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ConsenCUS

Midterm Exploitation Plan

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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 of facilitating 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 (may ’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) made use of the initial project results. Since then, an array of exploitation activities have been executed which have been comprised into this mid-term exploitation plan (M24). As the adjoining studies are not ready yet, their input will be used in the following 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, workshops, and seminars organized by the New Energy Coalition. For the initial exploitation plan, a questionnaire and a workshop was organised. 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.

For the current Midterm Exploitation plan, forms were distributed to project partners, and workshops and seminars were organised. Before the workshops and seminars were organised, exploitation template forms on which the project partners provided input. These forms were provided from the Horizon Results Booster service. The forms were filled in by the three technological project partners of Coval, Wetsus and DTU during bilateral sessions with NEC. Their input formed the basis for the first workshop for the midterm plan that constituted a session during the online General Assembly on the 5th of September 2022. Here, additional members of the exploitation committee provided additional input on exploitation risks (related to partnerships, technology, market, IPR, finance, and regulatory risks), use options for exploitation, and how a potential exploitation roadmap could look like. To receive additional input on these aspects, a second workshop was organised for industrial members of the exploitation committee. This workshop was organised on the 25th of January 2023 and was attended by AALPORT, OMV

Petrom, Actemium and Omexom. Lastly, the forms of the Horizon Results Booster service were revised during an exploitation seminar hosted by LC Innoconsult on the 18th of April 2023. The input of the beforementioned activities has been condensed into the current deliverable, and the revisions indicated during the exploitation seminar will result in an additional report on the exploitable results of the ConsenCUS project. Only with the help and input from consortium partners will the content be continuously updated as the developments within ConsenCUS ripen.

As mentioned, has New Energy Coalition acquired 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 is supporting the project strategy 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. If realised, this will be included in the Final Exploitation Plan. 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.

2. 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 CO_2-capture Existing equipment at DTU including: Mobile Test Unit (MTU) for capturing CO_2 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 CO_2-containing streams. <u>Additional background information:</u> The existing knowledge is linked to more than 15 years of experience at Wetsus in research and prototyping on electrodialysis-related processes and electrochemical CO_2-H_2O 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 CO_2 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, H_2 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.

3. 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.

4. Exploitable Results Background

Project results that can be exploited after the finalization of the project can be divided into a number of domains. Background information about these domains are listed below, following the consortium partners' statements about their reflections on the results or how they wish to pursue such exploitable results. After each statement, the partner that made the statement has been indicated. 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.

4.1 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).

4.2 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).

4.3 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).

4.4 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.

4.5 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.

4.6 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.

4.7 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).

4.8 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).

4.9 Process models

Other partners 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).

5. Key Exploitable Results

The exploitable results in the previous paragraphs, are grouped in two Key Exploitable Results (KERs) for the midterm exploitation plan (in cooperation with the Horizon Results Booster (HRB service):

- CO_2 capture: Novel electro-chemical regeneration (WETSUS)
- CO_2 conversion: Formate / FA production from CO_2 and H_2O (COVAL)

In this section, we will address the characterisation of the exploitable results from the above-mentioned KERs. This information constitutes the input from KER project partners on the Characterisation Table form from the HRB service as well as input from other members of the ConsenCUS project during various workshops and the HRB seminar.

5.1 CO_2 Capture – Novel electro-chemical regeneration

What problem is the ConsenCUS capture technology addressing?

Certain industry sectors such as thermal power plants, cement, magnesia, steel, and lime production have process-related CO_2 emissions. When new regulations and tighter restrictions come in place to combat climate change, these companies will have to pay a high price for the emitted CO_2. Additionally, these companies are under public pressure because of their high CO_2 emissions. These companies are looking to create a better relationship to their communities and to improve public acceptance. Therefore, they need to implement a process to capture the CO_2 they produce and store it or sell it to other industries to create a sustainable carbon value chain. The CO_2 capture technology used today in the industry is based on solvents producing carcinogenic substances in the process in the form of nitrosamines. Nitrosamines are under very tight regulations by authorities, and the energy efficiency of the technology is reaching its maximum. ConsenCUS is unique in that it does not rely on solvents producing nitrosamines.

