1. Publishable summary

On the 1st of April 2014 the European research project HELMETH started under the coordination of the Karlsruhe Institute of Technology (Germany). The objective is the proof of concept of a highly efficient Power-to-Gas process by realizing the first Power-to-Gas prototype that combines a pressurized high temperature steam electrolysis with a carbon dioxide methanation module. By using the heat of reaction from the exothermic carbon dioxide methanation to produce steam for the high temperature electrolysis, an innovation with a high potential for a most energy-efficient storage solution for renewable electricity is expected. Since the produced Substitute Natural Gas (SNG) is fully compatible with the existing natural gas grid and storage infrastructure, practically no capacity limitations apply to store energy from fluctuating renewable energy sources (Figure 1). A significant advantage of the HELMETH PtG technology in contrast to PtG plants with low temperature electrolysis modules is its higher efficiency resulting to considerably higher SNG output per electricity demand. The HELMETH consortium consists of the partners Karlsruhe Institute of Technology (Germany), Politecnico di Torino (Italy), Sunfire GmbH (Germany), European Research Institute of Catalysis A.I.S.B.L. (Belgium), Ethos Energy Italy, National Technical University of Athens (Greece) and Deutscher Verein des Gas- und Wasserfaches - Technisch-Wissenschaftlicher Verein eV (Germany). The research project with a duration of 3 years has a total budget of 3.8 million euro and is co-financed by the European Union's Seventh Framework Programme for the Fuel Cells and Hydrogen Joint Technology Initiative.

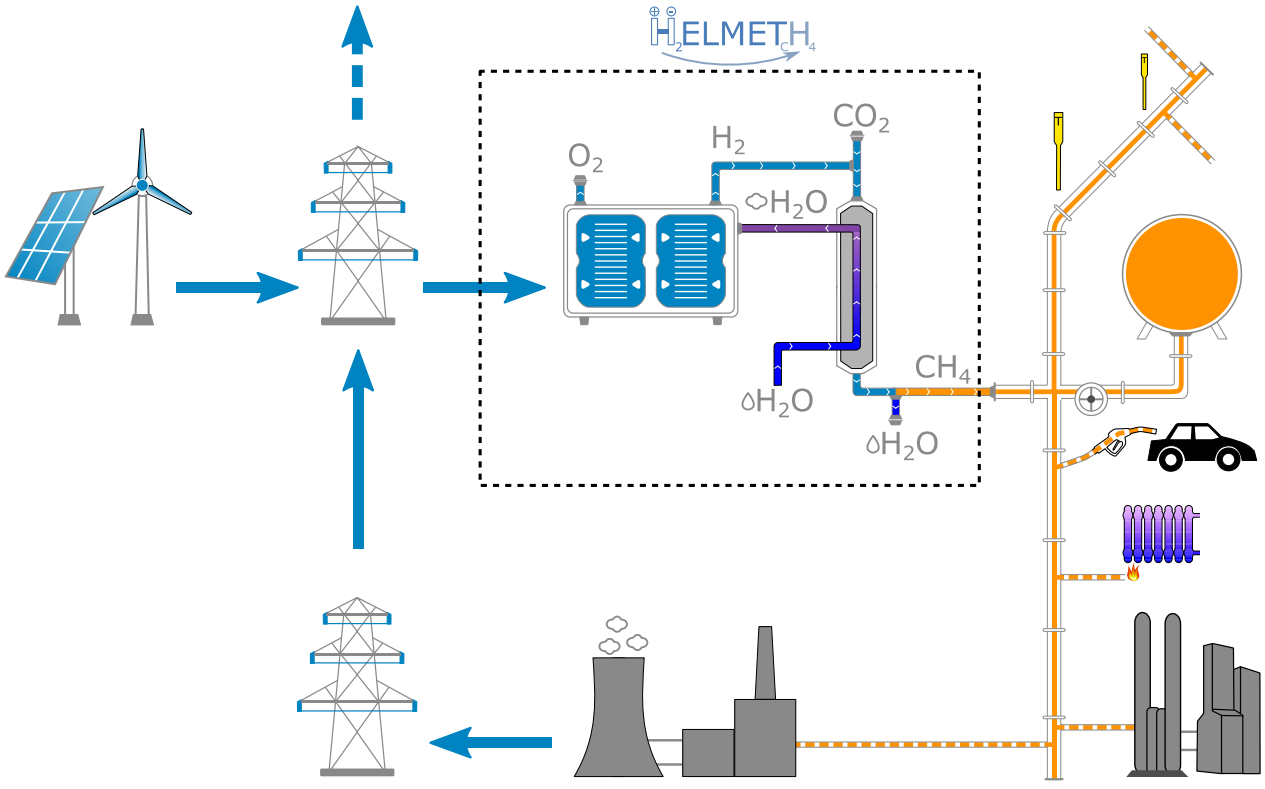

Figure 1: Schematic HELMETH PtG process, which enables an efficient conversion and storage of energy from fluctuating renewable sources

The realisation of the P2G technology as planned within HELMETH needs several development steps and HELMETH focuses on the following objectives, which have to be met in order to show the feasibility of the technology:

