A Novel Concept of Redox Oxides-Based Dual-Bed Thermochemical Energy Storage for Exploiting the Potential of Concentrated Solar Power (CSP) Technology

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1. Introduction

The world's energy system is currently in the transition to a less carbon-intense and more sustainable future. Photovoltaic (PV) technology and wind energy are in the center of this transformation. Nevertheless, given that these renewable energy sources (RES) are variable and unpredictable, massive grid-scale energy storage is compulsory. Concentrated Solar Power (CSP) is one of the promising technologies due to the dispatchability based on Thermal Energy Storage (TES), although it has some inherent limitations. To overcome these limitations, emerging Thermochemical Energy Storage (TCES) can offer viable solutions since it has the potential to store solar energy with higher energy storage density [1]. The ABraytCSPfuture ("*Air-Brayton cycle concentrated solar power future plants via redox oxides-based structured thermochemical heat exchangers/thermal boosters*") project presents a disruptive solution to integrate a redox oxides-based TCES system with an air-operated CSP plant that can achieve very high-temperatures and power an air-Brayton gas turbine cycle in order to reach high cycle efficiencies. Therefore, the main objective of the project is to develop a first-of-its-kind dual-bed thermochemical reactor/heat exchanger design based on earth-abundant and inexpensive oxides [2] in order to achieve minimum environmental impact and higher efficiencies. This is on one hand vital for competitiveness of CSP and on the other hand non-reachable by either PVs or molten salts and thermal oils. ABraytCSPfuture is a Horizon Europe funded project that started in November 2022 and will last 4 years.

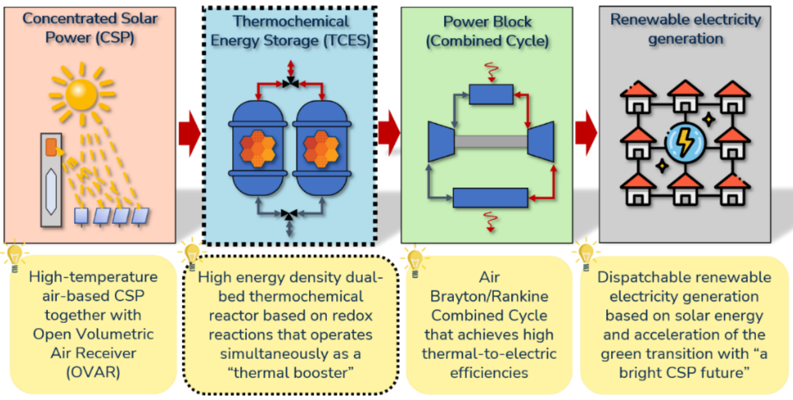

Fig. 1. Simplified ABraytCSPfuture concept.

2. The novel concept of ABraytCSPfuture

The ABraytCSPfuture approach operates between the oxidized and reduced form of a suitable metal oxide in a cyclic process. The dual-bed reactor/heat exchanger design allows continuous operation and the gas turbine is always fed with a high-pressure, high-temperature air stream (see Figure 2). In step 1, during on-sun operation, the high-temperature air stream at atmospheric pressure is introduced from the top of the right chamber to carry out the thermal reduction step, where the higher-valence oxide state releases oxygen and transforms to the lower-valence form. Meanwhile, the oxide in the left chamber is at its reduced state –due to the previous cycle - and compressed air from the compressor at low temperature is introduced in the lower end of the chamber. Thus, exothermic oxidation takes place and the reduced form is transformed to the oxidized form, releasing the stored heat and raising its temperature beyond the level achievable by only sensible heating (i.e. “thermal boosting” effect). In step 2, the flow of the two chambers is switched and the plant operates with exactly the same principle. Additional energy storage units are integrated for prolonged off-sun operation.

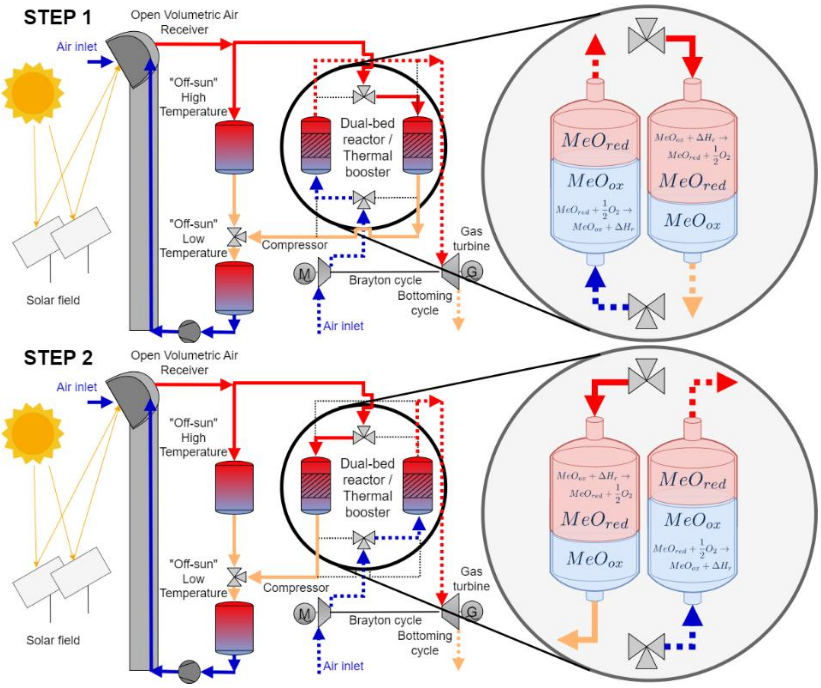

Fig. 2. ABraytCSPfuture proposed concept’s solar plant operation.

3. Conclusions and outlook

This work presents the innovative ABraytCSPfuture project and the assessment of its promising application. As a result, its presentation will introduce the concept of the proposed innovative technology and will include the latest advances regarding the main tasks of the project: (i) redox oxides powders synthesis, which will be also presented in more detail via a separate study [3] in the framework of the project, (ii) redox oxides structures preparation and evaluation, (iii) dual-bed design and integration in CSP, and/or (iv) the technology holistic assessment. The project expects a high energy density of the TCES system (≥300 kWh/m³) in the range of 300-1100 °C, low production cost (≤2 €/kg) and a Levelized Cost of Electricity (LCOE) lower than 6 c€/kWhe. The breakthrough technology introduced expects to exploit the high potential of CSP and it will maximize cost-effective and dispatchable use of the immense solar resource, accelerating the green transition.

References

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