Optimizing clean energy: solar-to-hydrogen cycles

Hydrogen is today one of the most widely used of the chemical elements. Many different industries and processes utilize hydrogen such as petroleum and chemical businesses and food industry (hydrogenation of fats is the method to make margarine from vegetable oil). Hydrogen is also useful in producing methanol and in reducing metal ores. Other uses for hydrogen may be found in welding, in power generators, and in cryogenics research. Space industry uses liquid hydrogen as a fuel boosting rockets into the orbit.
While about 75% of the universe's elemental mass is hydrogen, free hydrogen is relatively rare on Earth and is observed mostly in a form of water. In many recent studies, hydrogen is being pointed out as a source for clean fuel because water is the product of its reaction with oxygen. However, hydrogen must be extracted first: although it can be processed artificially from a variety of locally produced sources like methane, coal, water, gasoline, and biomass, there are also some different amounts of pollution. Whether or not hydrogen can help make a greener world for all of us, it will all depend on further research.
This is the intrinsic goal of SOL2HY2 - "Solar-To-Hydrogen Hybrid Cycles" – project: to demonstrate that hydrogen "green" production is possible through the exploitation of solar power. SOL2HY2 is a Research Project co-financed by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU - refer to info box).

The project concept outline

The FCH JU strategy has identified hydrogen production by water decomposition pathways powered by renewables such as solar energy to be a major component for sustainable and carbon-free hydrogen supply. Different solar-powered thermochemical and hybrid cycles are capable to directly transfer concentrated sunlight into chemical energy by a series of chemical and electrochemical reactions.
Despite the many thermochemical cycles have been proven to be theoretically possible, only few of them might be feasible for practical realization. Hybrid-sulphur (HyS) cycle, also known as Westinghouse cycle (Fig. 1), has been ranked by IEA HIA Task 25 "High temperature processes for hydrogen production" and some other parallel studies to be the most promising one. However, the original HyS cycle has been always associated with nuclear heat and electricity sources as the H2 production was evaluated to be more economic when combined with nuclear power than using pure solar power. The aim of the SOL2HY2 project is ultimately demonstrate that such cycle is possible to be realized using only renewable energy, like solar one.

The challenges in HyS realization remain mostly in materials (for electrolyser, concentrator, acid decomposer and BOP components) and with the whole process optimisation, which must be tailored to specific solar input and plant site location. The previous research projects have brought some solutions for these challenges, but still did not manage to present the consolidated, optimized plant and process design capable to complain with imposed costs, and operational constrains and the whole process chain objectives. The recent technology options at the large-scale (400-800 MW) hydrogen production plant concepts are unlikely to achieve hydrogen costs below 3.0-3.5 €/kg. For smaller scale plant (which might be more reasonable), the H2 costs might be substantially higher. Additional associated technical and operational risks do not encourage industries to start such plants construction, which does not allow examination of realistic bottlenecks and make