What alternative CO_2 capture solutions exist?

The industries that are heavy CO_2 emitters are testing new CO_2 capture technologies on pilot scale. At present the only viable and used technology is based on the use of nitrosamines.

Other technologies, including their strengths and weaknesses will be evaluated in the final exploitation report.

What is the Unique Selling Point USP / Unique Value Proposition UVP of the ConsenCUS capture technology?

The CO_2 capture benchmark process uses thermally regenerated amines to capture CO_2. The advantage of this process is the use of a highly stable alkaline solvent (potassium hydroxide) that does not degrade easily compared to amines. The ConsenCUS CO_2 capture plant is nitrosamine free and represents a technology suited (electrochemical CO_2 capture) with a great, untapped potential for energy efficiency improvements.

The technology uses electrical energy instead of thermal energy, which is expected to be cheaper, more available, and more sustainable (when coming from renewable electricity sources) than the heat generated from fossil-fuel-based energy.

The ConsenCUS technology is:

- Nitrosamine free
- Energy efficient
- Electricity driven
- Carbon neutral (if sustainable energy sources are used)

How would you describe the technology in short terms?

Patents, scientific publications and a pilot demonstration able to regenerate alkaline sorbent for CO_2 capture are results of the ConsenCUS project. The solution consists of a suite of patents covering key engineering aspects of a CO_2 capture plant which uses potassium hydroxide as the selective CO_2 capture solvent, and which uses an electrochemical cell to clean the solvent. After capture of the CO_2 the potassium hydroxide is regenerated electrochemically and the CO_2 captured, is released from the solution.

What is the target market?

Industries such as power, cement, magnesia, steel, lime production or Direct Air Capture or companies that sell specialty gasses. The companies represented in the Exploitation Committee stress they are mainly interested in mature technology that can be integrated in their industrial sites. For these companies the CO_2 capture itself is the most important, utilizing the CO_2 will require additional partnerships. Engineering companies will be necessary to build and maintain the installation after a FEED study, especially as the project partners will focus on licensing their

technology and will not be responsible for the realisation of the capture units. So, also companies designing, constructing and building CO_2 capture plants are target customers.

Who would be the early adopters?

Early adopters will be the companies that are under a lot of public pressure and that expect to start paying high taxes for their CO_2 emissions. Other companies, using high-purity CO_2 might want to create a more sustainable value chain. Some potential early adopters are:

- Pentair
- Ammongas
- PureTeq
- AircoProcess
- Alfa Laval

Which market competitors exist?

Competitors can be divided in three groups: (1) Companies that provide amine-based CO_2 capture and regeneration, (2) Companies that extract CO_2 from the air (direct air capture) and (3) Emerging technologies or processes that can directly utilize the CO_2 from flue gas.

Novozymes, for example, is developing an enzyme-based technology which promises to be nitrosamine free. But this is not commercially available yet.

A concern of the Exploitation Committee is that it is not clear yet, whether the technology can meet expectations. At present energy consumption is higher than expected, which increases the competition with other new and existing technologies. Also there are still uncertainties in the degradation rate, life time and maintenance costs.

A more in-depth analysis of market-competitors will be identified in the final exploitation report.

Which use models can be applied and what is the go-to-market strategy?

Several use models can be used. Examples are manufacturing of a new product, direct industrial use and technology transfer. Technology transfer is the main focus of the technical project partners and can be realized through license agreements or patent sales. The CO_2 emitting industry stresses that the use model is a future decision, based on what is needed for implementation of the technology. This could be in the form of partnerships as well.

The implementation of the technology itself is not expected to raise any issues. Standard amine capture installations are already installed in some of the sites and can be replaced with the ConsenCUS technology.

What is the optimal go-to-market timing?

