Deliverable 6.7:
Components integration and test-rig assembly finished: Demonstrator ready to start operation

CO_2-based Electrosynthesis of Ethylene oXIDE

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DELIVERABLE REPORT

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ABSTRACT

The present report D6.7 (Components integration and test-rig assembly finished: demonstrator ready to start operation) documents the assembling and the readiness to operate of the CO2EXIDE demonstrator. Gas cylinders filled with biogenic CO_2, a scaled-up PEM electrolyser with all accessories as well as an ethylene enrichment unit have been successfully delivered to AGH, Krakow. All components have been tested, all minor transport-related malfunctions removed and the readiness of all components for full operation verified. Appropriate connections of all components have been established according to specifications and the entire demonstrator is ready for operation. The chemical reactor for ethylene epoxidation as final process unit could not be transported to Krakow due to COVID-19-related safety reasons and will be operated by Fraunhofer in Straubing (Germany) instead.

1 BACKGROUND

The goal of the H2020-funded project CO2EXIDE is the establishment of an electrochemical, energy efficient and near-to CO_2-neutral process for the production of the bulk chemical ethylene from CO_2, water and renewable energy. The CO2EXIDE process chain (schematically illustrated in Figure 1) comprises i) the supply of raw materials, in particular of CO_2 from biogenic sources, ii) the simultaneous electrocatalytic conversion of CO_2 to ethylene (cathode) and of water to hydrogen peroxide H_2O_2 (anode), iii) the separation and purification of the generated ethylene, and iv) the chemical reaction of the purified ethylene with the anodically formed H_2O_2 to the platform chemical ethylene oxide. Ethylene oxide represents a valuable and versatile chemical product used in the chemical industry mainly for the production of tensides and plastic materials, such as polyethylene terephthalate (PET) for plastic bottles.

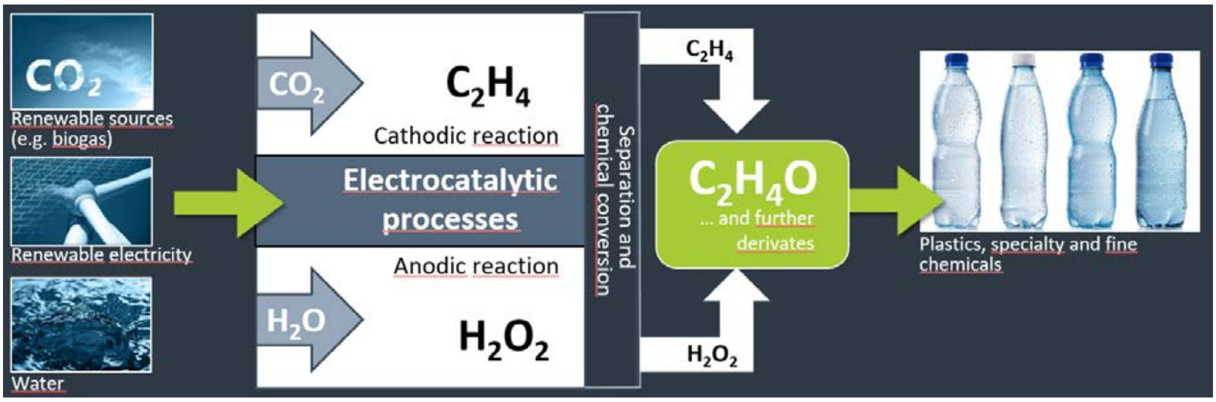

Figure 1: The CO2EXIDE process chain.

In the final phase of the project CO2EXIDE, a demonstrator unit is assembled and tested in the laboratory of the Academic Centre of Materials and Nanotechnology (AGH University of Science and Technology, Krakow), combining individual process steps and components in an integrated system. Specifically, the integrated components include a) the supply of purified biogenic CO_2 sourced from a biogas plant, b) a scaled-up PEM electrolyzer with 300 cm^2 geometric electrode area, c) a gas enrichment unit for purifying the ethylene generated in the electrochemical reactor, and d) a chemical reactor for the conversion of the enriched ethylene with H_2O_2 to ethylene oxide.