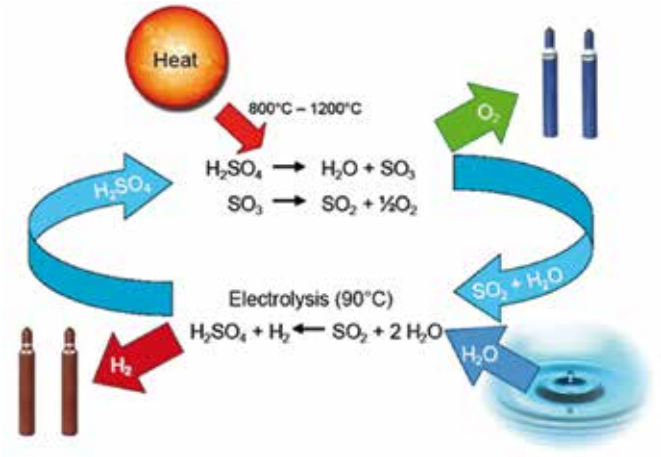

Fig. 1 - The HyS cycle scheme

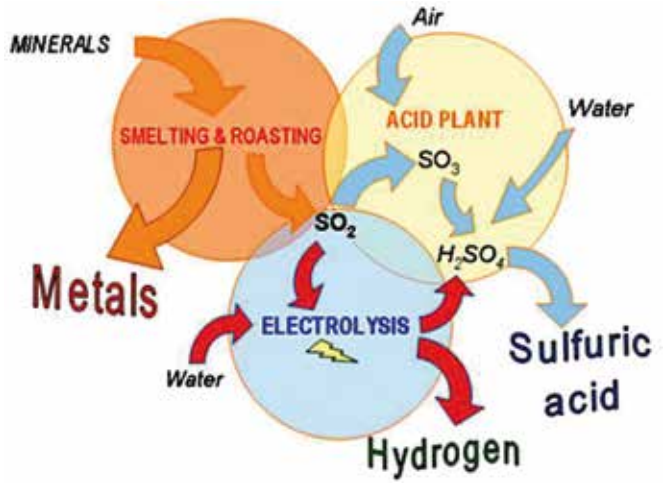

Fig. 2 - The Outotec® Open Cycle scheme

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necessary improvements. The SOL2HY2 project focuses on applied bottle-necks solving materials research, development and demonstration of the relevant key components of the solar-powered, CO2-free hybrid water splitting cycles.

In this project, the consortium provides and develops necessary solutions for solar-powdered hybrid cycle in several stages. Whereas the solar HyS cycle remains the best long-term solution, to ensure economic profitability for the short-term opportunities the consortium starts with the integration of solar-power sources with new Outotec® Open Cycle (Fig. 2).

This cycle does produce sulfuric acid together with hydrogen using different sources of SO2 from chemical and metallurgical plants and allows fast, scalable build-up of smaller scale hydrogen by-production plants without affecting acid production.

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a public private partnership supporting research, technological development and demonstration (RTD) activities in fuel cell and hydrogen energy technologies in Europe. Its aim is to accelerate the market introduction of these technologies, realizing their potential as an instrument in achieving a carbon-lean energy system. The three members of the FCH JU are the European Commission, fuel cell and hydrogen industries represented by the NEW Industry Grouping and the research community represented by Research Grouping N.ERGHY. http://www.fch-ju.eu

Simplified structure, extra revenues from acid sales and highly efficient co-use of the existing plants might lead to substantial reduction of H2 costs vs. traditional HyS process designs. This allows further developments to concentrate in a real-scale size technology, learning from the pilot and smaller scale production and developing key solutions for solar HyS in medium to long term. Besides providing key materials and process solutions, for the first time the whole production chain and flowsheet will be connected with multi-objective design and optimisation (MODAO) and meta-modeling algorithms ultimately leading to hydrogen plants and technology "green concepts" implementation.

Partners

The consortium

SOL2HY2, coordinated by EnginSoft, is a medium-sized, multi-disciplinary project with a strong participation of research-intensive university (Aalto University Foundation, Finland) and R&D centres (DLR - German Aerospace Authority, ENEA - Agenzia per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile; Italy), industry (Outotec Corp., Finland) and SMEs (EnginSoft S.p.A., Italy; Erbicol S.A., Switzerland, Oy Woikoski AB, Finland). This is a project in which partners aim at working together to learn the needs of each other and to contribute collectively – with the goal of accelerating the speed at which new breakthroughs might be made to help the European industrial sectors to compete more effectively in world markets.

The role of EnginSoft

EnginSoft will provide to all the partners MODAO (MultiObjective Design and Optimisation) tools and metamodelling methods, including elaboration of DoE strategy, data mining and optimisation. EnginSoft will also help SME and R&D performers in modelling issues, simulation of the relevant processes and elaboration of the models.

Moreover, EnginSoft has always employed many resources in R&D activities, at national and international level, with a strong participation at co-funded R&D projects, also with coordination responsibilities. Based on this fruitful experience, EnginSoft has taken the coordination of the project.

The web-based platform EUCOORD, developed by EnginSoft for supporting of the EU projects (www.eucoord.com), will be used in SOL2HY2 as a powerful and reliable project management tool.

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