosystem and accelerate the market development of CO_2 utilisation technologies and processes, which have been validated in an operational environment at a demonstrator scale. The demonstrator projects' objectives are to:

- Demonstrate leading edge technologies at a scale just below commercialisation to enhance the industrial confidence in making investments for profitable CO_2 conversion technologies
- Accelerate technology development and drive down costs
- Demonstrate how industrial integration and symbiosis between novel CO_2 utilisation processes and existing industry can develop
- Demonstrate the integration of complete chain of CO_2 utilisation, from source to the product end users, in a profitable manner

EXPECTED IMPACTS

- CO_2 utilisation demonstrators are included in the NER 400 Innovation Fund.
- Accelerated deployment of CO_2 utilisation technologies to demonstrator and then commercial scale

NEXT STEPS

Task	Timeframe	Responsibility
Review NER400 Innovation Fund and make recommendations of how CO_2 utilisation demonstrators can be included	2016	SCOT, CO_2 utilisation Association
Review alternate sources of funding for demonstrator projects	Late 2016 - 2017	CO_2 Utilisation Association
Advocate for inclusion of CO_2 utilisation Association demonstrators in NER400 Innovation fund	Late 2016 - 2017	CO_2 Utilisation Association, Industrial Clusters and Stakeholders

5 Capacity building and raising awareness of the CO_2 utilisation sector

As an emerging sector, CO_2 utilisation will benefit from a wider understanding of its advantages and benefits, as well as a practical and economic view of how and why the growth of the sector should be of interest to Europe. A range of stakeholders need information about CO_2 utilisation processes and products, as without an increased understanding of the opportunities that CO_2 utilisation offers alongside an appreciation of its perceived risks, the speed of deployment and market uptake of CO_2 utilisation products may be hindered. Understanding and addressing various perceptions of CO_2 utilisation will be helpful to create new approaches to raise awareness. Building capacity in the sector from the workforce to policy makers via tailored educational programmes is necessary too.

CONTEXT

CO_2 utilisation is an emerging sector, and as such, knowledge transfer and capacity building are important elements in developing the field. Having a range of differing stakeholders including European policy makers, industry, and the wider public understand the opportunities that CO_2 utilisation might offer is key to accelerating the sector's market deployment. New skills and competencies are likely to be needed in the industrial workforce to help ensure the growth of the sector, although many of these are expected to be transferable and embedded in existing industrial knowledge such as the chemicals sector. Raising the awareness generally across policy makers, industry, and the wider public is highly desirable for the sector.

It is important for the CO_2 utilisation sector that policy makers, government bodies, and public agencies have a better understanding of what CO_2 utilisation can and cannot deliver and how the growth of the sector could help to achieve wider policy targets. Understanding how the sector can contribute to the circular economy, decoupling economic growth from emissions and increasing energy security, means that the sector has a better chance of being considered when wider industrial and environmental policy is being drafted. The **active** promotion of CO_2 utilisation is needed, and an ongoing discussion about the policy support between and within Member States to achieve a viable and growing market for CO_2 utilisation products is required. Policy makers at Regional, Member State, and European levels therefore need to have access to information to understand how the CO_2 utilisation sector can help them meet their wider longer-term policy ambitions towards eco-efficiency with improved quality of life.

CO_2 utilisation is becoming an increasingly important option for the strategic management of carbon alongside the development of an integrated carbon capture and transport infrastructure that provides a link to long-term geological storage. The reduction in the use of fossil fuels themselves is also of major importance in order to reduce the consumption of non-renewable resources. However, the differences between these options for managing carbon also needs to be better understood by a wider range of stakeholders, as each has a separate set of priorities, drivers and scale. To help this wider understanding at a policy level, it is recommended that the European Commission requires that CO_2 utilisation options are considered in national 2050 low-carbon plans, alongside other carbon management strategies. In the next 5 years an initial step to build awareness of the sector is to have each European Region or Member State carry out a CO_2 utilisation assessment. This would take the form of a two stage process, with an initial outline assessment and potentially a detailed follow up assessment if the outline assessment has identified particular areas of interest. A typical set of assessment requirements are suggested in Appendix A.

Building knowledge and increasing skills through tailored educational courses would be undertaken via a number of routes such as technical colleges, higher education institutes, regional clusters, and consultancies. This will ensure that the new skills and competencies essential for the successful commercialisation and upscaling of CO_2 derived products and processes are available. The CO_2 association should have a role to play in promoting these tailored educational courses, and may be able to create and provide short courses for its members.