As a consequence of the ongoing COVID-19 pandemic, the chemical reactor unit for the conversion of ethylene into ethylene oxide (Figure 11) could not be integrated in the demonstrator unit in Krakow. The chemical conversion process, developed by Fraunhofer IGB in Straubing (Germany), involves a pressurized reactor system with explosive and toxic compounds. For safety reasons, the integration of this unit in the demonstrator in Krakow would require travelling of trained personnel from Fraunhofer IGB, which could not be realized, given the current pandemic-related restrictions. Therefore, deviating from the original plan, the chemical conversion unit will be operated in the Fraunhofer laboratory.

The objective of this deliverable D7.6 (Components integration and test-rig assembly finished: demonstrator ready to start operation) is to document the assembly of the demonstrator unit in the AGH laboratory, which is now ready for the beginning of the experiments.

2 ARRANGEMENT OF DEMONSTRATOR COMPONENTS IN THE AGH LABORATORY

All components were separately delivered to Academic Centre of Materials and Nanotechnology (AGH University of Science and Technology, building D-16) and placed in laboratory room 1.07. This room is fully equipped with a highly effective ventilation system, including 6 fume hoods and special suction lines designed for removal of potentially hazardous or suffocating heavy gasses. The laboratory is also equipped with sensors for hydrogen, carbon monoxide and flammable hydrocarbon gasses. Access to the room is controlled by central security system (personalized magnetic cards) and only qualified personnel can enter the room.

Gas cylinders with biogenic CO_2, synthetic CO_2, nitrogen and helium has been installed in ventilated gas cylinder cupboards or mounted on safe transport carts.

The electrolyser and all accessories (electrolyte reservoirs, pumps, sensors, pressure equilibration bottles) have been installed inside a fume hood on a specially designed board equipped with a safe rack hosting the electrolytic cell.

All accompanying electronics have been placed under the neighbouring fume hood, whereas the ethylene enrichment unit is located next to the fume hood hosting the electrolyser system.

Electrolyser power supply, equipped with connecting cables designed for currents up to 80 A, is placed on a mobile rack.

All necessary connections are based on hard polyethylene tubes (gasses) or soft PVC hoses (cooling water). The electrolyser is equipped with heat exchangers for independent cooling of the catholyte and anolyte. The heat exchangers are connected to a central cooling system (closed loop cooling water, average temperature 8°C).

Two gas sampling ports for analysis of gas samples have been established with soft gas sampling tubes terminated with Luer locks and connected to a gas chromatograph sampling loop via a set of three-way valves. One port is located between the gas cooler and the ethylene enrichment unit (EEU), the other at the retentate output of the EEU.

Connections of exhaust gases (EEU permeate, excess of the EEU retentate, blow-offs from the safety valves) are connected to the central ventilation hub via soft PVC lines.

In the following, the assembling and readiness to operate of the CO2EXIDE demonstrator is documented through a set of photographs.

Figure 2: General view of the lab, from left to right: gas cylinders, control electronics for the electrolyzer unit, electrolyte unit, primary gas cooling and dehumidification (small box of the floor), EEU, electrolyzer power supply.

Figure 3: General view of the lab, with the CO2EXIDE demonstrator.

Figure 4: Detailed view of the connection between EEU and gas cooler.

