ConsenCUS

Initial Exploitation Plan

ConsenCUS - D9.4 Initial Exploitation Plan 0.1-2201

Date	Version	Status	Initials	Changes Marked
17-05-2022	1.0	Final	TN, MvS	no
02-06-2022	1.0	Final	TN	yes

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement N° 101022484.

Version Control Sheet

WP: WP9 Communication and Dissemination

Lead author: NEC (Thomas Nielsen, Machiel van Steenis)

Contributing Authors: ECO (Exploitation Committee)

Due date: 2022-04-30

Date: 2022-05-20

Version: 1.0

Contact: t.nielsen@newenergycoalition.org

Dissemination Level: ■ PU: Public

☐ CO: Confidential, only for members of the consortium (including the Commission)

Table of contents

1. Introduction

1.1 Goal

Within the ConsenCUS project, novel carbon capture, storage and utilization techniques are developed and tested in real-life industrial settings. These developments are pursued to fulfil the ultimate goal: to facilitate the uptake of these techniques to help reach the climate goals of industries, countries and the EU. Next to validating the novel techniques, the ConsenCUS project is already planning a strategy of how these innovations can be best placed in the social-economic clusters of North-Western and South-Eastern Europe. Several adjoining studies, including cluster modelling, techno-economic analysis, life cycle assessments, societal impact and engagement analyses, paint a picture of what a successful rollout could look like.

In order to provide a clear overview of the activities currently in motion, finished or yet to come within ConsenCUS, NEC has formulated this exploitation plan. The plan is designed to identify:

(a) The definition of project results as well as their potential for exploitation;
(b) Exploitation roadmaps, IPR strategies, and synergies with the consortium;
(c) The analysis of markets and business models for the commercial KER's;
(d) Potential risks.

1.2 Timeline

The above aspects will be delivered in three (3) phases:

Deliverable	Date	Content
D9.4 Initial Exploitation Plan	M12 (may '22)	First identification of technology and IP strategies + the process to work on in the next year.

D9.6 Midterm Exploitation plan	M24 (april ’23)	Building on Initial Report + mapping potential results that could be exploited and process next years, including market analysis
D9.8 Final Exploitation Plan	M40 (aug ’24)	Building on midterm + finalizing the business model for the commercial KER’s

The Initial Exploitation Plan (M12) makes use of the initial project results. As the adjoining studies are not ready yet, their input will be used in the following mid-term exploitation plan (M24) and final exploitation plan (M40). In this way, the consortium will try to make the best use of ConsenCUS findings in terms of exploitable commercial, societal and political results.

1.3 Procedure

The exploitation plan is the result of research, questionnaires, and workshops organized by the New Energy Coalition. In the months preceding the General Assembly (GA) in Copenhagen (5 and 6 of April 2022), a questionnaire was developed and distributed to the consortium partners. Input from this questionnaire would form a basis for an Exploitation Workshop at the GA in Copenhagen on the 5th of April 2022. The workshop delivered some fruitful discussions and provided valuable insights into the considerations that the partners have about potential exploitation routes and future markets for CO_2 and products of CCU. The content from the questionnaire and the workshop form the basis for this report. With the help of and input from consortium partners, this content will be continuously updated as the developments within ConsenCUS ripen.

For the midterm exploitation plan, New Energy Coalition will look into the possibility for acquiring assistance from the Horizon Booster Service 1 Module C: Portfolio Dissemination & Exploitation Strategy Service in order to improve the quality of this deliverable. More information about the service can be found here. This service will support existing project strategies towards effective exploitation by:

- Reviewing of the key exploitable results of the project;
- Revising, complementing and clarifying existing exploitation plans of project results and/or outline exploitation paths of results;

- Developing techniques to identify all relevant stakeholders in the exploitation value chain;
- Supporting to perform a risk analysis related to the exploitation of results.

Furthermore, New Energy Coalition will assess whether the formulation of a business plan can be assisted by the EU Horizon Booster Service (HBS) 2: Business Plan Development. This will be included in the Final Exploitation Plan. More information about the service can be found here. As listed on the service's website, it includes:

- a market analysis,
- a business strategy,
- operations plan,
- competitor identification and analysis,
- a clear action plan to be implemented by the project and an estimation of time-to-market.

