Grant Agreement no. 768919

Carbon4PUR

"Carbon4PUR - Turning industrial waste gases (mixed CO/CO_2 streams) into intermediates for polyurethane plastics for rigid foams/building insulation and coatings"

Research and Innovation Action

Topic: [SPIRE-08-2017] Carbon dioxide utilisation to produce added value chemicals

Deliverable 8.9:

Exploitation Report

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The Carbon4PUR Consortium

#	Participant Legal Name	Short Name	Country
1.	Covestro Deutschland AG *(Project Coordinator)*	COV	Germany
2.	Recticel N.V.	Recticel	Belgium
3.	Viomichania Ritinon Megaron Anastasios Fanis Anonymos Etairia	Megara	Greece
4.	Universiteit Gent	UGent	Belgium
5.	Universiteit Leiden	UL	Netherlands
6.	Dechema Gesellschaft für chemische Technik und Biotechnologie e.V.	Dechema	Germany
7.	Technische Universität Berlin	TUB	Germany
8.	Commissariat à l'énergie atomique et aux énergies alternatives	CEA	France
9.	ArcelorMittal Maizières Research SA[1]	AMMR	France
10.	South Pole Carbon Asset Management Ltd.[2]	SPG	Switzerland
11.	Grand Port Maritime de Marseille	MFPA	France
12.	Rheinisch-westfälische technische Hochschule Aachen[3]	RWTH	Germany
13.	PNO Consultants BV	PNO	Netherlands
14.	Imperial College of Science Technology and Medicine	ICL	UK

[1] At ArcelorMittal two legal entities are involved as linked third parties: ArcelorMittal Méditerranée (AMMED) and ArcelorMittal Belgium NV (AMB)

[2] At South Pole the following legal entity is involved as linked third party: South Pole UK (SP UK)

[3] At RWTH three departments are involved: *Chair of Fluid Process Engineering* (RWTH-AVT), *Catalytic Center* (RWTH-CAT), and *Chair of Communication Science & Human-Computer Interaction Center* (RWTH-COMM)

Acronyms and Definitions

Acronym	Defined as
CA	Consortium Agreement
CO	Carbon monoxide
CO_2	Carbon dioxide
CCU	Carbon Capture and Utilization
EB	Exploitation Board
EO	Ethylene Oxide
GA	Grant Agreement
GHG	Green House Gases
IP	Intellectual Property
IPR	Intellectual Property Rights
LCA	Life Cycle Assessment
PO	Propylene oxide
PUD	Polyurethane Dispersion
PUR	Polyurethane
RTO	Research Technology Organisation
TEA	Techno-Economic Assessment
WP	Work package

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1. The Carbon4PUR project

Carbon4PUR aims at turning industrial waste gases (byproduct exhaust gas streams and flue gas streams of steel industry / mixed carbon monoxide (CO) / carbon dioxide (CO_2) / CO/CO_2 streams) into intermediates for polyurethane plastics for rigid foams/building insulation and coatings. The industrially driven, multidisciplinary consortium is developing a novel process based on direct chemical flue gas mixture conversion, avoiding expensive physical separation, thus substantially reducing the carbon footprint, and also contributing to high monetary savings. The interdisciplinary consortium consists of 14 partners from seven European countries (Germany, France, Belgium, The Netherlands, Greece, Switzerland and United Kingdom) and across sectors: four industries (Covestro Deutschland AG – short: COV, Recticel N.V. – short: Recticel, Viomichania Ritinon Megaron Anastasios Fanis Anonymos Etairia – short: Megara, ArcelorMittal – short: AMMR), five universities (Universiteit Gent – short: UGent, Universiteit Leiden – short: UL, Technische Universität Berlin – short: TUB, Rheinisch-westfälische technische Hochschule Aachen – short: RWTH, Imperial College of Science Technology and Medicine – short: ICL), one association (Dechema Gesellschaft fuer chemische Technik und Biotechnologie e.V. – short: Dechema), one research organization (Commissariat à l'énergie atomique et aux énergies alternatives – short: CEA), two service providers (PNO Consultants BV – short: PNO, South Pole Carbon Asset Management Ltd. – short: SPG) and the Grand Port Maritime de Marseille-Fos (short: MFPA).

Both the consortium and the work are organized along the full value chain starting with the provision and conditioning of industrial emissions from a steel *(AMMR, UGent)* to a chemical company *(COV)* in line with the concept of industrial symbiosis exemplarily at *Marseille Fos*, going through the transformation into chemical building blocks *(CEA, RWTH and COV),* which both will be further transformed into polymer intermediates *(RWTH, COV)* and flow into desired sustainable polyurethane applications of rigid foams and coatings *(Recticel, Megara)*. Life Cycle Assessment (LCA) and technology evaluation will be done *(UL, RWTH, TUB, SPG)* and replication strategies to transfer the technology to other applications will be elaborated *(Dechema, PNO, ICL)*.

The distinctive feature of the developed process is avoiding resource-intense separation of the gas components before the synthesis, and developing a chemo-catalytic process to deal directly with the gas mixture instead. The challenge and innovation are coming up with an adjustable process in terms of on-purpose and demand tailor-made production of required products, taking into account all variables at the same time: the available flue gases characteristic from the steel plant, material and process parameters, and the market requirements for the end product, thus flexibly involving the whole value chain with best results and possibly lower the prices.

2. Objectives and Overview

The present deliverable has been planned in the work package (WP) 8 “Exploitation and Dissemination of project results”, describing the exploitation plan of the Carbon4PUR results, technologies and concepts. It is a document which summarizes the beneficiaries’ strategy and concrete actions related to the protection and exploitation of the project results.

The document is divided into the following chapters:

- Chapter 2 briefly presents the exploitation objectives and provides an overview of Carbon4PUR workings;
- Chapter 3 elaborates the exploitation strategy and deployed approach for the systematic identification of the project’s exploitable results and actions;
- Chapter 4 outlines the management of the intellectual property rights;
- Chapter 5 discusses the exploitable results and activities of each project partner;
- Chapter 6 presents the joint exploitation activities and that their realization requires the collective effort from the project partners;
- Chapter 7 closes with an overview of the exploitable project results and activities per WP.

2.1 Exploitation Objectives

The main objective of this exploitation plan is to identify the Carbon4PUR’s exploitable results and maximize their exploitation opportunities by the planning and the realization of exploitation actions. By exploitation we mean **“the utilization of results for scientific, societal or economic purposes”**. The shaping of exploitation actions are geared towards:

- Proper management of the Intellectual Property Rights (IPR) of the developed project results. Partners shall take decisions on effectively and legally protect their intangible and/or tangible results, considering all forms of intellectual rights protection-such as copyrights, patents, trademarks-afforded by international agreements and national law.