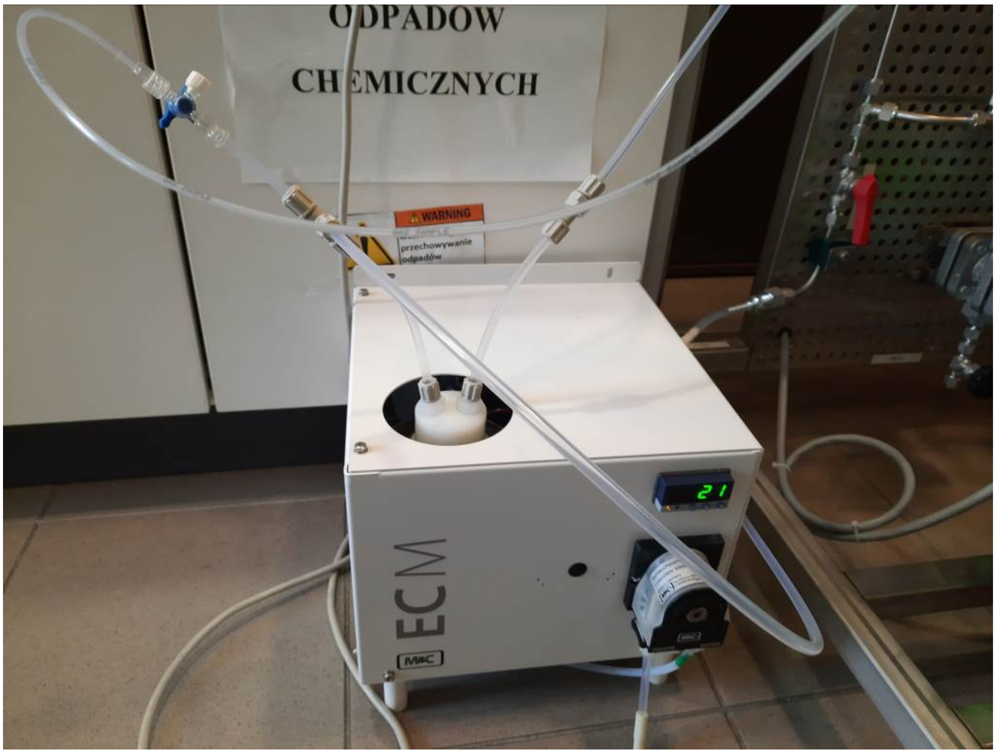

Figure 5: Detailed view: Gas cooler with gas sampling by-pass.

Figure 6: Detailed view – electronic control system for electrolyzer unit.

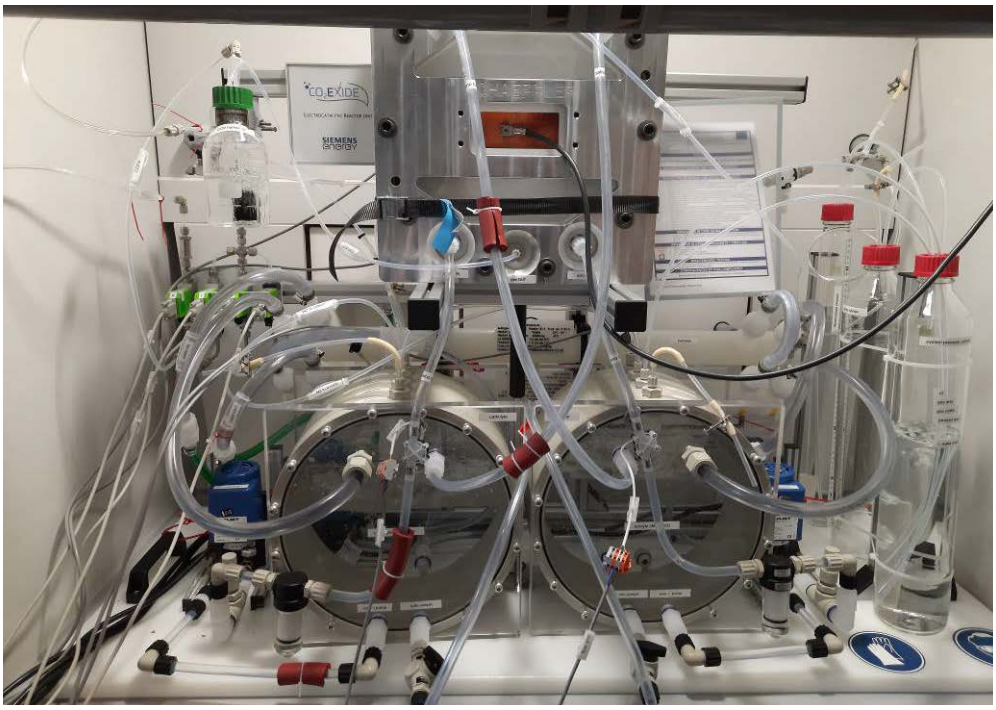

Figure 7: Detailed view of the electrolyzer unit during normal operation at low CO_2 flow (100 cm^3/min).

Figure 8: Detailed view – CO_2 humidifier at high CO_2 flow (500 cm^3/min).

Figure 9: Gas chromatograph connected to ERU and EEU.

Figure 10: Gas cylinder bundle with purified biogenic CO_2 and auxiliary gas cylinders connected to the system.

Figure 11: Chemical reactor (volume: 2 L) for the conversion of ethylene and hydrogen peroxide to ethylene oxide (located in the laboratory of Fraunhofer IGB, Straubing, Germany).

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