One of the main challenges limiting the increased use of renewable energy is intermittency, which can be mitigated by feeding the energy from renewable energy into a storage system when there is excess supply. On the other hand, large amounts of carbon are emitted as waste in the production of energy from fossil fuels. The most commonly studied technology to reduce CO_2 emissions is Carbon Capture and Sequestration, which consists of CO_2 capture, transportation and underground storage. Alternatively, the captured of CO_2 could be utilized and converted into fuels and chemicals, such as dry reforming of methane for synthesis gas production, or CO_2 hydrogenation to CH_4, methanol or higher alcohols.

Since catalytic reactions occur on the surface, most of the materials used to promote these reactions, are based on open porous structures, where the transport medium (gas or liquid), specific surface area and chemical (or electrochemical) reactivity determines the overall efficiency of the device. Specific reactivity (catalytic activity) usually depends on the chemical composition of the surface, whereas porosity, pore size and surface area influence the efficiency.

The high porosity that facilitates the transport of the media tends to reduce the specific surface area at the same time. This problem does not occur in hierarchical structures, where a network of larger pores serves as the pathway for the flow of reagents and nano/meso-porous structure elements are responsible for high surface area. 3D printing is a promising technique that might allow one to precisely control the size of pores, their shape and surface development.

3D printing and in general additive manufacturing techniques have already found many applications (even commercial ones), especially in the fabrication of structural elements. Recently they have been found to be useful also in the design of open-porous functional materials to fabricate bioimplants, sensors, batteries, fuel cells, membranes and other materials for catalysis.

This project aims to apply 3D printing technology to the fabrication of new open-porous catalytic materials with hierarchical microstructure. The scientific goal of this undertaking is the design of novel CO_2 conversion catalysts with high permeability and high specific surface area using advanced microstructure characterization and modeling to support the optimization of fabrication processes.

Materials fabricated within this project will be tested as the catalyst for principle process used to convert CO_2 into methane – the so called Sabatier reaction. Understanding the effect of the microstructure on this process is crucial for the development of new materials for other, abovementioned, applications utilizing CO_2 which will realize social, environmental and economic benefits.

Within this project new materials and the technology for their fabrication will be developed. Novel composite feedstock materials will be designed. A new concept of 3D printed open-porous functional materials will be demonstrated. Technology developed within the project might be further used for the fabrication of open porous materials for other applications (bio-medical, gas and liquid membranes, filters, etc.).

Modern 3D imaging techniques will be used to characterize the material microstructure. We will use a dual beam microscope (ion and electron) to describe the 3D pore structure at a very high resolution. Thanks to that the microstructure of the matrix (average pore size below 1 micron) will be studied with the level of detail not yet presented in the literature. An advanced quantitative description of the microstructure will be produced using software developed in the past by the project's coordinator.

Numerical simulations will be based on the porous material models obtained by X-ray tomography as well as the representative numerical models created by the algorithm, which mimics the real fabrication process.

Using this framework will allow us to provide quantitative relationships between the microstructure and properties of open-porous hierarchical materials. The results obtained within the project will be published in high Impact Factor journals i.e. Journal of Power Sources, Materials&Design, International Journal of Hydrogen Energy, Catalysis Communications and similar journals.