- Maximizing the deployment of project results considering the strategic ambitions of project partners. Partners in principle shall make best efforts to exploit the results they own or to have them exploited by another legal entity. This means that project partners must take steps to ensure the results they own are used in further research activities

other than those covered by the project concerned, or in developing, creating and marketing a product or process, or in creating and providing a service, or in standardization activities[1].

- Maximizing the chance of the implementation of a scale-up demonstration plant after the end of the project, which can include (whole or part of) the Carbon4PUR value chain and will most likely be led by (a selection of) Carbon4PUR partners, and the generation of spin-off projects, which will most likely include (a selection of) Carbon4PUR partners.

In order to ensure that there is a continuous overview of the project results and potential exploitation opportunities, Carbon4PUR has adopted a tailored exploitation management strategy which will be explained in the next chapter.

2.2 Carbon4PUR Value Chain

An overview of the Carbon4PUR value chain, the positioning of the project partners in the CO/CO_2-based value chain and the structure of the Carbon4PUR work packages is displayed in the figure below.

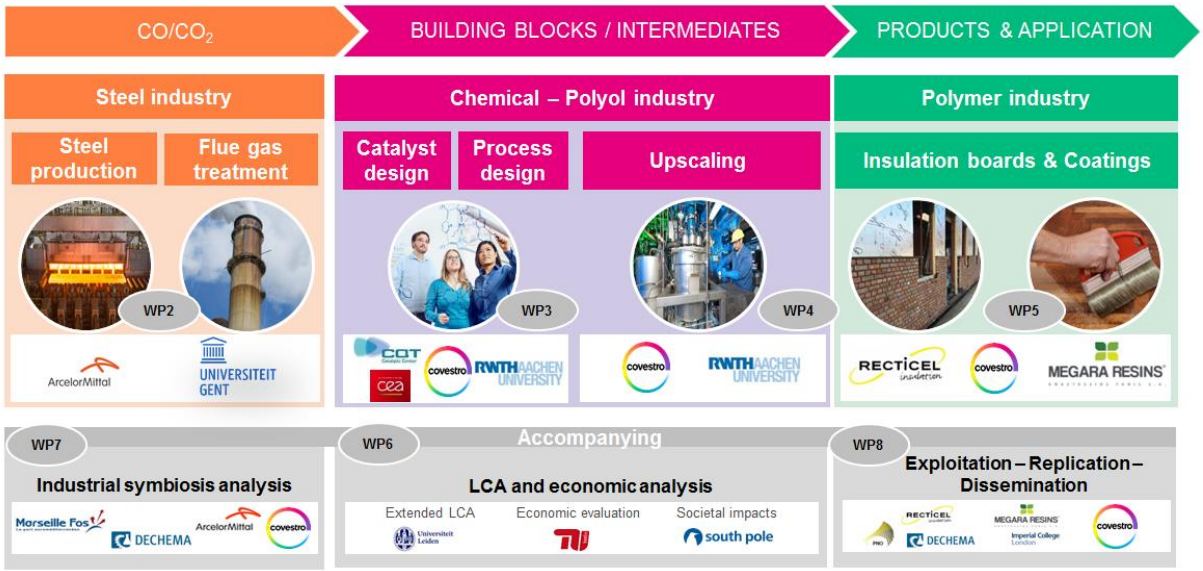

Figure 1: *Work package structure and project partners' positions along the CO/CO_2 value chain.*

Starting with the first step of the value chain, UGent and AMMR joined efforts in WP 2 "Conditioning of secondary raw material waste streams (CO/CO_2)" to address the required

[1] European IPR Helpdesk (2014) Fact Sheet How to manage IP in Horizon 2020: at the implementation stage

conditioning of the steel process gases for their use as feedstock for polyol production on the basis of the industrial requirements identified by the chemical industry.

Recycled carbon rich gases have been explored for the synthesis of polyols through a chemical catalytic conversion under WP 3 “Chemical technology development for CO/CO_2 conversion to polyols”. RWTH together with COV and CEA has explored different catalytic approaches for the accomplishment of a successful conversion route. Relying on WP 3 outcomes, WP 4 “Process development of CO-based polyol production”, has developed process concepts of the new Carbon4PUR technology in several scenarios, which served as basis for the assessment of economics and sustainability. The production of the most promising catalysts and polyol samples have been scaled–up for application testing.

The developed polyols have been processed and tested to prove their suitability for manufacturing of commercially attractive polymers under WP 5 “Further semi-industrial processing and tests of CO-based polyols”. This work stream has been led by the industrial partner Recticel, that has processed the delivered sample polyols at lab and pilot scale towards the development of novel rigid foams for buildings insulation boards. An additional application of the novel polyols has been explored by Megara for the development of water-based polyurethane dispersions (PUDs) used for wood coatings.

Carbon4PUR has devoted a work stream to research and evaluate the sustainability of its innovations. Results of WP 6 “Accompanying economic, environmental and societal research and project evaluation” can be considered as tools to be employed to guide and stimulate the project upscaling and the adoption of the Carbon4PUR innovations. Therefore, WP 6 results might be characterized as complementary, promoting the exploitation of the project’s main results. Leader of WP 6 was UL, whereas other involved partners include TUB and SPG.

A major hurdle in the adoption of carbon utilization technologies is the lack of infrastructure or network that could allow the transport of carbon-rich gases. Attempting to address this challenge, the Carbon4PUR project has included WP 7 “Industrial symbiosis preparation” to explore the potentials for constructing a carbon-rich gas pipeline (including infrastructure, investments, legal requirements and safety requirements) for connecting a chemical plant with a steel mill plant in the area of the Grand Port Maritime de Marseille, led by MFPA. The results of WP 7 will speed up industrial tests and replications in the future, thus promoting the exploitation of the main results of the project.

Lastly, WP 1 ”Project Management”, WP 8 “Exploitation and dissemination of project results”, and WP 9 “Ethics requirements” have been running in parallel throughout the project . WP 1 and 9 have been driven by the project leader COV, whereas WP 8 was led by Dechema.

3. Exploitation Management Strategy

Carbon4PUR has set up an exploitation strategy aiming at identifying exploitable results, stimulating their IPR protection and maximizing their uptake for the benefit of individual partners and the Carbon4PUR value chain as a whole.

Throughout the project, the exploitation potential of the developed innovations has been triggered and explored, whereas adequate exploitation activities have been shaped and implemented to enable their market introduction. Specifically, a systematic approach has been applied to yearly monitor the development of the innovations, IPR protection measures, exploitation ambitions and planning via the conduction an survey. In addition, the survey has triggered partners to reflect how to maximize the exploitation potential of their results already from the early development stages, which allows the realization of adjustments considering market needs and barriers. Lastly, it has also contributed to the shaping of common exploitation ambitions at a project level and the recognition of challenges hindering Carbon4PUR acceleration.