Building awareness throughout wider society is also important, as new products can take time to be understood and accepted in various markets. A better understanding of the perceptions of CO_2 utilisation by various stakeholders would be a valuable area of research, as this would provide feedback on the type of CO_2 utilisation products and processes that are likely to have greater market acceptance.

KEY OBJECTIVES

The overall objective is to ensure that the potential of CO_2 utilisation is well understood and that the sector gets the required societal, industrial, legislative, financial, political, academic and scientific support for accelerated growth. With that aim, the key objectives are:

- Inform policy makers and government agencies of the opportunities associated with CO_2 utilisation
- Promote that each Member State or Region should undertake an initial assessment of their CO_2 utilisation potential based on their CO_2 resource and existing developments in the sector
- Promote that each Member State and Regional 2050 low-carbon plans should include an analysis on the potential for CO_2 utilisation
- Develop further training programs in higher education (following on from those started during the SCOT project)
- Develop continuing professional development programmes targeting various stakeholder groups
- Promote knowledge transfer across the sectors and regions
- Understand emerging public attitudes towards CO_2 utilisation (and different CO_2 utilisation options) and the antecedents of these attitudes
- Communicate clearly and illustrate the benefits and risks of CO_2 utilisation technologies for key stakeholders (public, industrial, financial, academic and scientific, and political)

EXPECTED IMPACTS

- Creation of Regional or Member State assessments for CO_2 utilisation
- Increase the understanding of policy makers and government bodies
- Increase the understanding of the potential of CO_2 Utilisation in Europe and the need for further regional improvement
- Increase in skilled workforce for CO_2 utilisation
- Increase in industrial symbiosis (interconnection between sectors along the CO_2 value chain)
- Enhance the engagement of society and wider public acceptance of CO_2 based products
- Increase in societal awareness of the benefits and risks of CO_2 utilisation for Europe
- Improve the understanding of the perception of CO_2 utilisation by various stakeholder groups

NEXT STEPS

Task	Timeframe	Responsibility
Promote CO_2 utilisation assessment in future national 2050 low-carbon plans	Next 3 years	CO_2 Utilisation Association
Promote the undertaking of an initial CO_2 utilisation assessment in each Member State or Region with industrialists and technology developers	Next 3 years	CO_2 Utilisation Association
Develop educational resources including European Master level modules to be integrated in higher education programmes	Next 3 years	University of Sheffield, University of Liege
Promote education and knowledge transfer across Europe	Next 3 years	CO_2Chem, CO_2 Utilisation Association
Organise policy study trip and in-house training for policy-makers	Next 3 years	CO_2 Utilisation Association
Lobby to obtain funding to perform public perception researches	Next 3 years	CO_2 Utilisation Association
Develop a communication strategy to explain clearly the risks and benefit of the technologies	Medium term	CO_2 Utilisation Association
Organise public events to increase society awareness	Medium term	CO_2 Utilisation Association

6 European CO_2 utilisation policy assessment

CO_2 utilisation needs supportive policy to succeed, but in most cases it has been treated with little or no consideration in existing legislation, which is not unusual for an emerging sector. The SCOT project has made some initial steps in analysing relevant legislation (ETS[8], Waste directive[9], REACH[10], NER400[11], Fuel directive[12]) but these need more detailed analysis to make sure the opportunities afforded by CO_2 utilisation are supported by forthcoming European Commission proposals. The inclusion of certain CO_2 mineralisation routes in the EU-ETS, and the inclusion of CO_2 utilisation sector demonstrators in the allowable pool of projects for the NER400 Innovation fund are two areas identified for consideration by policy makers. Knowledge of the impact and role of CO_2 utilisation needs to be further understood via increased understanding of policy implications, and increased interactions with Member State and European policy makers.

CONTEXT

CO_2 utilisation processes and products hold the potential to decouple economic growth from carbon emissions and support a wider resource efficiency agenda. In common with other disruptive technologies, a strong legislative role will be required to accelerate the market development of CO_2 utilisation products and processes. However, before this is possible, policy makers need to have a better understanding of the merits of CO_2 utilisation and need to be more aware of where CO_2 utilisation fits in the current legislative landscape. Due to the wide range of technologies and early-stage nature of many CO_2 utilisation processes, various European policies could potentially be linked e.g. policies on renewable fuels, waste, energy, emissions, and the circular economy. The potential interplay of legislation can create confusion about the regulatory environment, which can ultimately hamper the market development of CO_2 utilisation products. Therefore, having a detailed understanding of the advantages and disadvantages that existing and proposed directives can have on the CO_2 utilisation sector is an important step.

