Deliverable 11.5
Training Seminar

WP 11 – Dissemination

Version 1.0

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Lead participant: IIT (written), All (event)

Delivery date: 05-06th Sept. 2019, 12th Nov 2019.

Dissemination level: Public

Type: Report / Other -*event*

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 760994. The content of this publication is the sole responsibility of the authors. The European Commission or its services cannot be held responsible for any use that may be made of the information it contains.

1 Revision History

Author Name, Partner short name	Description	Date
P. Hudson, KHT	Draft deliverable	0/10/2019
V.Margaria, IIT G.Traverso, IIT	Revision 1 and New inputs	8-28/10/2019
P. Hudson, KHT	Revision 2	11/11/2019
G.Traverso, IIT	Final Version	12/11/2019

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2 Introduction

As part of the training activities outlined in the ENGICOIN dissemination plan, we decided to host a Summer School for ENGICOIN participants, as well as members of other ongoing H2020 consortia that are involved in CO2 assimilation. An organizing committee was formed to set the program and invite speakers (Table 1). The Summer School was broadly separate into two themes: biological CO2 fixation and conversion, and chemical CO2 fixation and conversion. The first day of the session was to describe the various approaches and progress in 6 ongoing CO2 conversion projects. The second day was to comprise deeper "lectures" on specific technical aspects of some of the projects. The second day would also involve a site visit.

The intended audience was Ph.D. students and postdocs within these EU-funded projects. The Summer School was held in Amsterdam 05-06 September 2019. A website was created at https://www.co2olingearth.eu

Table 1. Organizing Committee: CO2OLING THE EARTH SUMMER SCHOOL

Name	Affiliation
Giuditta Traverso	IIT Italian Institute of Technology
Dr. Valentina Margaria	IIT Italian Institute of Technology
Prof. Paul Hudson	KTH Royal Institute of Technology Sweden
Prof. Paolo P. Pescarmona	RUG University, Gröningen Netherlands
Dr. Simelys Hernandez	IIT Italian Institute of Technology
Dr. Sergio Bocchini	IIT Italian Institute of Technology

3 Co2oling the Earth Summer School summary

The Summer School was attended by approximately 100 participants from 7 European countries. Approximately 150 flyers about ENGICOIN were distributed. There were 20 speakers over the 2-day event. Dissemination metrics are in Table 2. A picture from the Summer School is Figure 1. An attachment is the program booklet.

There was a plenary lecture from Michael Köpke, Head of synthetic biology of Lanza Tech, a renowned biotechnology company working on fermentation of waste gases. Michael described the some of the challenges with scaling up gas fermentation. He also gave a good overview of what synthetic biology can do to expand the product portfolio of CO2-fixing bacteria.

A second plenary lecture was from Marc Koper of Leiden University, a world-leader in electrochemical reduction of CO2. Marc explained the current state of the art in CO2 electrochemical reduction, in particular how to predict when CO2 will be reduced to CO or to formate. He also gave a good overview of the limitations of an electrochemical process (namely the need for very high surface areas).

There was a session dedicated to companies, their role in EU projects and the opportunities for technology exploitation. The companies were Titan (cement production), Avantium (Electrochemical CO_2 reduction), and Hysytech (H_2 generation).

There were several presentations giving overviews of the **6 EU-funded** projects that work with CO_2 conversion: RECODE, ENGICION, CELBICON CO2EXIDE, STORE&GO, BIOCON-CO2

Next, there was a session dedicated to communicating science to younger audiences and a session dedicated to Responsible Research and Innovation (RRI), and how we can use this framework for sustainability. Some take-home messages were

- The RRI framework is rarely applied to sustainability, even though it is heavily promoted in the EU funding schemes
- Sustainability is a difficult metric to use when evaluating research alternatives, since the problem is complex and the best solutions are not known
- There are some ways that the RRI framework can adapted for sustainability by:
    - What can the researchers do? Each team should try to minimize its carbon footprint, and promote this to other stakeholders.
    - Stakeholder management; stakeholders should be involved already in helping to form the goals of the project, as well as in evaluating alternatives. By broadening the input pool, we are more likely to get better perspectives on sustainability.

On the second day, there were several “Frontal lessons," where aspects of ENGICION (and other projects) were covered in more technical detail. These training sessions included:

- Considerations for engineering cyanobacteria for CO_2 uptake (ENGICOIN, Paul Hudson from KTH Stockholm)
- Engineering a biological methane reactor (ENGICOIN, Krajete)
- Biogas conversion by porous off-gas-burner (BIOROBURPLUS, Kit)
- Technology basics of Carbon Capture from the atmosphere
- Techno-economics of gas capture from steel mills (CERTH)

There was a poster session with approximately 20 posters.