Survey outcomes have been shared and discussed among members of Exploitation Board, which has been a dedicated structure on the project's exploitation. The Exploitation Board has held once a year and made decisions on individual (partner level) and joint (project level) exploitation planning, aiming at Carbon4PUR uptake and overcoming technical, financial, market, social and policy challenges. Decisions taken during the Exploitation Board Meetings and survey outcomes have served as key inputs for drafting the Carbon4PUR Exploitation Plans.

The figure below depicts the exploitation management strategy of Carbon4PUR, which will be further discussed in next sections.

Figure 2: *Schematic representation of the applied strategy for identifying Carbon4PUR's exploitable results and defining appropriate exploitation activities*

3.1 Monitoring of Exploitation Potential & Actions

Carbon4PUR has applied a systematic approach to monitor the exploitation potential of the developed innovations and the exploitation activities of project partners.

As aforementioned, a survey has been developed by PNO and distributed to project partners once a year. The main purpose of the survey is the systematic collection of partners' input regarding the development stage of their innovation, their application potential in market and/or science, IPR protection measures, exploitation barriers, and the progress of their exploitation activities. The survey has been consisted of a combination of open and closed questions, including lists of optional exploitation actions (such as the development of a follow-up project, standardization, engagement with potential clients etc), IPR protection measures, (such as patenting), and exploitation barriers (such as legal and policy framework, economics, compatibility with market needs etc). Hence, project partners have been invited to consider how to pave the way towards the results uptake and exploitation.

PNO has distributed the survey to consortium partners at least three months before the Exploitation Board meeting during which survey outcomes have been presented and thorough discussed.

3.2 Exploitation Management Structure

For accelerating the exploitation potential of project results, Carbon4PUR has constructed a management structure dedicated to exploitation, the Exploitation Board. It has been consisted of one representative per consortium member and headed by the Exploitation Manager.

The Exploitation Board's role has been to

- explore the exploitation potential of the project's results and identify exploitable results;
- facilitate the shaping of exploitation actions, protection tools and the valorization of the developed innovations;
- identify and contact relevant stakeholders for the upscaling of the project;
- identify funding opportunities for the upscaling of the project;
- support the project consortium in reporting about exploitation;
- propose actions to the General Assembly (the highest level decision-making body of the project, composed of one representative per partner) and to ensure that they are in line with the IPR arrangements laid down in the Consortium Agreement and Grant Agreement.

Throughout the project, three Exploitation Board meetings have been held. The first one was held at the 4th of September 2018 in Ghent, the second at the 13th of September, 2019 in Leverkusen and the third at the 28th of January, 2021 (online meeting).

During all the conducted Exploitation Board Meetings, outcomes of the survey have been discussed, decisions on exploitation actions and IPR protection have been made, whereas the pathway for the upscaling of the project has been explored, including exploitation barriers, targeted stakeholders and funding opportunities.

4. Management of Intellectual Property Rights

An effective exploitation of the generated results requires a IPR proper management. The protection of IPR allows project partners to turn their developed knowledge/results into tangible assets, attracts investors, provides exclusive rights and legal defense to their creators or inventors and encourages information sharing towards business, social and financial development.

Carbon4PUR has generated results with high academic and/or commercial interest. To manage the generated knowledge, partners, apart from the Grant Agreement, have developed and signed a Consortium Agreement, in which further rules about intellectual property ownership, access rights to background knowledge and results and the protection of IPR have been defined.

4.1 Background

To enable a trustful and reliable cooperation (i.e. to avoid disputes on the property of a specific information/knowledge), partners have identified and agreed on the “background” knowledge. By “background” we refer to any data, know-how or information, including any rights such as IPR that belonged to the beneficiaries before entering this project and is needed for the implementation of the project actions. Particularly, the Consortium Agreement includes a section (attachment 1), in which each partner has indicated the background needed to implement the action or exploit the results. Based on the Consortium Agreement, anything not identified in attachment 1 shall not be the object of access right obligations regarding “background”. However, each partner has the possibility to add further “background” to the attachment 1 during the project by providing a written notice to the other partners if the General Assembly approves it.

4.2 Results

Procedures have been in place for the management of the generated project results. Project results are regarded **as any tangible or intangible outputs of the action**, such as data, knowledge and information, irrespectively whether they can be protected. Results' ownership is governed by the Grant Agreement Article 26 stating that results are owned by the partner that generates them. In case two or more partners have generated results, then these results are jointly owned by the involved partners and the joint owners should agree on the allocation and the terms of exercise of their joint ownership.

The Consortium Agreement complements the Grant Agreement regarding the ownership, access rights and IPR of the results. Specifically, the Consortium Agreement allows each of the joint owners to use their jointly owned results for non-commercial research activities on a royalty-free basis and without requiring the prior consent of the other joint owners. Moreover, each joint owner is entitled to exploit the jointly owned results and to grant non-exclusive licenses to third parties, if the other joint owners are given at least 45 days advance notice and a compensation under fair and reasonable conditions. A license may include the right to make, have made, use, offer for sale, sell, import/export and/or otherwise dispose a product and/or use processes in the scope of the licensed result.

Each partner has to comply with the Horizon 2020 open access requirements under the terms and conditions laid down in the Grant Agreement. Scientific results of the project will be published with **open-access** after adequate assessment of the dissemination level and appropriate to the IPR regulations. Mandatory open access (free of charge online access for any user) is applied for all peer-reviewed scientific publications relating to project results complying with the Article 29.2 of the Grant Agreement. Procedures for the clearance of publications before their release have been set by the Grant Agreement and complemented by the Consortium Agreement, which request to be active during the project duration and one year after the end of the project.

Further information on the publications of the Carbon4PUR project is available in the public deliverable D8.8 "Dissemination and communication report".

5. Individual Exploitation Activities

The present chapter provides an overview of exploitable project results and how they are going to be exploited by individual project participants. The chapter is structured around three sections based on the organizational profile of the partners and their strategic interest in the deployment of Carbon4PUR results.

Exploitation of project innovations with commercial potential will be realized mainly by industrial partners to strengthen their business models and market position. Industrial partners have their strategic goal to develop and commercialize attractive products and processes. It is anticipated to take advantage of their significant presence in relevant markets and networks in order to accelerate the market introduction of Carbon4PUR innovations and conversion processes, extend their market share and develop new collaborations and strategic partnerships.

The academic partners (universities and Research and Technology Organization (RTO)) are interested in using newly gained knowledge as input to further research, scientific publications and advanced teaching purposes as well as using project results to initiate further research in carbon utilization and other related fields. RTOs also seek to increase their prestige and secure their position in the research community as cutting edge research and technological providers. They can use project results to generate new knowledge and research positions, develop new projects and partnerships with existing or new contact networks, particularly national public bodies due to their familiarity and close links to governmental activities, and potentially create spin-off companies.