8 · The **EU emissions trading system (EU ETS)**: It is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively.
9 · The **Waste Framework Directive** sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery.
10 · The European Union (EU) has established **REACH**, an integrated system for the registration, evaluation, authorisation and restriction of chemicals, together with a European Chemicals Agency.
11 · **The NER400 Innovation Fund**, successor of NER300 programme, aims to support new-to-market low carbon innovations in energy intensive industry by reserving 400 million allowances (representing an estimated 5-10 billion EUR), from 2021 onwards.
12 · **Fuel Quality Directive (FQD)**: Common fuel quality rules have been set-up in order to reduce greenhouse gas emissions from transport. They also ensure that air pollutant emissions from vehicles are optimally reduced, a single fuel market is established and vehicles operate correctly everywhere in the EU.

The Waste Directives, REACH, Fuel Quality Directive, The Renewable Energy Directive, the Industrial Emission Directive and the EU ETS have been identified as key policies to better understand their likely impacts on the CO_2 utilisation sector. The SCOT project has completed an initial review of the ETS, which provided some insights regarding the legislation on the CO_2 utilisation sector. Having certain mineralisation routes qualify under the EU-ETS would be a positive help for the sector, which is a legislative change the Association should seek to explore and promote further.

Harmonisation of various legislation is a benefit across Member States to create a single market. Problems created by lack of harmonisation are evidenced by the differences in end-of-life criteria between various Member States. This is a particular challenge in the carbonation of solid wastes where the carbonation process takes a solid waste and turns it into a potential building material. This needs to meet the end-of-life criteria set by a National Environment Agency, which can differ between Member States. Technology developers therefore need to satisfy criteria in different markets, which can be a major additional expense.

In more general terms, the difficulty in achieving a 'product' status from various wastes undermines the potential of mineralisation to contribute to Europe's objective for the development of a Circular Economy.

KEY OBJECTIVES

Build on the work of the SCOT project to present a coherent list of regulatory and policy areas which represent potential opportunities and barriers to the development of CO_2 utilisation. Several objectives are targeted:

- Promote the creation of certain market segments specifically for CO_2 utilisation products to provide scale-up opportunities to the sector. In particular, the Fuel Quality Directive should be an area of focus to provide a defined market for CO_2 derived fuels, while paying close attention to the calculated CO_2 reduction of these fuels.
- Make recommendations to clarify if different types of carbon management can be distinguished by the ETS framework, e.g. the permanent storage of CO_2 via mineralisation
- Review the Waste Directives, Fuel Quality Directive, Industrial Emissions Directive, Renewable Energy Directive and REACH and make recommendations for the CO_2 utilisation sector (through briefing papers and/or position papers)
- Consolidate strong arguments to ensure that CO_2 utilisation demonstrator projects are able to access part of the EU ETS Innovation fund (successor of NER 300)
- Identify and contact decision makers at EU level and potential stakeholders with similar interests (advocacy groups, other EU technology platforms, designated policy designers at DGs etc.)
- Provide a regulatory monitoring to increase the knowledge base of stakeholders by informing them about the regulatory barriers and overlaps that exists within the current legislation and provide solutions to overcome these (preparation of briefing papers, amendment proposals, brochures, etc.)
- Promote the harmonisation of Member State 'end-of-life' criteria and validation across the EU to provide a greater market for waste materials to be utilised for CO_2 utilisation

EXPECTED IMPACTS

- Increasing consideration of the CO_2 utilisation sector in legislation and the role that they could play
- Increasing markets for CO_2-derived products
- Increased awareness of national and European policy makers in the opportunities that CO_2 utilisation can provide

NEXT STEPS

Task	Timeframe	Responsibility
Build working groups with policy experts and makers	Next 3 years	CO_2 Utilisation Association
Identify contacts and work together at EU level with key stakeholders	Next 3 years	Policy working group under CO_2 Utilisation Association
Promote SCOT EU-ETS amendments for inclusion of mineralisation technologies that meet certain criteria in its implementation	Next 3 years	Policy working group under CO_2 Utilisation Association
Identify and prioritise EU and national policies where CO_2 utilisation could be supported. Create briefing papers and / or position papers to ensure CO_2 utilisation has greater awareness in future rounds of policy development	Medium term	Policy working group under CO_2 Utilisation Association

7 Understanding the impacts of CO_2 utilisation

Currently there are many questions surrounding the environmental and economic prospects of the various technologies within the CO_2 utilisation sector. An increased effort in Life Cycle Analysis (LCA), sustainability and techno-economic capability is needed to answer these questions and provide clarity to funders and investors.