It is estimated that developing a market ready concept will take 3 to 5 years.

On which IPR and knowledge background is the capture technology based?

For the answer to this question, please refer to the input from Wetsus and DTU in Chapter 2: Technology Watch.

On which IPR foreground is the capture technology based?

The IPR Foreground is performed by DTU and WETSUS. 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 transfer fully IP rights, under conditions that the technology is further developed. This is to ensure that the technology is further developed by industrial partners, toward commercialization. Wetsus would like to include the current Participant companies in the Wetsus research theme 'Sustainable carbon cycle'. These companies are able to valorise the ConsenCUS foreground of Wetsus.

5.2 CO_2 Conversion - Formate / Formic Acid production from CO_2 and H_2O

What problem is the ConsenCUS conversion technology addressing?

Coval Energy technology provides a solution that enables reduction of GHG emission for the energy intensive industry and a cost-effective use of renewable energy. The Colyser reactor is the core of the technology and an efficient and easy to operate electrochemical cell that converts CO_2 through an electrocatalytic process to chemicals such as formate and formic acid. Formate and formic acid are emerging intermediates of wide potential industrial interest.

What problem is the ConsenCUS conversion technology addressing?

There are limited alternative options to fulfil the requirements for CO_2 abatement for large scale industries that could be customers of the capture and conversion technologies. The use of renewable energy is not feasible for these industries due to the high energy demand. Furthermore, alternative technological solutions struggle with the production of formic acid, and tend to use hydrogen, making them more expensive to operate.

What is the Unique Selling Point USP / Unique Value Proposition UVP of the ConsenCUS capture technology?

Coval Energy uses renewable electricity to convert non-fossil carbon dioxide into a new energy carrier or intermediates, using a patented CO_2-electrolyser. The high-pressure CO_2 electrochemical cell is unique and the best available technology. The cell is cheap and uses abundantly available materials in a robust process. The high-pressure technology is unique and differs from low pressure techniques that require expensive Gas Diffusion Electrodes. Lastly, the technology is unique since it does not require any hydrogen.

How would you describe the technology in short terms?

The product is mainly Potassium Formate and Formic Acid that will be used to produce high value proteins and/or fatty acids via fermentation. The unique combination of an electrochemical reactor with bioreactors will allow the creation of circular processes, which improve the sustainability of the total process from CO_2 to fatty acids but will at the same time prevent dependency on supplies and reduce costs thereby improving the cost-effectiveness. There are three integration steps leading to four separate circularities:

- Recycle of potassium-to-potassium hydroxide electrolyte;
- Capture of CO_2 from the aerobic fermentation process to re-use it for the electrochemical conversion;
- Recirculation of water.

What is the target market?

Target markets of the high valuable proteins that are the end-products of the conversion technology are mainly in the food sector and sustainable aviation fuel consumers. These include:

- Energy intensive industry (CO_2 reduction);
- Food industry (high value proteins);
- Airline sector (Sustainable aviation fuels).
- Airline industry and waste sector.

These target markets depend on of the end-product are eligible to the Emissions Trading Scheme (ETS) and/or Environmental Product Declarations (EPD).

However, Coval will not be selling the end-products to these sectors, but will be licensing the technology CO_2 emitters. This target market includes large scale industries like the consortium partners Aalborg Portland, Grecian Magnesite, and OMV Petrom. It may also include smaller scale industries with high concentrations of CO_2 in their emitted flue gas.

Who would be the early adopters?

Some early adopters of the technology could be medium and small scale emitters of up to 100 ktons CO_2 per year. These volumes are not cost-effective for volatile based technologies and the ConsenCUS technology is thus more suitable. Direct Air Capture Systems may also benefit from the conversion technology in providing an alternative to carbon storage.

Which market competitors exist?

For sustainable aviation fuels there are limited options. These options are not flexible and therefore difficult to apply without the need for very costly hydrogen storage. Proteins are a highly competitive market, however, according to Coval, the competitors cost price and land use factor are weak compared to their solution. An identification of biochemical CO2 fermentation technologies with hydrogen will be included in the final exploitation report.