For each project partner, its main activities and associated results will be described in the following section, followed by the planned exploitation activities.

5.1 Industrial Partners

5.1.1 Covestro Deutschland

With sales of roughly 10.7 billion € in 2020 and approx. 16,500 employees (including 1,000 researchers and developers), COV is among the world's leading manufacturers of polymers and high-performance plastics. CO_2 as an alternative resource is a major topic at COV, as by means of open innovation and publically funded projects, it has developed, demonstrated and market launched the cardyon® technology for the production of polyether carbonate polyols, with an annual production capacity of 5,000 tons. Through Carbon4PUR, COV seeks to exploit the developed technologies towards the commercialization of new CO/CO_2-based products or business lines and to strengthen its technical capacities on a global level.

As the project coordinator COV has had an involvement in all work packages. Particularly, COV has assumed a crucial role in WP 3 "Chemical technology development for CO/CO_2 conversion to polyols" and in WP 4 "Process development of CO-based polyol production". It has delivered several polyol samples for the conduction of application testing to Megara and Recticel and has been naturally involved in WP 7 preparing the industrial symbiosis for the polyol production site at Fos.

In the course of Carbon4PUR, COV has developed commercial-oriented results for direct exploitation as described below:

- New process for the production of CO/CO_2-based polyols (process)
- New catalysts for CO/CO_2 conversion (technology)
- New CO/CO_2-based polyols (product)
- New CO/CO_2-based polyol intermediates (product)

New process for the synthesis of CO/CO_2-based polyols

In order to protect the IPR, COV has submitted 11 patent applications regarding processes for the production of polyether-/polyester-polyols (PET-/PES-polyols) from CO_2/CO or CO/CO_2-based intermediates. The project coordinator aspires to make use and integrate the novel processes into its polyol manufacturing routes. Once the processes will be further optimized, COV also intends to license the processes for additional revenue generation.

New catalysts for CO/CO_2 conversion

Research conducted by RWTH with the support of COV has led to the development of improved catalytic systems for the synthesis to polyol building blocks. The IPR of the new catalytic systems have been transferred to COV by transfer agreements, which has resulted in the submission of two patent applications, whereas one additional patent is in preparation to be submitted. For further exploitation of the results, COV considers the creation of spin-off SMEs-catalyst preparation companies for upscaling the catalytic systems and looking at the potential of additional applications.

New CO/CO_2-based polyols

COV envisages to introduce cost competitive CO/CO_2-based polyols into the market that can substitute and directly replace current fossil-based counterparts. Carbon4PUR has succeeded in developing novel CO/CO_2-based PET-/PES-polyols with substantial exploitation potential.

The market volume is estimated at > 2 million t/a for all types of replaceable polyols (PES- and PET-polyols). The global polyester polyol market was valued at 5.5 billion USD in 2015 and it is poised to grow by 2.24 billion USD, during 2020-2024 progressing at a compound annual growth rate of 5%. (source: Research and Markets, Global Polyester Polyol Market 2020-2024. Following market projections, the global polyester polyol market will reach 9.2 billion USD by 2027 (source ReportLinker, Global Polyester Polyol Market, 2020). Of this total market, the segment of aliphatic polyester polyols was characterized by a global consumption of 1,737 kt/a (source: IAL Consultants Global Market Overview, 2015) with an annual growth of 5% per year to 2,221 kt/a in 2020. Its market valued 191.1 million USD in 2017 and is likely to reach up to 7731.5 million USD by 2025 with a compounded annual growth of 5.2% over the period 2018-2025 (source: Reports Globe,2020). Typical applications for aliphatic polyester polyols are elastomers, coatings flexible foam and adhesives.The market growth is primarily driven by increasing applications of polyester polyol across the end-user industries such as construction, automotive, electronics and others.

In the aromatic polyester polyols market segment, the global consumption of all aromatic polyester polyols is at 737 kt/a with an annual growth of 4.2% p.a. to 884 kt/a in 2020 (source: IAL Consultants). It was valued at 1,000 million USD by 2018 end and it is expected to reach 1,500 million USD by the end of 2026, expanding at a compounded annual growth of 5.2% (source: Persistence Market Research, 2018). Aromatic polyester polyols are mainly used for the production of polyisocyanurate and polyurethane foams for elastomers, adhesives, spray foams, construction, slabstock / bunstock applications, among others. The growing building & construction industry is one of the prominent factor responsible for the growth of this market

segment. The increasing number of stringent building codes for energy efficient buildings, especially in the matured regions has increased the demand for efficient and innovative thermal insulation materials. Additional factors contributing towards the growth of the market include the rising automotive production and the increasing demand from other end use industry such as packaging and consumer appliances.

Especially for rigid foams, a production volume of ~ 200 kt/a of aliphatic and aromatic polyester polyols will be targeted, which is ~ 8% of the global production volume.

The polyether polyol market has a global consumption volume of about 5,300 kt/a and the production capacity has expanded significantly over the past 5 years, primarily led by the bedding, automotive and construction industries The global polyether polyols market size is forecast to reach 15 billion USD by 2025, after growing at an annual rate of 5.5% during 2020-2025. (source: Industry Arc,2020) Polyether Polyols are compounds with multiple hydroxyl functional groups produced by reacting monomers of propylene oxide or ethylene oxide with an initiator, which can be glycerin, sucrose, sorbitol, or water. Polyether polyols find use in numerous applications including rigid and flexible polyurethane foam, coatings, adhesives & sealants, elastomers, and plasticizers. However, the largest share in the polyether polyols market is held by polyurethane foam application.

Carbon4PUR polyols have been developed to satisfy the requirements of two targeted applications: rigid foams for buildings insulation boards and PUDs for wood coatings. However, the market potential of the developed polyols are much broader. Alterations and adjustments of the developed innovative polyols are feasible, paving the way to additional Carbon4PUR polyol applications. Deliverable D6.1 “Evaluation of additional commercial applications and market segments” has explored the potential additional commercial applications of Carbon4PUR polyols.

To proceed towards the industrial production of the innovative polyols, COV has already supplied the developed catalysts to a toll manufacturer for upscaling and is considering to further optimize the obtained polyols in a follow-up project. Barriers against the immediate exploitation of the novel polyols are the need for further upscaling, assessments, optimization and resources.

New CO/CO_2-based polyol intermediates

Furthermore, the project has achieved the synthesis of CO-based intermediates for polyol production that find also other industrial applications, such as pharmaceuticals, agrochemicals cosmetics and food & beverages.

To further explore the exploitation potential of the obtained results, Carbon4PUR has made the decision to put the primary focus of market analysis (D. 8.4) on the market potential of the CO-based intermediates, their industrial applications, their competing counterparts and their market trends and demand. In view of the wide range of additional applications, the market introduction potential, the viability of the business case, the integration into its strategic planning and the expansion to new markets was investigated.