The HBS Business Plan is usually done for a single Key Exploitable Results, however, multiple KERs can be grouped, thus supporting the market accessibility of not only one of the ConsenCUS project's results. The option of grouping KERs must be discussed during the HBS Portfolio Dissemination & Exploitation Strategy Service Module C. The consortium partners will be consulted on this matter.

2. Exploitation Report

2.1 Technology Watch

When developing their innovations, the partners of ConsenCUS make use of a broad range of existing knowledge. These may include, but are not limited to, open or closed access papers, patents, tools and equipment and public releases. The information utilised by the consortium partners to reach their findings are listed below:

Partner	Utilised sources of information
DTU	From the consortium agreement “Attachment 1: Background included” section: Models and software for: • General thermodynamics • Electrolyte systems • Carbon capture • General process simulation tools • Rate-based simulation for CO2capture Existing equipment at DTU including: Mobile Test Unit (MTU) for capturing CO2 using traditional solvent based technologies. Designed and constructed during the EUDP projects BioCO2 and Net-Zero Carbon Capture at ARC. PIDs for advanced solvent based carbon capture system. Advanced liquid and gas analysis equipment. Additional background information: The market is moving towards application of electricity. We expect this market to expand significantly during the coming years. DTU participates in many PtX projects and has a complete (DK) national overview of stakeholders both organizational and as individuals.
WETSUS	From the consortium agreement “Attachment 1: Background included” section: The knowhow of the Wetsus research theme “Sustainable carbon cycle” on the materials, components and processes involved in electrochemistry-based carbon capture and regeneration. The backgrounds comprises two patents (NL1040200 and NL2025044), the 2nd patent deals with electrochemical regeneration of C02-containing streams. Additional background information: The existing knowledge is linked to more than 15 years of experience at Wetsus in research and prototyping on electrodialysis-related processes and

	electrochemical CO2-H2O systems. In particular: Selection of relevant publications: • Shu et al, Environ. Sci. Technol. 54 (2020) 8990–8998. First demonstration of electromical regeneration of spent alkaline sorbents for direct air capture • Legrand et al, Environ. Sci. Technol. 52 (2018) 9478–9485. Demonstration of electrochemical CO2 capture via capacitive electrodes • Legrand et al, J. Colloid Interface Sci. 564 (2019) 478–490. • Legrand et al, Electrochim. Acta. 319 (2019) 264–276. • Arredondo et al, Water Res. 111 (2017) 330−337. First demonstration of hydrogen-recycling electrochemical cell for ammonia recovery Selection of relevant patents: • Hamelers et al., Electrochemical device, system and method for electrochemically recovery and/or regeneration of carbon dioxide from a stream, NL2025044 • Kuntke et al, H2 recycling for ammonia recovery in electrochemical systems, NL2017383 • Knowledge gained in relevant previous EU projects: • H2020 project (as coordinator) (2017-2021): “BAoBaB: Storage and recovery of renewable electrical energy by reversible salt water dissociation”. Development and demonstration of bipolar membrane electrodialysis for stationary energy storage • LIFE project (as coordinator) (2018-2021): “NEWBIES: Nitrogen Extraction from Water By an Innovative Electrochemical System”. Development and demonstration of electrochemical recovery of nitrogen from waste streams • H2020 project (as partner) (2016-2020): “REvivED water: Low energy solutions for drinking water production by a REvival of ElectroDialysis systems”. Demonstration of electrodialysis for brackish water and seawater desalination. Besides ConsenCUS, Wetsus currently runs 2 PhD projects on related topics (electrochemically-assisted DAC), and is constantly involved in literature search (as well as patent search, when needed).