There were also site visits (approximately 2-3 hr) to PHOTANOL and AVANTIUM, companies involved in ENGICOIN and RECODE, respectively.

There was a short workshop on **FUTURE PLANS**. This included setting up a joint mailing list for coordination between the various CO_2-capture projects.

- Overview of upcoming meetings within each project, and if there was potential to expand any of these to the other groups.
- Decided whether to pursue a recurring “Co2oling the Earth” summer school every year.
- One issue that must be resolved before a next summer school is what is the target audience? For example, this summer school was intended for only for Ph.D. students. There were suggestions that we invite more company representatives, or political actors.

Table 1 - Dissemination targets from the Summer School (Green)

ENGICOIN Tool	**Indicator**	
Flyers	Number of flyers distributed	150
Press releases	Number of press releases	1 under preparation
E-Newsletter	Number of newsletters distributed	
Presentations at conferences/fairs	Number of attended conferences with presentation or posters	20 speakers 6 EU consortia represented 15 posters presented
Training events	Number of registered participants	140/150 (audience+Speakers,Chairs)
	New stakeholders	30/45 new people from different organization + 5 EU associated projects
Social media	Number of members/followers	
	Number of retweets	>20 regarding the event
Website www.co2olingearth.eu	Monthly visits	TBD
	Country distribution	TBD
	Number of downloads per month	TBD

Figure 1. Photograph taken from Co2oling the Earth Summer School. Amsterdam, September 04 2019

Attachment. Program booklet (PDF).

Attachment

CO_2OLING THE EARTH

CO_2 CONVERSION PATHS EXPLAINED THROUGH EU FUNDED PROJECTS

September 5-6, 2019

Amsterdam Science Park, Netherlands

Science Park 123
1098 XG Amsterdam
+31 (0)20 592 6012
congreszalen@wcw.nl

www.co2olingearth.eu

The event is organized by Italian Institute of Technology (IIT) in the context of RECODE and ENGICOIN projects. These projects have received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 768583(RECODE) No. 760994(ENGICOIN). Additional sponsorship by CELBICON and BIOROBURplus receiving funding from EU H2020 under Grant Agreement No. 679050 and No.736272

SCHOOL AGENDA: THURSDAY, 5TH SEPTEMBER 2019

8:30 AM **REGISTRATION**

9:20 AM **WELCOME**

DR. SIMELYS HERNANDEZ

09:30 – 11:00 AM **PLENARY LECTURES**

CHAIR:PROF. PAOLO PESCARMONA AND PROF. PAUL HUDSON

09:30 AM **DR. MICHAEL KÖPKE- HEAD OF SYNTHETIC BIOLOGY OF LANZATECH**

COMMERCIAL SCALE GAS FERMENTATION FOR CONVERTING POLLUTION TO PRODUCTS

Rapid population growth and climate change are posing some of the most urgent challenges to mankind and have intensified the need for low-cost manufacturing of fuels, chemical-building blocks, materials and food from sustainable resources. Gas fermentation using autotrophic microorganisms offers a sustainable path to these products from a range of local, highly abundant, waste and low-cost resources. LanzaTech has pioneered a gas fermentation process using anaerobic acetogenic microbes capable of fixing carbon oxides. While 10 years ago, acetogens were considered genetically inaccessible and mass-transfer of gases was considered a major scale up hurdle, LanzaTech has since developed a suite of synthetic biology tools and successfully scaled up the process from the laboratory bench to full commercial scale. In May 2018, LanzaTech successfully started up a world-first commercial scale (48k MTA) gas fermentation plant using emissions from the steel making process as feedstock. The technology has been demonstrated with a diverse range of additional low-cost feedstocks including waste gases from other industrial sources (e.g., processing plants or refineries) or syngas generated from any biomass resource (e.g., unsorted and non-recyclable municipal solid waste, agricultural waste, or organic industrial waste) that vary in composition of CO and/or H2 with CO2. Integration with electrolysis further enables direct CO2 capture using zero-carbon electricity in absence of CO and/or H2. In order to maximize the value that can be added to the array of gas resources that the process can use as an input, LanzaTech has established advanced models and a unique biofoundry that enables automated strain engineering of anaerobic organisms and strain screening in context of flammable and toxic CO and H2 gases. Through this platform, LanzaTech has demonstrated direct production over 50 different products from gas.