Barriers hindering the commercialization of Carbon4PUR results are the lack of clear Carbon Capture and Utilization (CCU) policy and legislative framework, the need of further optimization supported by computational research tools and optimized analytics and the need for additional enhanced capacities of skilled personnel and resources. For overcoming these barriers, COV intends to develop a follow-up project, raise funding from public/private sources and contribute to the formation of a coherent and comprehensive EU CCU policy framework.

5.1.2 Megara Resins - Fanis Anastassios

Megara Resins - Fanis Anastassios S.A (Megara) is a diversified manufacturer and supplier of raw materials for industrial and architectural coatings as well as rosin based and other synthetic resins for the paint, adhesive, paper and construction industry. For the project, Megara has explored the applicability of the CO/CO_2-based polyols for the development of water-based polyurethane dispersions (PUDs).

PUDs are thriving in the market for polyurethane coatings due to their numerous product benefits, including environmental advantages, ease of application and high-quality exterior look. Water-borne polyurethane (PUR) coatings are applied for metal coating, plastic coating, wood coating, fibre coating and others – one of the fastest growing segments for the surface coating industry. The target application is wood coating, with a global wood coating resins market of estimated USD 4.24 billion USD by 2021, at a CAGR of 5.39% from 2016 to 2021.

Carbon4PUR polyols have been evaluated for the synthesis of attractive PUDs, revealing the commercial potential of the **novel PUDs used for wood coatings.**

The organization is going to keep the intellectual property of the new PUDs confidential and secret for obtaining a competitive advantaged against its competitors.

Megara is well positioned to commercially exploit of the innovative PUDs for wood coating applications, but also for other coating applications such as self-healing coatings, adhesives

and printing inks. To successfully exploit the novel PUDs, Megara plans to work in close collaboration with their customers to further assess their commercial potential, verify their market acceptance and develop a thorough business plan and follow-up project towards the PUDs industrial production.

Due to Carbon4PUR participation, Megara has extended its expertise in the synthesis of novel PUDs leading to the development of a new research project focusing on the synthesis of PUDs with encapsulation of micro/nano structures for ecological self-healing coatings. The project started on 16/06/2020, is coordinated by Megara Resins and is implemented in collaboration with two academic institutions, i.e. the University of Patras and the Foundation for Research and Technology Hellas (FORTH) and an industrial coatings producer, ER-LAC KOUTLIS S.A. The project is funded under the funding scheme NSRF 2014-2020/RESEARCH – CREATE – INNOVATE, organized by Greek National Authorities.

5.1.3 Recticel

Recticel is a polyurethane manufacturer, seeking to make an essential difference in the daily life of everyone. Although the group primarily produces semi-finished products (flexible foams and automotive), it also manufactures finished goods and durable goods for end users (bedding and insulation).

For the purposes of the project, Recticel has processed samples of Carbon4PUR polyols on lab and pilot scale to evaluate their suitability for the formation of **new PUR insulation rigid foams**. The basis for the testing of new rigid foams are the official standards for petrochemical products and the rigid foam specifications which meet the market requirements. This basis makes the comparison of the newly developed insulation boards with the conventionally manufactured insulation boards feasible.

PUR rigid foam is extensively used as insulation material in building and construction, for inner and outer walls, floors, and roofs. The total market for thermal insulation products in Europe is estimated to grow at a rate of > 3%, mainly due to environmental protection and energy efficiency trends. Stricter regulations on energy efficiency, CO_2 emissions mitigation, and volatility of energy prices are pushing the market towards more effective building insulation.

Test results have shown the application potential of the novel polyols in the synthesis of rigid foams. Recticel recognizes the market potential of the expected new products in the PUR

insulation rigid foam. Once further polyol optimization is achieved, Recticel aspires to be able to gradually replace fossil based polyols with the Carbon4PUR polyols.

The strategy of the organization for protecting the intellectual property of the new rigid foams is to keep their formulations/recipes secret as highly confidential information.

5.1.4 ArcelorMittal Maizières Research

ArcelorMittal Maizières Research (AMMR) takes a leading role in the industry's efforts to find solutions to combat climate change. It has had a key role in the project to define the future activity size (in collaboration with COV) and to develop a concept for gas treatments on site (in collaboration with UGent).

Outcomes of the aforementioned tasks will support the upscaling of the project. AMMR is going to work together with COV on a future link of the infrastructures in the port of Fos for the development of the industrial symbiosis between the steel and the chemical industry, a business model that can shape the collaboration between these two industries. In addition, the partner is actively involved in EU policy making discussions and envisages to contribute to the shaping of a EU policy framework beneficial to industrial symbiosis and the recognition of its CCU potential as a CO_2 abatement measure.

5.2 Academic and RTO partners

5.2.1 Universiteit Gent

For Carbon4PUR, UGent has succeeded in developing two technological processes for the conditioning of secondary raw material waste streams (CO/CO_2), the **catalytic oxidation** and the **chemical looping process,** and has contributed to the development of heterogeneous catalyst systems for the CO/CO_2 conversion into reactive monomers for polyol synthesis.

Catalytic oxidation

The cascaded oxidation reactor process has been developed to satisfy the project's gas requirements for polyol manufacturing. Therefore, the developed purification technology has a direct application in the CO/CO_2-based polyol production and it might be relevant to other

applications requesting dehydrogenation of fuel gases. UGent is going to further explore its exploitation potential for other industrial processes and its intellectual property protection by patenting. For the development of the purification process, 1 PhD position has been created delivering 1 PhD thesis.

Triple chemical looping

Chemical looping is a technology that provides the opportunity to intrinsically separate gases, due to its 2-steps configuration. This technology does not only remove H_2 but also N_2 and H_2O while producing a purer CO/CO_2 stream which potentially leads to the reduction of costs at the downstream of the process. UGent has evaluated different chemical looping approaches for the conditioning of BFG and found a great potential in their triple chemical looping process, which is a complete new technology. Apart from the polyol production, the triple chemical looping process could find other applications related to CO-production from waste gas which is relevant to produce additional CO by converting large amounts of CO_2 into CO through Super-Dry Reforming (SDR), a concept that has been demonstrated at the Laboratory for Chemical Technology of UGent.

Recognizing the exploitation potential of the completely new catalytic process, UGent has submitted 2 patent applications to protect the ownership of the invention.

Given that the suitability of triple chemical looping for the production of CO as a key platform molecule in a sustainable future requires the conduction of further research and piloting after the end of the Carbon4PUR project, UGent foresees to set up a pilot plant to explore the applicability to other industrial processes, to develop a proof of concept and to conduct a techno-economic assessment aiming to compare competing purification/separation technologies.

