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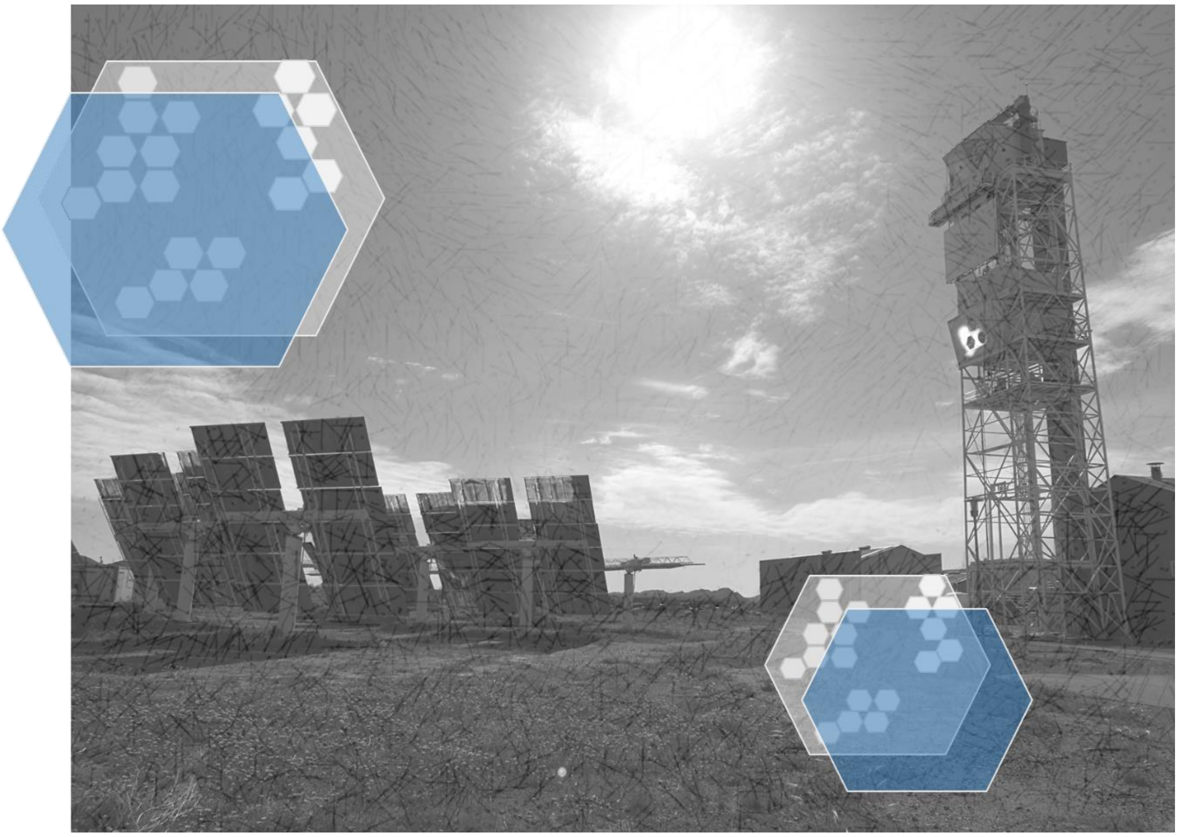

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Publishable Summary

The HYDROSOL-beyond project continues the series of HYDROSOL-related research programs and its main goal is to increase the efficiency of the already existing 750kW solar plant in Almeria, Spain. The solar platform takes advantage of the HYDROSOL technology in order to produce renewable green hydrogen. HYDROSOL concept is based on the utilization of concentrated solar thermal power for the production of Hydrogen from the dissociation of water via redox metal oxide based thermochemical cycles.

Figure 1. Picture of the Hydrosol-beyond plant in operation

Continuing the work that has been done in the first project period, the second period of the HYDROSOL-beyond project dealt with the activities at the laboratory level on the investigation, design and development of novel concepts that are going to be integrated in the existing HYDROSOL solar platform at the Plataforma Solar de Almeria in Spain as well as concepts that are investigated for future implementation towards further enhancing the process efficiency. Tasks and activities undertaken for the preparation and the preliminary testing at the level of the solar platform run in parallel.