CONTEXT

Greater understanding of the climate mitigation potential of CO_2 utilisation processes and products is an important consideration for many markets and legislation. Transparency of Life Cycle Analysis and sustainability methods are required to be able to compare differing CO_2 utilisation products, which is especially important when they are compared to a conventional product route with the use of fossil resources. Trust in CO_2 utilisation products will be helped enormously by increasing transparency and the introduction of a guidance framework for boundaries, allocations and functional units for LCA and sustainability CO_2 utilisation studies. Today, there is a lack of published data on the LCA and sustainability of the different CO_2 - derived products. In order for policy to be more evidence based, products need to be benchmarked against other already established alternatives. Standardised application of allocation, boundaries and functional units, sustainability criteria and gap closures would allow a set of standards, certification and labelling schemes to be created, and this would undoubtedly help with public perception too.

In conjunction with increased use of more standardised LCA and sustainability score, CO_2 utilisation processes need early evaluation for economically viability too. Better data on the production yields, costs of the different process configurations, supply chain and market analysis are essential in order to determine the economic welfare of each technology. The Modular Pilot Plant and Verification centres have a role to play here, and data should be shared, where possible, when the confines of commercial confidentiality allow.

CO_2 utilisation has an important role in the renaissance and sustainability of Europe industrial sector, e.g. in the sustainability and broadening of the feedstocks of the European chemicals sector. Marketing of CO_2 utilisation products would benefit in some circumstances from an

independent certification system to allow manufacturers to communicate the environmental benefits of their products. Such a system based on comprehensive LCA and quantified sustainability metrics would enable consumers to make informed choices regarding the environmental impacts of the products, and increase understanding of the utilisation of CO_2 as a carbon feedstock.

KEY OBJECTIVES

- Create guidelines to give a consistent LCA and sustainability methodology for CO_2 utilisation which expands upon ISO 14040/14044, enabling calculations to be comparable to each other and to non-CO_2 utilisation processes. Guidelines on consistent boundary conditions, allocations, choosing functional units and the transparency of calculations will be especially helpful.
- Promote conditions that all future EU funded calls for CO_2 utilisation should carry the requirement for the production of a published LCA, sustainability, and broad techno-economic analysis, with published data showing boundary and allocation choices
- Promote conditions for increasing the amount of publicly available data on LCAs, sustainability, and cost estimations (which should be helped by the development of the European Modular Pilot Plant and Verification Centres)
- Create an independent environmental footprint certification scheme for CO_2 utilisation products

EXPECTED IMPACTS

- Accelerated paths to market
- Smarter screening of viable process routes to ensure environmental credentials
- Clarity for policymakers and investors on the impacts of CO_2 utilisation on economy and environment

NEXT STEPS

Task	Timeframe	Responsibility
Ensure LCA, sustainability, and techno-economic analysis included in grant calls	Ongoing	Commission, Regional and National Funding Bodies
Create a working group to produce guidance for undertaking LCA in CO_2 utilisation and identify areas where a policy support is needed in order to provide a commercially proven technology	Short term	Working group
Create a Certification Scheme for CO_2 utilisation environmental footprint	Medium term	Partnership with Certification bodies, interested stakeholders

8 Building the European CO_2 utilisation eco-system through a new Joint Technology type Initiative

Joint Technology Initiatives (JTIs) are long-term Public-Private Partnerships involving industry, research community, and public authorities. Their aim is to pursue common ambitious research objectives which support large-scale multinational research activities in areas of major interest to European industrial competitiveness and issues of high societal relevance. It is proposed that a new CO_2 utilisation JTI is created to ensure the delivery of the actions identified as key for the development of the sector and promote the development of demonstrators. The CO_2 utilisation JTI will be the tool of the European Commission to facilitate cooperation between the private sector and the public sector and the academic community to accelerate the market development of CO_2 utilisation products and processes.