10:15 AM PROF. MARC KOPER - PROFESSOR OF SURFACE CHEMISTRY AND CATALYSIS AT LEIDEN UNIVERSITY.

ELECTROCATALYTIC REDUCTION OF CO2: CATALYSTS AND MECHANISMS

The electrocatalytic reduction of carbon dioxide is a promising approach for storing (excess) renewable electricity as chemical energy in fuels. I will talk about recent advances and challenges in the understanding of electrochemical CO2 reduction. I will discuss existing models for the initial activation of CO2 on the electrocatalyst and their importance for understanding selectivity. Carbon-carbon bond formation is also a key mechanistic step in CO2 electroreduction to high-density and high-value fuels. I will argue that both the initial CO2 activation and C-C bond formation are influenced by an intricate interplay between surface structure (both on the nano- and on the mesoscale), electrolyte effects (pH, buffer strength, ion effects), and mass transport conditions. This complex interplay is currently still far from completely understood.

11:00 AM COFFEE BREAK

11:20 – 12:45 AM FLOOR TO COMPANIES: HOW CO2 CONVERSION CAN BE EXPLOITED IN INDUSTRY?

CHAIR: ANIEK VAN DER WOUDE, PHOTANOL

DR. MARIOS KATSIOTIS, TITAN CEMENT GROUP

CARBON MITIGATION IN THE CEMENT INDUSTRY – FOCUS ON CARBON CAPTURE AND INNOVATIVE TECHNOLOGIES

Cement is the most used manufactured product on a global scale, an indispensable material that allows for affordable, durable and sustainable construction of buildings and infrastructure. Although its specific embedded carbon emissions are among the lowest compared to other construction materials, global production is above 4Gt and accounts for up to 7% of total anthropogenic CO2 emissions annually. Considering population increase and urbanization trends, cement consumption is expected to increase in the coming years. In order to meet the Paris agreement goal to limit global warming to 2oC and to achieve net zero greenhouse gas emissions by 2050, the sector is considering and implementing a number of mitigation methods across the entire value chain of cement-based construction materials.

The talk provides an overview of conventional and novel CO2 mitigation routes specific to cement manufacturing, with focus to carbon capture and innovative technologies. Progress in research & development towards reducing CO2 emissions achieved by TITAN Cement Group and other stakeholders will be presented, including collaborative work performed within the Horizon2020 programme.

DR. KLAAS JAN SCHOUTEN, AVANTIUM

REDUCING CO2, PRODUCING CHEMICALS: THE POTENTIAL OF ELECTROCHEMISTRY

Since 2012, Avantium has been developing a technology platform based on electrochemistry. Using electrocatalysis and zero-carbon electricity we aim to produce chemicals with a much lower carbon footprint, and even convert CO2 itself into products. Avantium has built a leading patent portfolio in the field of electrocatalytic carbon dioxide reduction.

By targeting high value products, lowering the power costs by combining oxidation and reduction reactions, and by deploying the trans-disciplinary approach that is needed for the introduction of these advanced technologies, Avantium is addressing the critical elements that are currently hindering new electrochemical processes to enter the market.

In November 2016, Avantium acquired Liquid Light, a Princeton 2009 start-up in which more than 35 million dollars was invested. Liquid Light has developed proprietary process technology to make major chemicals from CO2. The acquisition combines the technologies of both Liquid Light and Avantium to develop a world leading electrocatalysis platform with both short and long term applications.

Using this technology platform Avantium aims to develop an integrated process for the production of high-value C2 chemicals. Avantium is accelerating this development by participating in 2 consortia within Europe, respectively the OCEAN and the RECODE project. The OCEAN project aims to develop an integrated process for the production of high-value C2 chemicals from carbon dioxide using electrocatalysis. This will be achieved by improving and optimizing the technology just one-step away from commercialization by demonstrating the CO2 reduction technology at the site of an industrial electricity provider. The production process of high-value C2 products and polymers thereof will also be developed and demonstrated. The RECODE consortium will develop technology for CO2 utilization in the context of cement manufacturing. The aim is to synthesize C1 and C2 product through electrocatalytic and chemical pathways to be used as hardening acceleration promoters, grinding aids, or ionic liquids additives.

Avantium is also part of the European TERRA project, which aims at the development of a tandem electrolyser, combining the anodic formation of a dicarboxylic acid and the cathodic formation of di-alcohols. This tandem electrolysis will increase the energy efficiency and therefore reduce the ecological footprints of the products even further.