Coval	From the consortium agreement "Attachment 1: Background included" section: Direct CO_2 conversion to formate using COVAL's high-pressure technology (a two-chamber liquid-fed electrolyzer); patent number 3325692. Coval is also close to patenting on an innovative purification process and a formic acid from formate production method.
CERTH	From the consortium agreement "Attachment 1: Background included" section: Tools and know-how generated and gained by CERTH / CPERI research groups in the framework of H2020-funded projects (e.g. FlexFlores, Lig2Liq, SMILE, CLARA, BIOSPHERA, LIFE BIOMASSC+) including: • Chemical process modelling • LCA/LCC environmental models
AALPOR	Aalborg Portland is taking part in GreenCem, a concept study for a CCUS cluster in the Aalborg area. As part of this, we have evaluated the lay-out of a 1 million tons per year CO_2 capture plant at Aalborg Portland using the amine process. The GreenCem project is therefore an excellent baseline for ConsenCUS. More info can be found here: https://greencem.dk/
	This table will be updated with new information if this is relevant for the development of the ConsenCUS technology and/or ConsenCUS partners.

2.2 Intellectual Property Rights Management

The partners of the project are the first to exploit the results that ConsenCUS will generate. The results can be exploited by either the partner's own efforts or by facilitating exploitation from other internal or external parties. There are different tools with which the project's results can be exploited by the partners. These include but are not limited to: Patent publications; establishment of spin-off or start-up companies; license practices (open, copyleft); use the results for academic purposes (PhD, post-PhD). Below is an initial indication of how some of the consortium partners intend to manage the intellectual property of the findings of this project.

Partner	Exploitation tool for IP	Elaboration
DTU	Patent publication; License practice;	DTU intends to patent new innovations and sell patents or licenses on hardware and process parameter optimisations.
Wetsus	Patent publication; Spin-off establishment; Academic purpose, PhD	Wetsus has a standard IPR, as described in the Consortium Agreement. In case of IP, Wetsus first files a patent with the researchers as inventors. Next, Wetsus officially offers all the industrial members of the Wetsus Sustainable Carbon Cycle theme the possibility to fully transfer IP rights, under conditions that the technology is further developed. This is to ensure that the technology is further developed by industrial partners, towards commercialization. Wetsus already has a patent on the general concept idea exploited in ConsenCUS. Future results (i.e., regarding novel cell design or applications) might likely lead to further IP exploitation in the project. Moreover, the possibility to create a Wetsus spin-off on the developed technology has been foreseen during proposal writing, and will be evaluated in due time. Wetsus currently runs 2 PhD projects on ConsenCUS related topic (electrochemically-assisted DAC).
Coval	Patent publication, License practice	Coval does not have a formal IP strategy since they only own a single patent which is a very expensive process to uphold. Whenever additional inventions are discovered new patents are filed. But patents are usually too expensive to keep within the organization. Furthermore, COVAL intends to license its generated IP to industrial users who can use the conversion IP to make own (sustainable) products with the captured/converted Carbon. Coval does not intend to built industrial processes themselves.
STORK	Not specified	It is a common trend that industry has to work together with patent or license owners in order to redesign their

		processes. No specific hurdles are worth mentioning in this process and this will usually happen when a business case is discovered. What is worth attending to is the timing of when a technology is marketed given its changing availability.
GM	License practice	GM would not be interested in owning patents, or to commercialize project results for that matter. GM is only interested in free access – or access under favourable conditions – to the project's results for its own use.
HWU	Patent publication	If IP is developed, e.g., jointly with Wetsus or DTU, HWU intend to file an invention disclosure and follow-up patent application.
RGU	Start-up establishment; Patent publication	RGU is developing an educational resource for teaching school children about the design process of CCUS. These educational resources could potentially be patented. An idea of how to exploit the results of such a resource could be to establish a start-up company through the university, however, this is a complicated process. Another route would be to apply for follow-up funding but this is currently not budgeted.

2.3 Exploitable Results Identification

Project results that can be exploited after the finalization of the project can be divided in a number of domains. These domains are listed below, following the consortium partners' statement of how they wish to pursue such exploitable results. The Key Exploitable Results (KERs) for the technical partners can be found in Table 2.2 Key Exploitable Results Annex 1B Description of the Action in the Grant Agreement.