Novel lattice structures of existing redox oxides have been manufactured and evaluated at the laboratory scale both for the water splitting as well as for the oxygen trapping concept. The redox lattices for the water splitting reaction were tested for a significant number of cycles. The final long-term durability on the qualified structures will run until the end of the project and in parallel to the experimental campaigns at the solar platform.

(a) (b) (c)

Figure 2. Novel lattice redox structures based on (a) $CeZrO_2$, (b)$NiFe_2O_4$ for water splitting and (c) Co_3O_4 for N_2 purification via O-trapping respectively

Minimization of the inert gas can be achieved either by lowering the inert gas flow rate, provided that sufficient reduction extent of the redox water splitting material can be achieved, or by introducing concepts of recycling of the inert gas after its purification and the removal of O_2 that is released during the thermal reduction step of the water splitting redox material. Two approaches were investigated based (i) on O-trapping on redox materials and (ii) on reverse Pressure Swing Adsorption (PSA). A novel concept of an O-trapping redox system based on cobalt oxide structured bodies that is coupled with the water splitting reactor and can remove oxygen from the inert gas stream that exits the water splitting reactor was successfully tested at the laboratory scale in a dual reactor testing rig and under consecutive cycling mode proving the applicability of the process. In the case of the reverse PSA a modified experimental set-up was used to investigate the applicability of the concept.

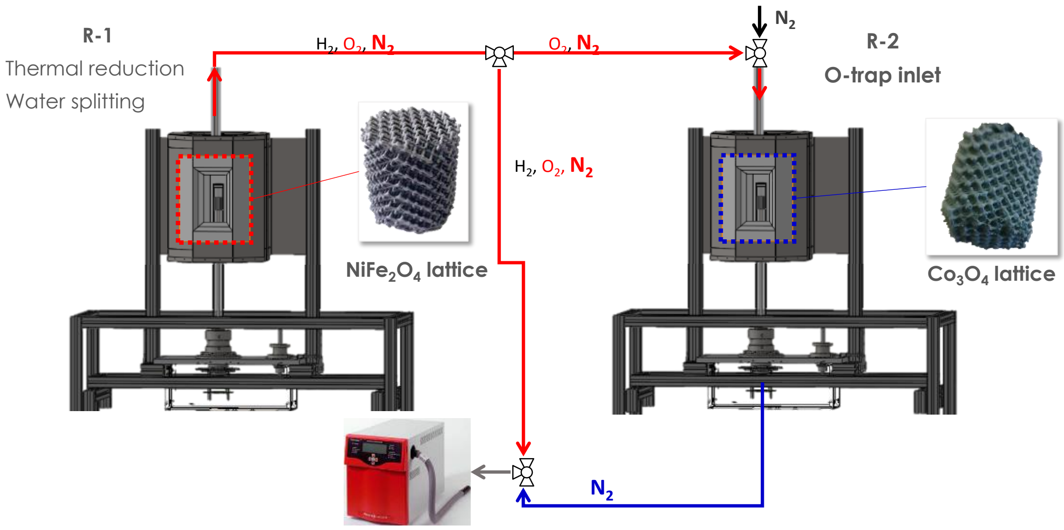

Figure 3. Coupled dual redox reactors: R1 $NiFe_2O_4$ water splitting reactor , R2 CoO/Co_3O_4 N_2 purification reactor

A hybrid high-temperature heat exchanger for the recovery of the high temperature waste heat that is produced in the solar thermochemical H_2 production was constructed and its performance was experimental assessed at the laboratory scale, leading to valuable results for the optimization of its design.