An ultimate solution to lower CO2 levels in the atmosphere is to convert CO2 that is directly captured from air. The decentralized processing of CO2 and biobased feedstocks is investigated in the European CELBICON project, where 12 partners from 7 countries will put their key enabling technology developments together. By combining CO2 adsorption from air, pressurizing, electrolysis, and fermentation, a robust and efficient technology to produce bioplastics and other added-value chemicals from CO2 and biomass is being developed.

DR. MASSIMILIANO ANTONINI, HYSYTECH

12:45 AM **BREAK**

2:00 – 4:30 PM **PROJECT PESENTATIONS**
CHAIR: PROF.PAOLO PESCARMONA & PROF. PAUL HUDSON

2:00 PM
DR. SERGIO BOCCHINI
RECYCLING CARBON DIOXIDE IN CEMENT INDUSTRY TO PRODUCE ADDED-VALUE ADDITIVES

CO2 from the flue gases of a rotary kiln in a cement industry (CO2: 25 vol%) will be used for the production of value-added chemicals (acid additives for cement formulations) and materials (CaCO3 nanoparticles to be used as concrete fillers). A circular-economy-approach is enabled: the CO2 produced by cement manufacturing is re-used in a significant part within the plant itself to produce better cement-related products entailing less energy intensity and related CO2 emissions by a quadratic effect.
Ionic liquids (bare or amine-functionalized) will be the key technological playground for the efficient and cost-effective (<30 €/ton) purification of CO2 to a purity grade sufficient for the above mentioned utilization paths. A dedicated pilot plant (flue gas flow rate: 50 Nm3/h) will be developed, based on the knowledge-based selection of the best ionic-liquids composition and operating conditions.
Within a final TRL 6 integrated system demo campaign, the thereby derived CO2 will be utilized in parallel to:
-) promote the precipitation of nano-CaCO3 powders which act as strength enhancer and accelerator of the hydration rate.
-) synthesize through electrocatalytic and catalytic pathways formic acid, oxalic acid and glycine to be used as hardening acceleration promoters, grinding aids or ionic liquids additives, respectively.
Distinctive features of the RECODE approach are the high process intensification and scale-up-ability; the use of low-grade heat sources; the meaningful reduction of CO2 emissions (>20% accounting for direct and indirect means) and the good market potential of their products at a mass production scale.
The first two years of the project will be focused on the development of key functional materials and process units at TRL 4-5, the third year on the assembly of single-process lines certified at TRL 5-6, and the fourth year on the assembly and testing at a cement manufacturing site (TITAN) of the TRL 6 integrated CO2 process.

Website: https://www.recodeh2020.eu/
Twitter: @RecodeH2020

2:20 PM

DR. KATALIN KOVACS

ENGINEERED MICROBIAL FACTORIES FOR CO2 EXPLOITATION IN AN INTEGRATED WASTE TREATMENT PLATFORM

The ENGICOIN proposal aims at the development, from TRL3 to TRL5, of three new microbial factories (MFs), integrated in an organic waste anaerobic digestion (AD) platform, based on engineered strains exploiting CO2 sources and renewable solar radiation or H2 for the production of value-added chemicals, namely:

MF.1) the cyanobacteria Synechocystis to produce lactic acid from either biogas combustion flue gases (CO2 concentration ~ 15%) or pure and costless CO2 streams from biogas-to-biomethane purification.

MF.2) the aerobic and toxic metal tolerant Ralstonia eutropha to produce PHA bioplastics from biogas combustion flue gases and complementary carbon sources derived from the AD digestate.

MF.3) the anaerobic Acetobacterium woodii to produce acetone from the CO2 stream from biogas-to-biomethane purification.

High process integration will be guaranteed by taking advantage of low-grade heat sources (e.g. from cogenerative biogas-fired engine or an tailored PEM electrolyser), exploitable side gas streams (e.g. O2 from electrolysis, CO2 from biomethane purification), low-price electricity produced during night-time by a biogas-fired-engine cogeneration unit or even intensified operation conditions (e.g. up to 10 bars pressure for the anaerobic acetone production bioreactor; led-integrated photo-bioreactor). This is an essential feature, alongside with the high conversion rates enabled by synthetic and systems biology on the above microorganisms, to achieve competitive selling prices for the key target products (1.45 €/kg for lactic acid; 3.5 €/kg for PHA; 1 €/kg for acetone).

Notwithstading the key application platform (anaerobic biorefinery based on organic wastes) the innovative production processes developed have a great exploitation potential in other application contexts: flue gases from different combustion appliances (e.g. cement kilns), alcoholic fermentation CO2 streams (e.g. lignocelluosic biorefineries, breweries), etc.