For the development of this novel purification technology, UGent has created 2 PhD positions that will result in 2 PhD theses. In addition, 4 master theses have been submitted.

Lastly, UGent has collaborated with RWTH for the development of heterogeneous catalyst systems for the CO/CO_2 conversion into reactive monomers for polyol synthesis. UGent has tested the potential of heterogeneous catalyst candidates developed by RWTH. For the performance of this task, UGent has created 1 Postdoc position.

5.2.2 Universiteit Leiden

UL has led WP 6 “Accompanying economic, environmental and societal research and project e/8*valuation”, performing an Life Cycle Assessment (LCA) of the lab-scale versions of the Carbon4PUR innovations and an LCA of upscaled versions of novel technologies aiming at evaluating environmental impacts of the developed technologies and identifying sustainability hotspots.

Results of the performed LCAs and their generated knowledge will be used by project partners to identify hotspots for sustainability improvements and technical optimizations. Due to Carbon4PUR, UL has been able to strengthen its position in the academic field of LCA of emerging technologies by establishing 1 PhD position, which will result in the submission of a PhD thesis. Knowledge gained will be deployed for the development and realization of future research projects.

5.2.3 Technische Universität Berlin

TUB’s main contribution to Carbon4PUR has been the evaluation of the economic potential of the project. Particularly, the partner has carried out a baseline techno-economic assessment (TEA) of conventional fossil-based PURs and steel industry mill gases, TEAs of the novel technologies on lab/pilot scale and on a large scale and an evaluation of additional commercial applications and market segments.

The results of the performed TEAs (knowledge type results) are useful tools for maximizing the economic viability of the project. Project partners can make use of the generated +knowledge to assess whether and to which extent technical alterations and optimizations are needed for improving their commercial potential of the project. In addition, the economic feasibility of the Carbon4PUR process and products compared to conventional production processes and products determine the commercial potential of the Carbon4PUR project, offering a strong and convincing argument for the added value of the project to key stakeholders and investors to trigger interest in and support for Carbon4PUR.

The utilization of the generated results in science is restricted, as detailed outcomes of the economic assessments are confidential – only to be released to the consortium. However, the deployed approach and methodologies contributes to better globally accepted standards for the conduction of similar analyses and the scientific track record of the TUB. Due to the project, TUB has established 1 PhD position that will lead to 1 PhD thesis, whereas 1 master thesis

has already been realized. Knowledge gained will be deployed for the development and realization of future research projects.

5.2.4 Rheinisch-Westfälische Technische Hochschule Aachen

Three institutes of RWTH have contributed to Carbon4PUR: the Catalytic Center (CAT), the chair of Fluid Process Engineering (AVT.FVT) and the chair of Communication Science at the Human-Computer Interaction Center (HCIC).

RWTH-CAT's main task has been the development of efficient catalyst systems for the CO/CO_2 ring expansion of propylene oxide (PO) and ethylene oxide / propylene oxide (EO/PO) mixtures to yield intermediates for polyol synthesis and polymerization strategies. As a result of this work stream, **novel catalysts for the conversion of CO to polyol intermediates** have been obtained. The of the developed catalytic systems have been transferred to COV, as discussed in section 5.1.1.

Concerning AVT.FVT, the institute has co-developed together with COV a **new conceptual process of for the formation of CO_2- and CObased PET-PES polyols**. This conceptual process design was the basis for LCA and TEA by WP 6 and the industrial symbiosis analysis by WP 7.

Lastly, HCIC has explored the social perception and acceptance of CCU insulation boards to provide insights into the societal readiness and communicative requirements for its market introduction. Potential consumers of the PUR insulation boards made from CO/CO_2-based polyols in Germany and the Netherlands were selected as the target group of this study. Outcomes of the study have shed light on the market potential and acceptance of the insulation boards as one example of the Carbon4PUR innovative products helping, thus, the industrial partners to set tailored communication and engagement strategies with end-users, aiming at enhanced social and market adoption.

Due to RWTH institutes' participation in Carbon4PUR, RWTH can promote further its research competencies and scientific reputation in catalysis, conversion processes and interdisciplinary research. 1 PhD position on model-based design of multi-phase reaction processes has been created by RWTH-AVT and 2 post doc positions have been created by RWTH-CAT, whereas 1 master thesis has been submitted related to the social perception and acceptance study.

5.2.5 Commissariat à l'énergie atomique et aux énergies alternatives

The CEA team has contributed to the development of proof-of principle of the catalyst lead structure for the conversion CO and CO_2. It has worked on alternative carbonylation catalyst development producing **new catalytic systems for the formation of CO-based intermediates for polyol production.**

The application of the generated technologies are of high importance in science and market as well, as it could lead to a better understanding of other catalysts and to the design of new catalysts, finding a variety of applications in industrial processes. CEA is the single owner of the results and has undertaken actions for the protection of its IPR by submitting 1 patent application, whereas another patent application is expected.

Carbon4PUR participation has allowed CEA to further raise its reputation as a competent RTO in disruptive catalytic systems, considering that 1 PhD position and 1 Postdoc position have been created. Louise Ponsard successfully defended her PhD thesis on the 12th of January 2021.

5.2.6 Imperial College London

ICL has been involved in WP 7 on industrial symbiosis, collaborating with Dechema on the mapping of CO/CO_2 mixed and pure sources in Europe revealing information about possible replication sites. The developed online geographical information tool provides a valuable basis for Carbon4PUR replication as well as for other similar symbioses using combined or single streams. It assists with matching emission sources and polyol production sites. Since the tool is freely available, it will benefit other stakeholders across the CCU community such as policy makers and researchers. ICL has also explored the replication potential of the project in collaboration with PNO and Dechema. By identifying key logistical constraints to establishing a symbiosis, the tool will be useful to a broad audience including regional governments, investors and project developers of CCU initiatives in general. In this way, ICL has enhanced its reputation in the field of CCU. The approach enables European industry to take general CCU developments as a production paradigm one step closer to common business objective. Investors, policy makers, industry and science can more easily identify practical details of their own commercial applications and market segments. Knowledge gained will be deployed by ICL and partner for the development of future research and consultancy projects.

5.3 Other Partners

5.3.1 DECHEMA Gesellschaft für Chemische Technik und Biotechnologie

Dechema has been the lead beneficiary of WP 8 “Exploitation and Dissemination of project results” being responsible for and involved in communication and dissemination activities. Communication and dissemination activities aim at transferring project results to relevant targeted audiences and maximizing their impact by enabling their wide dissemination and making targeted audiences aware of the Carbon4PUR objectives and progress. Such activities reinforce exploitation actions, given that stakeholders, interested in the project, will naturally come closer to the project partners and be engaged in the exploitation of the results . Thus, there is a kind of push and pull relation in which dissemination and communication are making project results available and through exploitation results are being used.