Which use models can be applied and what is the go-to-market strategy?

Coval will mainly focus on license agreement after successful demonstration of the entire production chain.

What is the optimal go-to-market timing?

Coval projects to have a first commercial demonstration plant in 2028/29.

On which IPR background is the capture technology based?

Patent application nr 16757367.4 -1108 has been granted and describes a unique formate/formic acid purification method.

On which IPR foreground is the capture technology based?

An IPR foreground of the conversion technology will be provided in the final exploitation report.

6. Market Analysis

This paragraph will focus on analysing the 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 midterm 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.

6.1 (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. CO_2 utilization in the form of formate does not reduce the CO_2 footprint of the company as this CO_2 will be emitted into the atmosphere in a short time period.

- 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?

6.2 CO_2 market

The CO_2 market is an important factor for the feasibility of CO_2 capture technologies, but CO_2 prices are very volatile. At present the CO_2 price is 80 euros per ton, but is expected to increase to 140 euro per ton in the near future. Permanent CO_2 storage is required to be able to make use

of the allowances. A major drawback here is that in general the ConsenCUS CO_2 emitters are not close to potential storage sites.

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

6.3 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 the production process.

- Are these volumes sufficient as feedstock for industrial processes?

6.4 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, even though the present market is still quite small.
Additionally the costs for formate production might be higher than the standard production process and it is not clear whether the market is willing to pay a premium for green formate.

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

6.5 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.)?

6.6 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.

6.7 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.

7. Exploitation Roadmap

The Exploitation Roadmap will help the consortium to identify and plan activities to be performed after the end of the project. Having a specific plan for exploiting the project's results will make this process a lot easier once ConsenCUS has ended. The information in this section constitutes the input from KER project partners on the Characterisation Table form from the HRB service as well as input from other members of the ConsenCUS project during various workshops and the HRB seminar.

7.1 Actions

What actions should be executed three to six months after the end of the project?

CO_2 Capture – Novel electro-chemical regeneration

For the CO_2 capture KER, several actions are identified:

- Spin-out licensing or providing technical solutions for CO_2 emitting companies;
- Promote the demonstration results in the scientific community and with relevant stakeholders (e.g. conferences);
- Peer-reviewed publications with results of the pilot demonstrations;
- Apply to more European-funded projects to further develop CO_2 capture technology;
- Policy advice offering analyses and policy recommendations on cost-effective paths towards EU's 2030 and 2050 decarbonization targets, also taking into account the pilot demonstration results.

CO_2 conversion: Formate / FA production from CO_2 and H_2O

Coval will continue with their development and lessons learnt from the industrial site demonstrations. The focus will be on three topics:

- Balancing the plant and adjustments on the engineering design package.
- Reactor design and process conditions.
- Cell / stack design optimisations.

7.2 Roles

Which roles should other project partners assume in the abovementioned actions?

CO_2 Capture – Novel electro-chemical regeneration

The role of other project partners in the CO_2 capture technology is:

- HWU/CERTH/RGU: A rigorous techno-economic and business case analysis of the ConsenCUS CO_2 capture and conversion technologies, advised by technology and costing experts of the industrial partners;
- DTU/WETSUS: Provide a novel method to capture CO_2 and regenerate KOH solution for the effective capture of CO_2 from various flue gasses.

CO_2 conversion: Formate / FA production from CO_2 and H_2O

The role of project partners in the CO_2 conversion technology is:

- DTU: Support on lessons learnt and engineering designing of the balancing of the capture plant.

7.3 Milestones

Which milestones and KPIs should be used to monitor the abovementioned actions?