Website: https://www.engicoin.eu/
Twitter: @Engicoin_H2020

2:40 PM

DR. SIMELYS HERNANDEZ

COST-EFFECTIVE CO2 CONVERSION INTO CHEMICALS VIA COMBINATION OF CAPTURE, ELECTROCHEMICAL AND BIOCHEMICAL CONVERSION TECHNOLOGIES.

CELBICON aims at the development, from TRL3 to TRL5, of new CO2-to-chemicals technologies, conjugating at once small-scale for an effective decentralized market penetration, high efficiency/yield, low cost, robustness, moderate operating temperatures and low maintenance costs.

In line with the reference Topic text, these technologies will bridge cost-effective CO2 capture and purification from the atmosphere through sorbents (with efficient heat integration of the CO2 desorption step with the subsequent process stages), with electrochemical conversion of CO2 (via PEM electrolysis concepts, promoting CO2 reduction at their cathode in combination with a fruitful oxidation carried out simultaneously at the anode), followed by bioreactors carrying out the fermentation of the CO2-reduction intermediates (syngas, C1 water-soluble molecules) to form valuable products (bioplastics like Poly-Hydroxy-Alkanoates - PHA -, isoprene, lactic acid, methane, etc.) as well as effective routes for their recovery from the process outlet streams.
A distinctive feature of the CELBICON approach is the innovative interplay and advances of key technologies brought in by partners (high-tech SMEs & companies, research centres) to achieve unprecedented yield and efficiency results along the following two processing lines: i) High pressure process line tailored to the production of a PHA bioplastic and pressurized methane via intermediate electrochemical generation of pressurized syngas followed by specific fermentation steps; ii) Low pressure processing line focused on the production of value-added chemicals by fermentation of CO2-reduction water-soluble C1 intermediates.
Over a 42 months project duration, the two process lines described will undergo a thorough component development R&D programme so as to be able to assemble three optimised TRL5 integrated test-rigs (one per TP) to prove the achievement of all the quantified techno-economic targets.

Website: http://www.celbicon.org/

3:00 PM

ADVANCED DIRECT BIOGAS FUEL PROCESSOR FOR ROBUST AND COST-EFFECTIVE DECENTRALISED HYDROGEN PRODUCTION

BioROBURplus builds upon the closing FCH JU BioROBUR project (direct biogas oxidative steam reformer) to develop an entire pre-commercial fuel processor delivering 50 Nm3/h (i.e. 107 kg/d) of 99.9% hydrogen from different biogas types (landfill gas, anaerobic digestion of organic wastes, anaerobic digestion of wastewater-treatment sludges) in a cost-effective manner.
The energy efficiency of biogas conversion into H2 will exceed 80% on a HHV basis, due to the following main innovations:
1) increased internal heat recovery enabling minimisation of air feed to the reformer based on structured cellular ceramicscoated with stable and easily recyclable noble metal catalysts with enhanced coking resistance;
2) a tailored pressure-temperature-swing adsorption (PTSA) capable of exploiting both pressure and low T heat recovery from the processor to drive H2 separation from CO2 and N2;
3) a recuperative burner based on cellular ceramics capable of exploiting the low enthalpy PTSA-off-gas to provide the heat needed at points 1 and 2 above.
The complementary innovations already developed in BioROBUR (advanced modulating air-steam feed control system for coke growth control; catalytic trap hosting WGS functionality and allowing decomposition of incomplete reforming products; etc.) will allow to fully achieve the project objectives within the stringent budget and time constraints set by the call.
Prof. Debora Fino, the coordinator of the former BioROBUR project, will manage, in an industrially-oriented perspective, the work of 11 partners with complementary expertise: 3 universities (POLITO, KIT, SUPSI), 3

research centres (IRCE, CPERI, DBI), 3 SMEs (ENGICER, HST, MET) and 2 large companies (ACEA, JM) from 7 different European Countries.
A final test campaign is foreseen at TRL 6 to prove targets achievement, catching the unique opportunity offered by ACEA toexploit three different biogas types and heat integration with an anaerobic digester generating the biogas itself.