Dechema has also been involved in WP 7 on the preparation of industrial symbiosis. Specifically, the partner has mapped the CO/CO_2 mixed and pure sources in Europe (D 7.1), provided in an online interactive tool linked to the Carbon4PUR website. Furthermore, it has assessed the replication potential and preferred sites for industrial symbiosis (D 7.2) with the support of ICL and PNO. Both reports endorse Carbon4PUR exploitation efforts, as they shed light on the replication potential of the Carbon4PUR concept in other EU areas paving the way for the development of spin-off projects and future collaborations.

Dechema intends to use its developed results to advance its competencies in innovation services, boost its position as a network (members based) organization capable of promoting further carbon utilization research and innovation and create spin-off projects.

5.3.2 South Pole Carbon Asset Management

South Pole Carbon Asset Management (SPG) is a leading sustainability solutions and service provider. Being involved in WP 6, SPG supported by its linked third party South Pole UK has delivered: a) a methodology that can be used to determine the GHG reductions resulting from the Carbon4PUR process, b) an analysis on the social benefits of the Carbon4PUR innovations and c) an analysis of the climate policy landscape.

The developed social impact assessment (methodology) is a market oriented result to be further exploited by the partner. It can be considered a standardised methodology that can be

applied as designed or adapted if necessary, to accommodate similar process set-ups for enabling potential new clients to commercialize innovative processes of chemicals. The methodology on the Green House Gases (GHG) reductions can also serve as a tool for further promoting the added value of Carbon4PUR to key stakeholders, whereas SPG will deploy it as a standardized consulting service included in its service portfolio. Coming to the climate policy landscape analysis, it will be used directly by SPG to increase its knowledge and expertise in CCU policy framework and indirectly by the project consortium to draft an appropriate advocacy plan targeted at EU policy makers of CCU policies.

5.3.3 Grand Port Maritime de Marseille

MFPA has been the lead beneficiary of WP 7 on the industrial symbiosis that deals with the industrial symbiosis concept to be exemplarily investigated at Marseille Fos, where ArcelorMittal has a steel mill and Covestro a PUR production side. MFPA has assessed the feasibility of the connecting infrastructure for setting up the foundations (distance, potential pipeline length, investments, legal requirements, safety, economic model), based on which a follow-up demo project can be developed. These results, apart from being deployed for the set-up of the Carbon4PUR follow-up and/or spin-off projects, will be used by MFPA to develop learnings on the potentials and hurdles impeding the realization of industrial symbiosis activities in its industrial zone. Such learnings will be incorporated in the design of strategic developmental pathways aiming at strengthening the competitiveness of the Fos industrial site.

5.3.4 PNO Consultants

PNO as a service provider in the area of grants and innovation management, aspires to utilize its results in order to exercise its expertise in innovation services and raise its profile in the area of carbon utilization. PNO has carried out a value chain and stakeholder analysis to identify the most important stakeholders of the Carbon4PUR technology along the value chain and a market analysis. In addition to these activities, PNO has been responsible for setting up the exploitation strategy, drafting of exploitation plans and of a mini business case of the project presented at the final technical report.

The value chain and stakeholder analysis has identified relevant stakeholders along each step of the Carbon4PUR value chain and cross-cutting stakeholders. The analysis revealed end-users of the developed innovations and stakeholders that could potentially enter into

businesses with Carbon4PUR partners. In addition, context setters such as relevant policy makers, associations, networks and civil society organizations, that could potentially support the Carbon4PUR exploitation, have been pointed out. Lastly, the analysis has mapped investors and standardization organizations, all significant stakeholders for the project upscaling and acceleration, and has provided recommendations for stakeholder engagement strategies to be employed by the project partners.

The conducted market analysis has served to assess the market segments, trends and growth of the Carbon4PUR polyol intermediates, rigid foam insulation boards and PUDs. Outcomes of the analysis will be used by the industrial project partners to make informed decisions on the development of their commercial and business planning towards the commercialization of their Carbon4PUR innovation.

6. Joint Exploitation Activities

The present chapter provides exploitation actions that have been agreed to be pursued on the Carbon4PUR project level and not on the partners level in order to reinforce project's exploitation efforts.

6.1 Follow-up Project Development

Members of the Exploitation Board have recognized the need for further research and advancement for accelerating project results and bringing the innovation closer to market. The advancement of the innovative conversion route (from steel mill gases to polyurethane products) will require the upscaling of the process to further validate its technical feasibility and economic viability through the development of a follow-up demo project. Project development involves funding acquisition for the support of a demo project, a more concrete business plan and business cases, identification of potential demo locations and stakeholder engagement.

6.1.1 Funding Opportunities

PNO as a member of the consortium and an experienced grant and innovation consultancy with a strong record in project development supports, has helped the Carbon4PUR consortium in identifying funding opportunities. PNO has presented upcoming EU calls and EU funding opportunities during Exploitation Board Meetings, whereas additional funding opportunities and investors are also presented in the submitted "Value Chain and Stakeholders Analysis". Apart from PNO, SPG is committed to assist Carbon4PUR furtherwith developing a follow–up project by exploring and capturing climate finance opportunities.

6.1.2 Business Model for Project Scale-up

Project partners are working together at shaping the business plan and the model for setting up the collaboration between the steel and chemical industry. The developed business plan will rely on project results from the realized TEA, the feasibility study on the industrial symbiosis concept application in the port of Marseille, the market analysis, the LCA, and the optimal process route for the synthesis of CO/CO_2-based polyols. In addition, results of the conducted

analysis on the identification of replication sites will be considered for the future roll-out of the project. A first version of the business plan will be presented at the final technical report of the project, whereas it will be further detailed by project partners after the end of the project.

6.2 Policy Change

A supportive policy framework towards CCU innovations can encourage a transition towards the commercialization and use of CO/CO_2-based polymers. However, the current EU legislations and policies hinder the extensive adoption of Carbon4PUR results and similar carbon utilization technologies. Carbon4PUR partners have recognized that there are still no specific guidelines on the allocation of the carbon utilization benefit between the involved industries (the process gas provider and the recycled carbon user), neither sufficient reward for industries putting effort into carbon utilization options. Hence, project partners have been committed to put joint effort in policy change activities for addressing policy barriers as a common action for the Carbon4PUR acceleration.

In particular, outcomes of the climate policy impact report will be used for the darting of an advocacy and communication plan, while outcomes of the value chain, stakeholder analysis and replication report will be deployed for the selection of targeted audiences, champions and the establishment of stakeholder groups and coalitions.