CO_2 Capture – Novel electro-chemical regeneration

The following milestones and KPIs to be used for monitoring the implementation of the actions in the CO_2 Capture technology are defined:

- Pilot demonstration at relevant industrial sites across Europe (within project timeline);
- Techno-economic assessment (within project timeline);
- Scientific publications (within the project timeline and at least one more year after the end of the project);
- Identify and apply to European-funded projects (within the project timeline and at least one more year after the end of the project).

CO_2 conversion: Formate / FA production from CO_2 and H_2O

The following milestones and crucial KPIs to be used for monitoring the implementation of the actions in the CO_2 Conversion technology are defined:

- The energy use in kWh/ kg product;
- Cost price of the final product.

7.4 Financial costs

What are the cost estimation of to implement the planned actions after 1 and 3 years?
The results of WP6 will be used to make financial cost estimations to implement planned activities during the first one to three years. These includes raw CAPEX and OPEX estimations for the first plants. A first indication of potential investors will also be given. The abovementioned actions will be included in the final exploitation report.

7.5 Revenues

What revenues and eventual profits are projected for the KER after 1 and 3 years?

The techno-economic assessment of the project will be performed in WP6 and should deliver the expected revenue and cash flow of the CO_2 capture technology. This will be included in the final exploitation report.

7.6 Other sources of coverage

What resources are needed to bridge the investment for ensure the desired TRL and usage of the technology?

Based on the CAPEX and OPEX costs, and the expected level of private investments, other resources may be needed to bridge the investment needed to increase TRL and ensure the results are used. If these are needed they will be included in the final exploitation report.

7.7 Impact in 3-year time

What impacts will the technology have for society in terms of growth and benefits?

The ConsenCUS project represents the first demonstration of a CO_2 capture process coupled with electrochemical regeneration. As such, it can lead to the development of novel (electricity driven) approaches for CCUS. The societal (jobs created), environmental and economic impact are still unknown and will be investigated.

8. Risk assessment

The highest risk a consortium faces is not being able to implement the exploitation and dissemination plan and increase the TRL level or go to market, due to lack of resources. The Exploitation Risk Assessment is designed to address these risk, mitigate them and pave the way towards effective exploitation and a stronger societal impact. The risk assessment will be included once the partners have updated the risk assessment forms based on the comments of the Horizon Booster Service.

9. Upcoming Actions

The activities listed below will be organized to get further input from the partners as the project progresses. The input from these actions will be integrated the final exploitation report. Besides these official actions, NEC will continuously stay in contact with the consortium partners to stay up-to-date with exploitation developments.

9.1 Revised Exploitation Material

As mentioned in section 8 above, the foreseeable exploitation risks provided by KER project partners will be revised and assessed after the publishing of the current deliverable. Furthermore, the input provided by project partners on the exploitation roadmap, characterisation table, and use option will be revised and reassessed. These revisions will culminate in a report provided by LC Innoconsult from the Horizon Booster Service 1 Module C: Portfolio Dissemination & Exploitation Strategy Service. The report will be readily available for all ConsenCUS project partners, and, if needed, dissemination activities will be organised by New Energy Coalition.

9.2 Horizon Booster Service 1 Module C second seminar

Once the revised material from the KER project partners has been received, LC Innoconsult may host a second seminar. However, it is still unclear if this will be necessary.

9.3 Exploitation Committee and external members

At present the Exploitation Committee has three external members: Actemium, Omexom, 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. New Energy Coalition aims to organise additional exploitation events where these committee members will give their feedback on the exploitable results of the ConsenCUS project.

9.4 Workshops and seminars

If needed, additional workshops and seminars will be organised for project partners and external committee members alike where input on the exploitable results is requested. This may become relevant once results from additional studies within the ConsenCUS project is realised.

9.5 EU Horizon Booster Service (HBS) 2: Business Plan Development

If feasible, New Energy Coalition will apply for the EU Horizon Booster Service (HBS) 2: Business Plan Development. This service from the Horizon Results Booster is aim for projects having completed the Service 1 Module C, being the case for the ConsenCUS project. A more detailed description of this service can be found at the end of section 1.3.