THE SOLZINC-PROJECT FOR UP-SCALING THE SOLAR CHEMICAL TECHNOLOGY FOR PRODUCING ZINC AS A SOLAR FUEL

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A joint European research project by six partners, PSI (CH), ETHZ (CH), CNRS (F), WIS (IL), ChemTEK (D), and ScanArc (S), has been successfully negotiated with the European Community. The project, called "SOLZINC", aims at scaling-up the chemical reactor technology of the most promising process for the solar production of Zn by carbothermic reduction of ZnO. Furthermore, the ZnO-Zn cyclic process encompassing the Zn-production solar plant combined with a Zn-air fuel cell will be developed to deliver solar electricity independent of location and time.

1 INTRODUCTION

Intermittent solar energy can be converted into a storable and transportable fuel via the production of Zn from ZnO using concentrated solar radiation as the source of high-temperature process heat [1]. The energy content of zinc can be recovered as electricity in 70% efficient zinc-air fuel cells [2]. Zinc can also be reacted with water in an exothermic reaction for producing high-purity hydrogen for H_2-O_2 PEM fuel cells [3]. In both power generating routes, the chemical product is ZnO, which is recycled to the solar reactor. Thus, Zn serves as the chemical energy carrier for storing and transporting solar energy.

The thermal dissociation of ZnO requires operating temperatures above about 2000 K. The use of carbonaceous materials as reducing agents (e.g. coal, coke, biomass, or natural gas) allows operation at much more moderate temperatures, in the range of 1300-1600 K, but at the expense of releasing CO_2. If biomass is used as a reductant, the process has zero net CO_2 emissions. Nevertheless, compared to the conventional fossil-fuel-based production of Zn, the solar-driven carbothermic processes can reduce CO_2 emissions by a factor of 5 to 10. Furthermore, their development can profit from the traditional pyrometallurgical know-how.

The stoichiometric carbothermic reduction of ZnO, using either C or CH_4 as reducing agents, can be represented by the overall net chemical reactions:

$$ZnO + C \rightarrow Zn(g) + CO \quad (1)$$

$$ZnO + CH_4 \rightarrow Zn(g) + CO + 2H_2 \quad (2)$$

Under-stoichiometric feeding of reducing agents would be more advantageous [4], but is more difficult to realize. These reactions have been successfully demonstrated in small-scale (5 kW) solar reactor prototypes [5]. A joint international research project with participation of 4 research laboratories and 2 industrial partners has been defined to perform the logical next step in the solar chemical technology development, i.e. scale-up to a pilot plant. The project is partially financed by the European Community, with the Swiss contribution being funded by the BBW - Swiss Federal Office for Education and Science. The SOLZINC Consortium is listed in Table 1.

Partner	Location/Country	***Main* task** (partners are active in further tasks)
CNRS-IMP	Odeillo/ France	Administrative coordination, thermal and energetic diagnostic
PSI	Villigen/Switzerland	Scientific coordination, solar reactor design, buildup, test
ETHZ	Zurich/Switzerland	Solar reactor modeling and optimization: solar simulator
WIS	Rehovot/ Israel	Balance of plant for pilot Infrastructure: 1MW beam down solar concentrator
ScanArc	Hofors/Sweden	Zn-condensation (operation limits, pilot plant)
ChemTEK	Oberderdingen/ Germany	Zn-air fuel cell optimisation Treatment of spent cell products prior to reuse in solar plant

Table 1: The SOLZINC Consortium: two industrial partners (ScanArc, ChemTEK) and four research institutes (PSI, ETHZ, CNRS, WIS).

2 PROJECT OBJECTIVES

The key objective of SOLZINC is to develop and to experimentally evaluate a solar carbothermic ZnO-reduction process at the solar power input level of about 0.5 MW. In addition, the project includes the investigation of the material cyclic process and the interface of Zn-air fuel cells with the solar process. (Figure 1).