Website: https://cordis.europa.eu/project/rcn/207658/factsheet/en

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3:20 PM

DR. LENARD CSEPEI

CO2-BASED ELECTROSYNTHESIS OF ETHYLENE OXIDE

The CO2EXIDE project aims at the development of a combined electrochemical-chemical technology for the simultaneous "200%" conversion of CO2 to ethylene at the cathode, water oxidation to hydrogen peroxide at the anode and a subsequent chemical conversion of both intermediates to ethylene oxide and oligo-/polyethylene glycol in a cascade, boosting this technology from TRL4 to TRL6. The CO2EXIDE technology combines a modular nature for the feasibility of a decentralised application, a high energy and material efficieny/yield and the substitution of fossil based production of ethylene oxide. The CO2EXIDE technology will be combinable with renewables and allows for the direct creation of products, which can be integrated into the existing supply chain. The reactions will be operated at low temperatures and pressures and forecast significant improvements in energy and resource efficiency combined with an enormous reduction of GHG emissions. All improvements will be quantitated using Life Cycle Assessment.
The CO2EXIDE approach will bring together physicists, chemists, engineers and dissemination and exploitation experts from 5 universities/research institutions, 3 SMEs and 2 industries, innovatively joining their key technologies to develop and exploit an unprecedented process based on CO2, renewable energy and water to combine the chemical and energy sector.
Within 36 months project duration, the CO2EXIDE technology will undergo a thorough material and component R&D programme. A 1kW PEM electrolyser for CO2-reduction and water oxidation in combination with an ethylene enrichment unit and subsequent chemical conversion cascade reactor will be manufactured to produce ethylene oxide as intermediate for oligo-/polyethylene glycol synthesis. This will prove the achievement of the quantified techno-economic targets of CO2EXIDE.

Website: http://www.co2exide.eu/

3:40 PM

DR. ALEXANDRU MOROSANU

INNOVATIVE LARGE-SCALE ENERGY STORAGE TECHNOLOGIES AND POWER-TO-GAS CONCEPTS AFTER OPTIMISATION

This proposal is an application to the EU programme “Horizon 2020” and its topic “Large scale energy storage” (LCE-09-2015). The presented project “STORE&GO” will demonstrate three “innovative Power to Gas storage concepts” at locations in Germany, Switzerland and Italy in order to overcome technical, economic, social and legal barriers. The demonstration will pave the way for an integration of PtG storage into flexible energy supply and distribution systems with a high share of renewable energy. Using methanation processes as bridging technologies, it will demonstrate and investigate in which way these innovative PtG concepts will be able to solve the main problems of renewable energies: fluctuating production of renewable energies; consideration of renewables as suboptimal power grid infrastructure; expensive; missing storage solutions for renewable power at the local, national and European level. At the same time PtG concepts will contribute in maintaining natural gas or SNG with an existing huge European infrastructure and an already advantageous and continuously improving environmental footprint as an important primary/secondary energy carrier, which is nowadays in doubt due to geo-political reasons/conflicts. So, STORE&GO will show that new PtG concepts can bridge the gaps associated with renewable energies and security of energy supply. STORE&GO will rise the acceptance in the public for renewable energy technologies in the demonstration of bridging technologies at three “living” best practice locations in Europe.

STORE&GO Website: https://www.storeandgo.info/

4:00 PM

DR. ANA LOPEZ CONTRERAS

BIOTECHNOLOGICAL PROCESSES BASED ON MICROBIAL PLATFORMS FOR THE CONVERSION OF CO2 FROM IRONSTEEL INDUSTRY INTO COMMODITIES FOR CHEMICALS AND PLASTICS

The main objective of BIOCON-CO2 is to develop and validate in industrially relevant environment a flexible platform to biologically transform CO2 into added-value chemicals and plastics. The versatility and flexibility of the platform, based on 3 main stages (CO2 solubilization, bioprocess and downstream) will be proved by developing several technologies and strategies for each stage that will be combined as puzzle pieces. BIOCON-CO2 will develop 4 MCFs based on low-energy biotechnological processes using CO2 from iron&steel industry as a direct feedstock to produce 4 commodities with application in chemicals and plastics sectors using 3 different biological systems: anaerobic microorganisms (C3-C6 alcohols by Clostridia), aerobic microorganisms (3-hydroxypropionic acid by Acetobacter) and enzymes (formic acid by recombinant resting E. coli cells and lactic acid by multi-enzymatic system). The technologic, socio-economic and environmental feasibility of the processes will be assessed to ensure their future industrial implementation, replicability and transfer to other CO2 sources, such as gas streams from cement and electricity generation industries. BIOCON-CO2 will overcome the current challenges of the industrial scale implementation of the biotechnologies routes for CO2 reuse by developing engineered enzymes, immobilization in nanomaterials, genetic and metabolic approaches, strain acclimatization, engineered carbonic anhydrases, pressurized fermentation, trickle bed reactor using advanced materials and electrofermentation. The project aims to capture at least 4% of the total market share at medium term (1.4Mtonnes CO2/year) and 10% at long term (3.5Mtonnes CO2/year) contributing to reduce EU dependency from fuel oils and support the EU leadership in CO2 reuse technologies. Policy recommendations and public perception and acceptance will be explored and a commercialization strategy will be executed by a detailed exploitation plan and technology transfer.