CONTEXT

A strong CO_2 utilisation industrial sector will significantly help Europe become less and less dependent on fossil fuels by becoming more resource efficient, which helps to safeguard the competiveness of its industries and security of supplies. It also provides Europe with a route to decouple economic growth from damaging environmental impacts, and aligns with its aims for a low-carbon circular economy. This nascent sector is expected to grow rapidly and create new markets and jobs. The SCOT project's recommendation is, therefore, to develop a new Joint Technology Initiative in order to join all the resources needed to push the CO_2 Utilisation sector further and gain momentum.

A new CO_2 utilisation JTI is viewed as the logical step forward to ensure that CO_2 utilisation technologies and processes are demonstrated in an operational environment and reach the market faster. The JTI will help to converge all actions into a single and larger European initiative to build a unique and interconnected European CO_2 utilisation eco-system. By defining the topic of funding calls along with key industrials the CO_2 utilisation JTI will accelerate the development and deployment of CO_2 utilisation and make Europe become more competitive by facilitating its energy transition, enhancing its circular economy growth and decoupling its emissions from wider economic growth.

The CO_2 utilisation JTI will act in collaboration with the existing initiatives with which it will have strong synergies and will be able to deliver significant opportunities for the European industry:

- The JU BBI: in cooperation with the CO_2 Utilisation sector, the bio-based industry would offer a greater support to the European transition towards a circular economy

- The JU FCH: in cooperation with CO_2 Utilisation sector, the fuel cell and hydrogen energy technologies would facilitate the European Energy transition
- Clean Sky: in cooperation with CO_2 Utilisation sector, the air industry will perform further researches to support the decarbonisation of hard-to-decarbonise transport and would enable a transfer of air technology to terrestrial application

KEY OBJECTIVES

The CO_2 utilisation JTI will involve the European Commission, Industrial stakeholders in the form of a consortium, the research community, and an operational body in charge of following-up on the priorities agreed upon by the EC and the industrial consortium. The SCOT SERIA would constitute the basis for defining these priorities. Therefore, it is recommended a regular revision of the SCOT SERIA should be jointly carried out as further developments and innovation occur. The operational body will manage a fund provided by the EC and the industrial actors. The objective of the future JTI is to accelerate the market development of CO_2 utilisation products and processes by:

- Demonstrating technologies that enable CO_2 to be utilised to replace existing fossil-based feedstocks
- Developing new business models that involve new types of actors to work together supporting the industrial symbiosis, and prove the economic feasibility of CO_2 utilisation
- Help de-risking the emerging industry by giving more clarity to investors on the techno-economics of CO_2 utilisation
- Accelerate technology development and drive down costs
- Develop and validate new value chains
- Close the innovation circle by bringing the technologies to the customer
- Setting-up flagship initiatives for a resource efficient, low carbon economy enabling the deployment of the technologies and business models for CO_2-based materials, fuels, chemicals, and processes

EXPECTED IMPACTS

- A more coordinated approach to accelerate the market development of the CO_2 utilisation sector.
- Increased competitiveness of the EU economy through re-industrialisation and sustainable growth
- Creation of new value chains between unconnected sectors
- Development of novel CO_2 derived products and markets based on circular use of resources leading to the diversification of industries' revenue streams

NEXT STEPS

Task	Timeframe	Responsibility
Consult with other JTI's (e.g. BBI, Fuel Cells and Hydrogen) for constructive feedback	2016	Greenwin, Axelera
Engage industrial, public sector and academic stakeholders to get their commitment on such an initiative	2016	CO_2 Utilisation Association
Initiate process to set-up the CCU JTI	2017	CO_2 Utilisation Association

Checklist for Member State or Regional CO_2 utilisation assessment exercise.

APPENDIX A

It is recommended that Member State or Regional assessments take the form of a two stage process, with an initial outline assessment and potentially a detailed follow up assessment if the outline assessment has identified particular areas of interest.

An outline assessment of the potential of CO_2 utilisation at a Member State or Regional level should include:

- identification and categorisation of existing large CO_2 sources e.g. type, tonnage, biogenic or non-biogenic, likely concentration.
- a forecast of how these sources of supply might change out to 2030
- a CO_2 supply map of the geographical area
- identification of existing CO_2 demands
- a forecast of how these CO_2 demands might change out to 2030
- identification of existing CO_2 utilisation research, development and deployment in the geographical area
- identification of solid waste streams that may be amenable to CO_2 mineralisation
- identification of industrial clusters that would lend themselves to greater industrial symbiosis using CO_2

A detailed assessment of the potential of CO_2 utilisation at a Member State or Regional level would aim to fill in many of the gaps in knowledge identified in the outline assessment e.g. an understanding of the smaller CO_2 sources available.

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