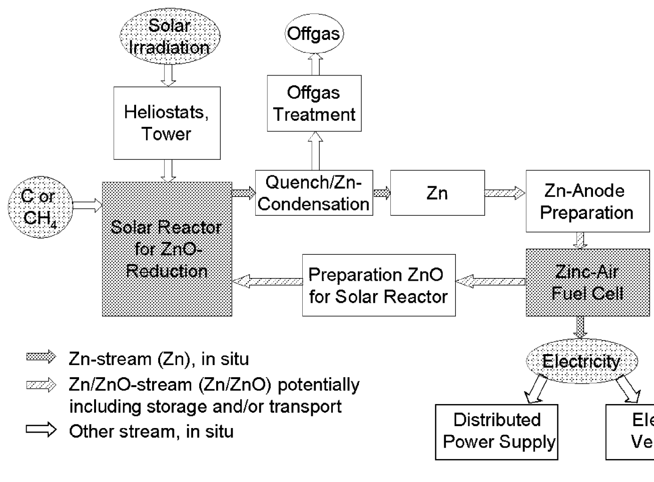

Fig. 1: Material cyclic process for solar electricity generation, using Zn as the solar fuel.

3 PROJECT METHODOLOGY AND WORK PLAN

SOLZINC started in December 2001. The 4-years work plan consists of three major phases:

Phase 1: Optimization on 5kW scale (year 1).

Based on all available previous experience, the solar reduction technology that is most promising for scaling up to commercial size will be selected. Three reactor concepts are considered for this evaluation, all of which have already been tested on a 5kW scale: (a) a tubular reactor [6] for reaction (1), (b) a rotating hearth reactor originally designed for Electric Arc Furnace Dust treatment [7], which has been tested at PSI for reaction (1) in autumn 2001, (c) the Synmet-reactor [5] for reaction (2). PSI is in charge of the optimisation of the chosen reactor concept. The testing will be performed in ETHZ's High-Flux Solar Simulator.

In parallel, ScanArc will perform experimental evaluation on Zn-condensation techniques for addressing the re-oxidation issue of the off-gases exiting the solar reactor. ChemTEK will work on the optimisation of the Zn-air cells for the specific goals of SOLZINC (e.g. optimisation for maximal efficiency rather than maximal power) and for solving the interface problems (e.g. separation and reuse of KOH-electrolyte from the Zn-air fuel cell).

Phase 2: Design and test in pilot scale (years 2-3).

It will be based on the small-scale reactor optimisation and will be assisted by detailed process modelling, performed by ETH. Design and build-up of the solar reactor for the pilot plant will be mainly carried out by PSI. ScanArc will realize the corresponding Zn-condensation unit. The diagnostic instrumentation equipment will be provided by the CNRS group in Odeillo. ChemTEK will build and operate a 10 kW Zn-air cell module. The solar pilot plant will then be erected and tested in the existing solar concentrating facility of the Weizmann Institute of Science (WIS), in Israel. Figure 2 shows the set-up for a beam-down optical configuration, which allows operation of the Zn-plant on the ground [8]. Two extensive solar test campaigns are scheduled.

Phase 3: Conceptual design of a demo unit (year 4).

The results from the first two project phases will be used to perform detailed design studies for the complete solar to electricity cycle process, including eco-efficiency studies for different scenarios of technology implementation, such as electricity generation for peak demand, different consumer locations, etc.

4 CONCLUSION

The SOLZINC-project marks a milestone in solar chemistry R&D for storing and transporting solar energy. A successful up-scaling of the solar production of zinc will provide the basis for a sound judgment of the potential implementation of this novel, sustainable, and clean electricity generation technology for stationary and mobile applications.

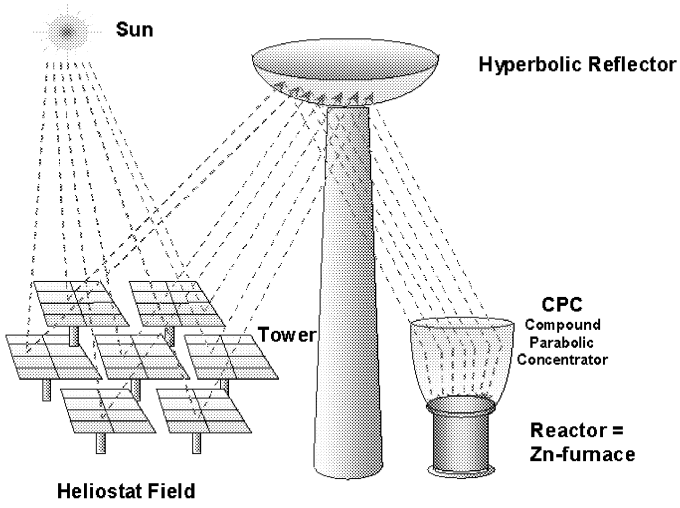

Fig.2: Scheme of the solar concentrating optical configuration chosen for the SOLZINC-technology [8].

5 ACKNOWLEDGEMENT

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