2.3.1 Carbon value chain

The consortium is aware that it is impossible to predict the economic situation in 5 years. Even though the technological developments of today need to have a clear purpose, they should also be viewed as building blocks that can be used for other unforeseen applications in the future. ConsenCUS introduces developments that are usable in industry and that have an economical benefit that other technologies can build on. The current developments should primarily be viewed as steps in the right direction. Capture, utilization and other technological advances in the field of CO_2 can be used for other useful applications, and value chains for these alternative developments will become more clear in years to come (Coval).

2.3.2 Storage options

Geological storage will remain an important aspect for reaching EU CO_2-targets. There is a temporal difference in when the CO_2 is emitted and its effect on the climate. The emissions that were made years ago are felt today, and today's emissions will be felt in the future. Thus a fast track to geological storage becomes increasingly important (BGS).

2.3.3 Integrated CO_2 capture and conversion

This project represents the first demonstration of a CO_2 capture process coupled with electrochemical regeneration. As such, it can showcase the development of novel (electricity-driven) approaches for CCU (Wetsus). The integration of flue gas absorption into an alkaline solution with the electrochemical regeneration cell should lead to a new, operational, type of CO_2 capture and conversion technology, with clear advantages compared to incumbent technologies. The impact of the integration includes the ability to demonstrate this technology at small scale and start developing it for large scale applications (HWU).

2.3.4 CO_2 capture cost reduction

Energy use is an important component of the costs incurred in present CO_2 capture technologies. Increased energy efficiency of a CCUS plant involving non-thermal processes through numerous discrete technical innovations and through an increased ability to model and predict the behaviour of the physical system using existing or new software packages will be beneficial to the commercial exploitability of CO_2 capture (DTU). Results developed by DTU at the ConsenCUS will also be utilized in a CCS in the INNOVANDI initiative. AALPOR is also a partner within this initiative.

2.3.5 Advanced CO_2 capture

The technology developed during the ConsenCUS project is not only relevant for the development of future carbon regeneration cells. It can also be adapted for air capture technologies. Because of the lower CO_2 concentrations, the energy consumption will be higher for air capture. Thus more renewable energy sources are needed. In 50-60 years there will be no more CO_2 emissions, but carbon capture will still be needed to get the residing carbon out of air. The use of the ConsenCUS technology for Direct Air Capture will be part of the Wetsus research programme.

2.3.6 CO_2 as carbon source

With increasing deployment of sustainable energy production, the use of fossil resources will be decreased. The ultimate target is to not use any fossil resource at all. However, part of the fossil resources are used as feedstock for carbon derived products. Without fossil resources only two carbon sources remain: biomass and CO_2. Therefore, in future the capture and re-use of CO_2 will be very important to be able to produce carbon-based products.

2.3.7 Policy

Given the taxing schemes of CO_2, at present carbon emissions are a resource for governments. Therefore, future tax regulations and policies will have to be developed to address the issue of lost income from decreased emissions (RUG).

2.3.8 Patents, licences and publications

New innovations like novel design of electrochemical cells for CO_2 capture (Wetsus) or upscaling of the electrochemical cell (DTU) will be patented and sold, licensed and published (DTU, Wetsus).

2.3.9 Process models

Other partners (HWU) will develop open access (HWU) or inhouse (DTU) models. The exploitable result would really be a well-designed (or different configurations of) the integrated capture – regeneration process. Possible markets include smaller scale CO_2 emitters that need an easy add on to scrub CO_2 out of their flue gases, possibly in the order of 10’s of kilotons to 1 megatons per annum scale (HWU). The application of DTU in-house computer models like the Extended UNIQUAC model to absorber-electrochemical cell systems might also become of practical use (DTU).

2.4 Market Analysis

This paragraph will focus on analysis of potential markets of the CCUS concept, both for the technology, the storage concept, and the CO_2 derived products. Several components will be elaborated during the ConsenCUS project. As mentioned in section 1.3 of this deliverable, New Energy Coalition will investigate the possibility of receiving support from the Horizon Booster Service in producing a market analysis. This would be part of the service 2: Business Plan Development. If the service is received, an elaborate market analysis will be available in the final exploitation plan. For this initial plan, some preliminary questions are posed for making a baseline for the topics that will be investigated during the ConsenCUS project. These are based on input from the consortium partners via the questionnaire and exploitation workshop.