Moreover, outcomes of the social impact report, the GHG baseline and monitoring methodology description & EU Emission Trading System impact, TEAs and LCAs are considered to be used for the development of factsheets and supported documentation, intended to be distributed among targeted regulators and policy makers. Furthermore, the developed factsheets with key metrics of the process (economics, GHG-environmental benefits, social benefits) can be distributed among stakeholders active in potential replication sites, investors & financial organizations and end-users to facilitate the establishment of a follow-up project.

7. Overview of Exploitable Results and Actions

The following tables describe the exploitable results and actions per work package.

***Table 1**: Overview of exploitable results and actions of WP 2 - Conditioning of secondary raw material waste streams (CO/CO_2)*

Exploitable Result	Type of Result	Applications	Owner	Actions undertaken	Actions planned	IPR protection	Exploitation barriers
Triple chemical looping	Technology	Carbon4PUR polyol production CO production	UGent	2 PhD positions 4 master theses	2 PhD theses Follow-up research project Piloting 2 patent applications	Patenting	Further Research Testing
Catalytic oxidation	Technology	Carbon4PUR polyol production	UGent	1 PhD position	1 PhD thesis Patenting exploration		

Table 2: *Overview of exploitable results and actions of WP 3 - Chemical technology development for CO/CO_2 conversion to polyols*

Exploitable Result	Type of Result	Applications	Owner	Actions undertaken	Actions planned	IPR protection	Exploitation barriers
A new catalyst for the carbonylation of the polyol intermediates	Technology	Carbon4PUR polyol production Carbon4PUR intermediate	CEA	1 PhD position 1 Postdoc position	1 PhD thesis 1 patent application	Patenting	Further research
A new catalyst for the isomerization of the polyol intermediate	Technology	Carbon4PUR polyol production Acrylic acid production	CEA	1 patent application	Follow-up R&D project	Patenting	Financials Lack of a project consortium for a follow up R&D project
New catalytic systems for the conversion of CO to polyols	Technology	Carbon4PUR polyol production Potential applications for other reactions and intermediates	COV RWTH UGent	3 post doc positions 2 patent application IP transfer agreement	1 patent applications Spin-off SMEs-catalyst preparation companies	Patenting	
New CO-based polyols	Product	Rigid foams PUDs Other PUR applications	COV	Further testing and upscaling Exploration of additional applications	Follow-up innovation project Policy Action Spin-off SMEs Market introduction	Protected by patenting of the new process, see WP4	Further research Enhanced Capacities Further Testing Financials Legal/Policy framework
New CO-based intermediates	Product	Carbon4PUR polyol production Other multiple applications	COV	Market Analysis, Upscaling of samples	Expansion to new markets, exploration of new markets Business plan	Protected by patenting of the new process, see WP4	

Table 3: *Overview of exploitable results and actions of WP 4 - Process development of CO-based polyol production*

Exploitable Result	Type of Result	Application	Owner	Actions undertaken	Actions planned	IPR protection	Exploitation barriers
New process for the production of CO and CO_2 - based polyols	Process	Carbon4PUR polyol production CO-based intermediates	RWTH, COV	1 PhD position IP transfer agreement 11 patent applications	1 PhD thesis 1 patent application Licensing	Patenting	
New process for the production of the CO-based intermediates	Process	Carbon4PUR polyol production CO-based intermediates	COV	Further optimization		Patenting Protected by patenting of the new process - see WP4	Further research and optimization

Table 4: *Overview of exploitable results and actions of WP5 - Further semi-industrial processing and tests of CO-based polyols*

Exploitable Result	Type of Result	Application	Owner	Actions undertaken	Actions planned	IPR protection	Exploitation barriers
New CO/CO_2-based PUDs	Product	Wood coatings Other coating applications: -self-healing coatings, -adhesives, -printing inks	Megara, COV	New research project for the synthesis of PUDs with self-healing properties	Follow-up project Business plan Market introduction of the new PUDs from CO-based polyols	Secrecy	Further research/testing Financials
New CO/CO_2-based rigid foam	Product	PU insulation boards	Recticel, COV	Carbon4PUR $PACO_2$- - social perception and acceptance study	Follow-up project Market introduction of the new insulation boards	Secrecy	Further research/testings Financials

Table 5: *Overview of exploitable results and actions of WP 6 - Accompanying economic, environmental, societal research & project evaluation*

Exploitable Results	Type of Result	Application	Owner	Actions undertaken	Action planned	IPR protection	Exploitation barriers
LCA	Knowledge	Carbon4PUR polyol production	UL	1 PhD position	1 PhD thesis Development of follow-up research projects Policy Change	Confidential	Financials
TEA	Knowledge	Carbon4PUR polyol production	TUB	1 PhD position 1 master thesis	1 PhD thesis Development of follow-up research projects Policy Change	Confidential	Financials
Social impact methodology	Methodology	Carbon4PUR polyol production CCU projects	SPG		Business development (consultancy service) Policy Change	Secrecy	
GHG baseline and monitoring methodology	Methodology	Carbon4PUR polyol production CCU projects	SPG		Business development (consultancy service) Policy Change	Secrecy	
Climate Policy Framework	Knowledge	Carbon4PUR polyol production CCU projects	SPG		Business development (consultancy service) Consulting services Policy Change	Secrecy	

Table 6: *Overview of exploitable results and actions of WP7- Industrial symbiosis preparation*

Exploitable Results	Type of Result	Application	Owner	Actions undertaken	Action planned	IPR protection	Exploitation barriers
Map of CO/CO_2 sources	Tool	Carbon4PURpolyol production Other CCU projects	Dechema, ICL		Development of spin-off projects Policy change	Publicly available	
Identification of replication sites	Knowledge	Carbon4PUR polyol production	Dechema, PNO,ICL		Development of spin-offs projects Policy change	Publicly available	Legislation Financials
Pipeline construction feasibility	Knowledge	Carbon4PUR polyol production	COV, AMMR, MFPA		Development of follow-up project Carbon4PUR business plan	Confidential	Legislation Financials

Table 7: *Overview of exploitable results and actions of* WP8 - Exploitation and dissemination of project results

Exploitable Results	Type of Result	Application	Owner	Actions undertaken	Action planned	IPR protection	Exploitation barriers
Stakeholder Analysis	Knowledge	Carbon4PUR polyol production PUD production PUR insulation boards	PNO		Business development (consultancy service) Development of follow-up and spin-off projects Stakeholder engagement Policy change	Secrecy	
Market Analysis	Knowledge	Polyol intermediate production PUD production PU insulation boards	PNO		Development of follow-up and spin-off project	Secrecy	
$PACO_2$ perception, acceptance and communi-cation concepts for a CO/CO_2-derived product	Knowledge	Carbon4PUR polyol production Carbon4PUR Insulation boards	RWTH	1 master thesis	Follow-up research project		Financials

This final chapter has presented an overview in table format of the Carbon4PUR exploitable results, applications, IPR protection measures, exploitation activities and barriers hindering their future exploitation and uptake.