- Design and construction of a pressurised electrolysis module including high corrosion resistive and long-term stable heat exchangers
- Design and construction of a multi-step CO_2 methanation module that produces SNG which is fully compatible with the existing natural gas grid and storage infrastructure
- Thermal integration of pressurized high temperature steam electrolysis with CO_2 methanation
- Demonstration of the technical feasibility of a conversion efficiency > 85 % from renewable electricity to methane, which is superior to the efficiency for the generation of methane or even hydrogen via conventional water electrolysis.
- Elaboration of the conditions / scenarios for an economic feasibility of the P2G process towards methane as chemical storage, without significantly deteriorating the CO_2-balance of the renewable electricity.
- Life Cycle Analysis of the overall process and evaluation of the impact of CO_2 sources on the system CO_2 footprint

Achievements to date: At first the European natural gas grid regulations were evaluated in order to specify the overall system requirements and especially the targeted SNG quality criteria. This process was essential for the development of the methanation module, which has to produce SNG that is fully compatible with the existing natural gas infrastructure. Based on the development of the overall system specifications, several PtG integration schemes with different methanation reactor concepts were investigated by detailed process simulation. The consortium choose a multi-step methanation module that is operating at 300°C, producing saturated steam for the steam electrolysis module and leading in the overall integrated scheme a renewable electricity to methane efficiency of greater 85 % in industrial scale. First short stack tests of the high temperature steam electrolysis module showed degradation rates below the set targets of 0.5 % / 1000 h. The development of high corrosion resistive high temperature direct laser metal sintered heat exchangers resulted in several prototypes that are currently evaluated. Further electrolysis stack tests were conducted in co-electrolysis mode and provide a good basis for assessing the potential to produce a synthesis gas for the methanation process. This offers the chance to further increase the overall PtG efficiency by reducing the electrolysis steam demand. In order to reach high methane yields in the methanation module, the catalyst developing partners ERIC and Polito tested and optimised different Nickel and Ruthenium catalysts. The first Life Cycle Analysis of the overall HELMETH module was conducted against benchmark scenarios and evaluated the impact of different CO_2 sources on the system CO_2 footprint.

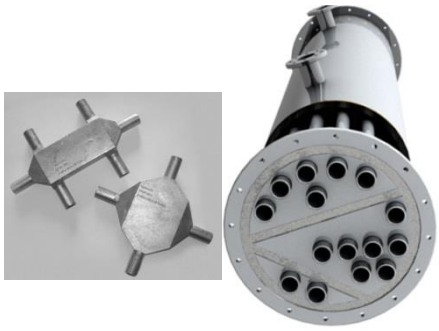

Figure 2: Methanation reactor with sophisticated heat exchangers

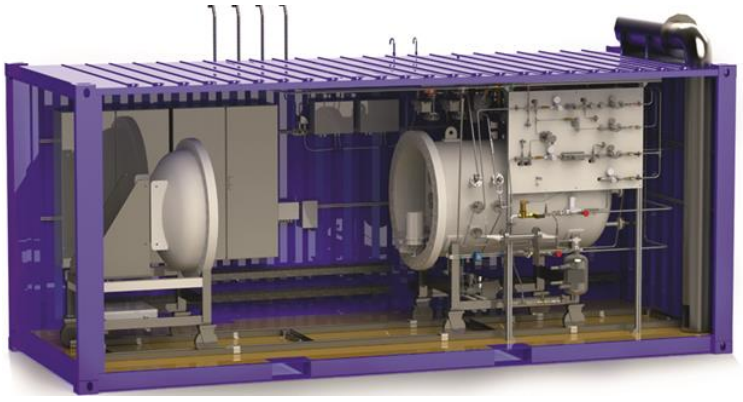

Figure 3: Pressurised high temperature steam electrolysis module

So far very promising results have been achieved: For the chosen design, realistic calculations predict an efficiency greater than 85% and an SNG quality, which corresponds to the natural gas grid regulations expected in the near future. The results of the first pressurised electrolysis show low degradation rates. The project is in time and all milestones of the first half of the project were reached.

Expected results and impact:

It is expected that the operation of the final HELMETH prototype shows the technical feasibility of the coupling of pressurized high temperature electrolysis in the 10-15 kW range with CO_2 methanation and that conversion efficiencies > 85 % from renewable electricity to methane are reachable for industrial scales. Based on the promising results of the already performed tests, it is anticipated that the long term tests will prove the durability of the developed high temperature electrolysis cells at high current loads (> 1 A/cm²), at a temperature of ca. 800°C and pressurized conditions of up to 15 bar.

For a future market entry of this PtG technology, a breakthrough milestone is the proof-of concept by realizing the highly efficient HELMETH prototype. The industrial partners aim at units in a MW scale, which most likely will be achieved by a modular approach as far as the stack is concerned. On the other hand the scaling up of the methanation reactor is rather standard engineering, when the proof of concept and optimal operating parameters have been elaborated. Thus, the proof of concept in the 10-15 kW range will be the enabling step for the further technology development. The impact on the renewable energy sector and the environment are currently investigated by life cycle analysis and market studies and a realistic quantification of these potential impacts is expected as project result.

Project Consortium:

No	Name	Short name	Country
1	Karlsruhe Institute of Technology	KIT	Germany
2	Politecnico di Torino	POLITO	Italy
3	Sunfire GmbH	SUNFIRE	Germany
4	European Research Institute of Catalysis A.I.S.B.L.	ERIC	Belgium
5	Ethos Energy Italy	EEI	Italy
6	National Technical University of Athens	NTUA	Greece
7	Deutscher Verein des Gas- und Wasserfaches - Technisch-Wissenschaftlicher Verein eV	DVGW	Germany

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