BIOCON-CO2 Website: https://biocon-co2.eu

4:30 PM **COFFEE BREAK**

4:50 – 6:30 PM **SPINNING TABLES: NOT JUST "HARD" SCIENCE**

CHAIR: DR. SIMELYS HERNANDEZ AND DR. SERGIO BOCCHINI

DR. GONZALO DURANTE

GAMIFYING AND PLAYING SCIENCE

Scientific Outreach is an activity that is a challenge in today's society. As scientists, we have a duty to transmit knowledge to society in a simple and understandable way. There are several ways to tackle this mission and transmit the passion for science to stimulate scientific vocations. This takes on special value when the audience we are targeting is childish.

In this workshop, we will review the main platforms, channels and strategies used to make Scientific Outreach, and different tools and anti-tools that we can use or avoid, respectively. We will focus in a couple of tools called: surprise effect and gamification. The surprise effect is based in the ability to transform abstract concepts in comprehensible and surprising explanations. Several examples will be shown during the workshop, based on pictures and numbers. Gamification, in general terms, is the ability to convert any activity in a game. When it comes to spreading science it is a very powerful tool, especially with children. Some games will be achieved during the workshop, previously tested with children successfully.

DR. EDURNE INIGO

CONNECTING SUSTAINABILITY TO RESEARCH TO ETHICAL RESPONSIBILITY AND SOCIETY: THE ROLE OF RRI

Can sustainability-oriented research ever be irresponsible? Researchers aiming to tackle sustainability challenges seldom ask themselves this question, since trying to solve these problems seems inherently good. However, how can we assess responsibility and ethics in sustainability-oriented research and innovation programmes, beyond its goals? The responsible research and innovation framework, strongly backed by the European Commission, aims to include responsibility in the procedural and outcome dimensions of the process. At a practical level, we will examine how this framework concerns sustainability research, particularly in the context of publicly funded projects. Moreover, we will also discuss the connections and trade-offs between environmental sustainability, social responsibility and ethics, which are often overlooked by researchers and innovators.

SCHOOL AGENDA: FRIDAY, 6TH SEPTEMBER 2019

8:30 AM **REGISTRATION**

8:45 – 1:00 PM CO2 CONVERSION PATHWAYS_FRONTAL LESSONS

CHAIR: DR NICOLÒ VASILE

8.45 AM **ENGICOIN**

PROF. PAUL HUDSON, KTH, ROYAL INSTITUTE OF TECHNOLOGY

DR. SEBASTIEN BERNACCHI, KRAJETE GmbH

DEVELOPMENT STRATEGIES FOR GAS CONVERTING BIOPROCESSES – CO2 UTILISATION IN CELBICON AND ENGICOIN

Over recent years the interest in new biofuel generations, based on converting gaseous substrate(s) such as carbon dioxide (CO2), carbon monoxide (CO) or hydrogen (H2) to gaseous product(s), arose. One of the most extensively studied gas converting bioprocess so far, is the biological methane production process using CO2 as sole carbon source (CO2-BMP). Axenic cultures of *Methanothermobacter marburgensis* grown in a defined mineral medium already proved that high conversion rates of CO2 and H2 to methane (CH4) can be reached.

However, such gas converting bioprocesses are often reaching a gas transfer limited state during operation. Therefore, the kinetic limitation towards an increased methane productivity cannot be overcome solely by the growth of more biomass during e.g. a continuous operation. As important is the development of a suitable bioreactor system that allows reaching higher mass transfer of the limiting gaseous substrate in the liquid phase which is needed to enhance productivities as well as for developing appropriate feeding strategies to maintain sufficient suspended biocatalyst to support realistic production scenarios.

In this talk we will present the different development steps, the methods as well as the applied process analytic technologies, experimental designs and control approaches that have been employed in the development of the CO2-BMP process within CELBICON project. Furthermore, we will also present the transfer and adaptations of such strategies to the development of a new gas converting bioprocess aiming to produce acetone from CO2 and H2 in ENGICOIN project.