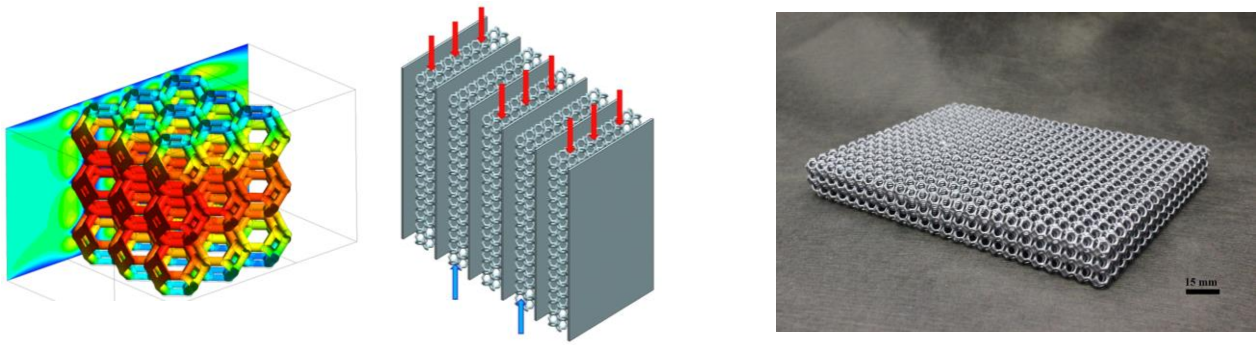

Figure 4. Novel hybrid heat exchanger core geometry, conceptual design and ceramic core construction

Figure 5. Prototype heat exchanger and insulation casing and parts for the covering of the ducts.

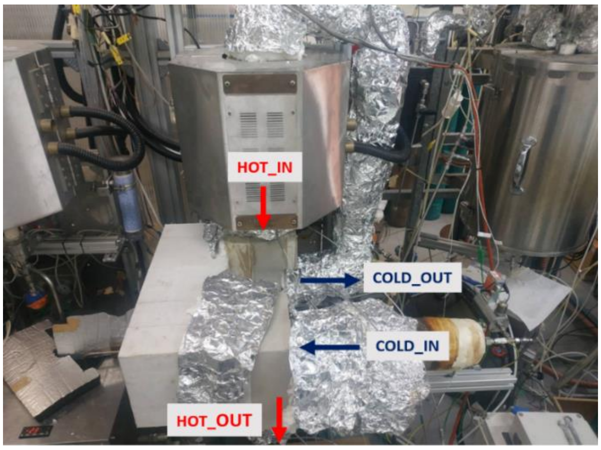

Figure 6. Experimental test rig of the prototype assessment

A second updated design has been developed and will be manufactured and directly integrated on the solar platform downstream of the directly irradiated solar cavity reactor for testing under real plant conditions.

Full scale experiments on the modified directly heated solar cavity reactor coupled to conventional heat exchanger units took place at the high flux solar simulator at Jullich. Additionally, the performance analysis of an alternative indirectly heated tube reactor concept has been reported. The analysis for both reactor types reveals the issues and limitations in the operation and proved that there is a margin for improvement, however, inherent characteristics of the directly heated solar cavity reactor design as well as of materials limit the potential increase of the efficiency.