2.4.1 (Temporary) storage or conversion

The CO_2 captured can either be stored or converted into products, or temporarily stored when the availability of CO_2 exceeds processing capacity:

- What will the fraction of the utilization and the storage parts of CCUS be?
- Will the developments within CCUS steer towards utilization streams or storage streams?
- What further developments would impact which direction will be chosen and how will it affect the future CO_2 markets?

2.4.2 CO_2 market

- What are alternative applications of CO_2 compared with the ConsenCUS goals?
- What is the market size of these CO_2 applications?

2.4.3 Future carbon supply for industry

For cement, magnesia and other minerals there will always be process emissions from decomposition of carbonates. More than 50% of the total emissions is from production process.

- Are these volumes sufficient as feedstock for industrial processes?

2.4.4 Market size formate and formic acid

The key to having a sustainable CCUS production is to produce a product that has widespread use and ideally replaces current (fossil) market products or raw materials. Formate and formic acid are one of such widely applicable products.

- What is de market potential of formate and formic acid?
- What are downstream products that are derived from formate or formic acid?

2.4.5 Other CO_2 derived products

Polymerization is another possible product from CCUS but the process of attaining polyacids through polymerization is expensive. However, it is essential to realize that the developments made now must be seen as improvements and stepping stones towards more widespread application of CCUS.

An example of an economical push is the Danish shipping company Maersk which is currently investing heavily in methanol shipping thus pushing the market for renewable methanol production as alternative to conventional diesel.

- What other products can be made from CO_2, for example polymers and how does this compare to formate (energy use/commercial, etc.)?

2.4.6 Future EU and global market trends

At the moment industry is developing decarbonization masterplans. The first stage of this are low hanging fruit improvements like energy efficiency improvements, re-use of heat, and capturing CO_2. The big change will come when large volumes of green H_2 will be available at a lower price. When this turning point is reached this will have major impact on expectation of ConsenCUS. Industry players indicate that there is a time window of 5 to 7 years until this turning point is reached.

Developments may occur in future income policies regarding the CO_2 emissions of products. For example, today water treatment is included in the bill that one pays for their water supply. In the future, the capture of CO_2 may be included in fuel prices. A company such as Shell will be motivated to decrease the price of CCUS thus shrinking the market for CO_2. Such big energy companies have to transition towards more sustainable fuel types and supporting CCUS developments can also accelerate this shift.

We have to be aware that stability in the market is not a given. Recently there have been major disruptions such as the conflict between Ukraine and Russia. Technology can deliver great advances but some of these may not be relevant in the future due to such disruptions.

2.4.7 Policy development

Carbon capture is a very feasible and mature technological development that has already been extensively tested. However, governmental guidance and funding has halted its industrial development and will have to be developed to a higher standard.

3. Upcoming Actions

The below listed activities will be organized to get further input from the partners as the project progresses. The input from these actions will be integrated into later versions of the exploitation report, the most imminent being the mid-term exploitation report. Besides these official actions, NEC will continuously stay in contact with the consortium partners to stay up-to-date with exploitation developments.

3.1 Workshops with partners

Similar to the exploitation workshop in Copenhagen in April 2022, future general assemblies will include workshops where partners can express how their plans to pursue their KERs, manage IPRs, identify exploitable results, and preferences for how to introduce the findings to the market. The workshops will be organised by NEC. A questionnaire will be developed and sent to the partners, and the answers of which will be addressed at the online or physical workshop the general assembly. The next upcoming exploitation workshops will take place at the digital general assembly in October 2022 and physically in Scotland in April 2023.

3.2 Exploitation Committee and external members.

At present the Exploitation Committee has two external members: INEOS and Stork. These companies provide valuable insights into the exploitation of the ConsenCUS results. The Committee is still open for additional members, after signing an NDA and approval by the ECO members and the GA.