10.15 AM **RECODE**

PROF. GEORGE SKEVIS AND DR. AKRIVI ASIMAKOPOULOU, CERTH, CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

MEMBRANE-BASED TECHNOLOGIES FOR CO2 CAPTURE AND CONVERSION TO VALUE-ADDED CHEMICALS

Mitigation of the adverse effects of climate change requires a transition to a CO_2 economy with recycling of CO_2 to carbon-negative chemicals and minerals using renewable sources. The mineralization of CO_2 is an alternative to conventional geological storage and results in permanent storage as a solid, with no need for long term monitoring and no requirement for significant energy input. Novel technologies for CO_2 capture and mineralization involve the use of gas-liquid membrane contactors for post-combustion capture. Hollow fiber membrane contactors are well established in the field of gas separation/bubbling/extraction applications since very high and well defined surface areas can be obtained with no dispersion of the gaseous phase into the liquid solvent. Membrane contactors can be used for direct CO_2 capture from the flue gases and simultaneous conversion to useful chemical compounds, depending on the appropriate solvent selection. Membrane-based precipitation of carbonates offers an ideal route for mineralization with controllable morphological and structural properties of the precipitated particles. Interesting applications include calcium carbonate nanoparticles production for partially substituting cement in high-performance concrete.

DR. MARIANA ARAUJO, AVANTIUM

ELECTROCHEMICAL CO2 CONVERSION TO CEMENT ADDITIVES

11:30 AM **COFFEE BREAK**

11:45 AM **CELBICON/BIOROBUR PLUS**

PROF BJÖRN STELZNER, KIT, KARLSRUHE INSTITUTE OF TECHNOLOGY

SIMULTANEOUS CO2 COMPRESSION/DISSOLUTION PROCESS AND NOVEL BURNER DEVELOPMENT

DR. SORANI MONTENEGRO, HYSYTECH

DEMONSTRATORS OF CO2 CAPTURE AND UTILISATION

1:00 PM **BREAK**

2:00 - 3:30 PM **POSTER SESSION**

2:30-3:30 PM **COORDINATION OF FUTURE JOINT DISSEMINATION AND EXPLOITATION ACTIVITIES AMONG PROJECTS**

CHAIR: ANDREAS SCHWEINBERGER

RESTRICTED TO PI AND DISSEMINATION LEADERS

3:30 - 6:30 PM **SITE VISITS**

AVANTIUM CHEMICALS BV

DR. PAREDINHA ARAUJO MARIANA

Avantium is a leading chemical technology company and a forerunner in renewable chemistry. Together with its partnersAvantium is a leading chemical technology company and a forerunner in renewable chemistry. Together with its partnersaround the world, Avantium develops efficient processes and sustainable products made from biobased materials. Avantiumoffers a breeding ground for revolutionary renewable chemistry solutions. From invention to commercially viable productionprocesses. One of Avantium's success stories is YXY technology, with which it created PEF: a completely new, high-qualityplastic made from plant-based industrial sugars.

PHOTANOL BV

DR. VAN DER WOUDE ANIEK

Photanol is a spin of company of the University of Amsterdam. Shareholders are venture capital firm Icos Capital,Photanol is a spin of company of the University of Amsterdam. Shareholders are venture capital firm Icos Capital,the University of Amsterdam Holding and the scientific founders. Since the start of the company in 2008,€ 15 million has been invested in technology development by shareholders and from grants (EU and and NL). Photanol's objective is to bring to the market new production routes for the production of bio-compounds withCO_2 as a feedstock. The first focus is on the production of LLA to be followed by other valuable organicchemicals such as other organic acids, biofuels, essential oils, and sugars.

CONFERENCE ORGANIZING COMMITTEE

GIUDITTA TRAVERSO,

IIT, ITALIAN INSTITUTE OF TECHNOLOGY, ITALY

DR. VALENTINA MARGARIA,

IIT, ITALIAN INSTITUTE OF TECHNOLOGY, ITALY

PROF. PAUL HUDSON,

KTH, ROYAL INSTITUTE OF TECHNOLOGY, SWEDEN

PROF. PAOLO P. PESCARMONA,

RUG UNIVERSITY, GRÖNINGEN

DR. SIMELYS HERNANDEZ,

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DR. SERGIO BOCCHINI,

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ENGINEERED MICROBIAL FACTORIES FOR CO_2 EXPLOITATION IN AN INTEGRATED WASTE TREATMENT PLATFORM

RECO2DE

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The event is organized by Italian Institute of Technology (IIT) in the context of RECODE and ENGICOIN projects. These projects have received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 768583(RECODE) No. 760994(ENGICOIN). Additional sponsorship by CELBICON and BIOROBURplus receiving funding from EU H2020 under Grant Agreement No. 679050 and No.736272