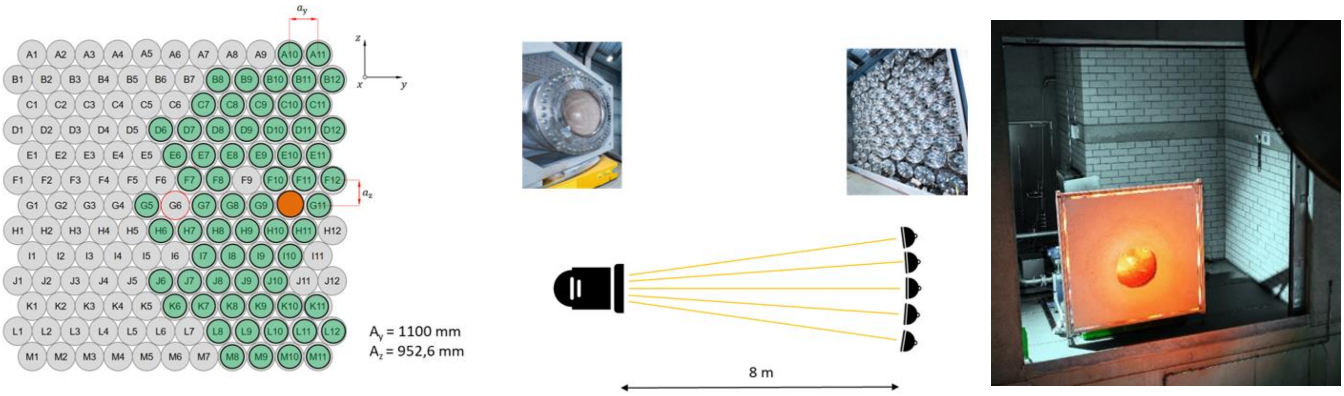

Figure 7. Scheme and photograph of the set-up used to test the HYDROSOL-beyond reactor in SYNLIGHT

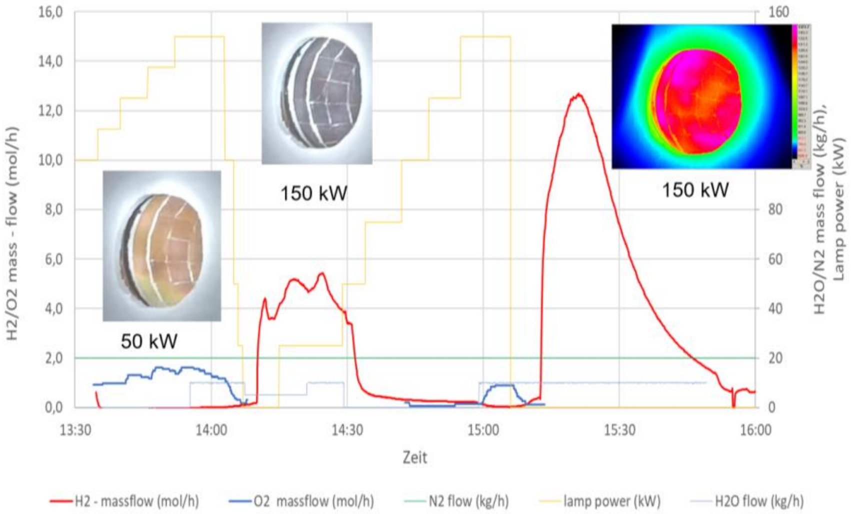

Figure 8. Further example of a splitting test performed in SynLight. The higher steam mass flow leads to a significantly higher H_2 yield

The repair and restoration actions on the HYDROSOL solar platform at the Plataforma Solar de Almeria in Spain that have taken place in order for the platform to be operable focused on the secondary concentrators and the quartz window fitting on the reactor. Several tests were performed and significant progress has been made with the operation of the plant at the higher temperature of 1200°C. H_2 production was achieved on the solar platform with the highest production recorded since the previous project (total H_2 yield of 156 lt). Several issues were further identified in the case of the quartz window and the effect of reactor degradation on the window optical properties as well as in the case in the temperature distribution within the cavity

With respect to the peripheral components of the current plant, a preliminary thermal balance of the current heat-exchangers has been performed, providing very good results, with efficiencies being around 50% or even higher.

Data have been collected for setting up the technoeconomic analysis and the life cycle assessment of the HYDROSOL-beyond process. A preliminary LCA was initiated with data from the previous project and the original platform of the HYDROSOL-Plant during (reported in the first project period) as a benchmark for future comparison with the corresponding analysis of the Hydrosol-beyond modified platform and the evaluation of the environmental impact of modifications in the plant.

HISTORY OF CHANGES		
VERSION	PUBLICATION DATE	CHANGE
1.0	31.08.2022	Initial version
1.1	01.11.2022	Revision
1.2		