Solid State Thermochemical Fuel (SoFuel) for Long Duration Storage (008992)

Pellet flowability at 1500°C enables production of solid-state rechargeable fuel that can provide heat at 1000°C.

1. Impact

Duration of Storage: Indefinite, Energy Storage Cost is <$15kWh$^{-1}{}_{thermal}$, Levelized cost of storage<$0.09 kWh$^{-1}{}_{thermal}$, Solar-to-Fuel Conversion Efficiency> 50%

2. Project Goal

The project goal is to develop a high energy density, concentrated solar thermochemical storage solution in the form of a zero-emission solid state fuel called SoFuel. SoFuel can be indefinitely stored for long duration and can directly supply 1000°C heat to an adjacent plant for electricity generation or as process heat.

3. Method(s)

SoFuel consists of a pelletized form of highly reactive magnesium manganese oxide (Mg-Mn-O). Thermal reduction (charging) of SoFuel occurs in a cylindrical cavity chemical reactor consisting of vertical ceramic tubes. The reactor cavity is designed to capture concentrated solar radiation from a solar field or heat from renewable electricity. SoFuel pellets flow/fall down the reactor tubes and undergo thermal reduction as they are heated to a temperature greater than 1350 °C. Counterflow of thermal capacity matched oxygen depleted air not only ensures near ambient inlet and outlet temperatures but also maximizes the conversion of thermal energy to chemical energy. A similar counter flow oxidation reactor is proposed for heat release to the industrial plant.

4. Outcome(s)

A a novel non-mechanical solid flow controller was developed to minimize particle attrition. Solid pellet flowability at 1500°C, energy storage flux > 900 kWm^{-2} and overall system efficiency of 28% in the lab scale test facility was demonstrated. Thermal to chemical conversion efficiency of 97% was estimated. Achieved 1100°C air discharge from charged pellets. Overall energy density of 1400 MJm^{-3}.

5. Conclusion/Risks

Key operational and design strategies identified: Thermal capacity matched counterflow gas must be pulsed at low frequency (0~0.01 Hz) to enable pellet flow at T>1300°C, Counterflow gas must be partially bypassed in reaction zone to achieve solid flux >1 kgm^{-2}. Reactors tubes must be thoroughly insulated above the reaction zone to avoid pellet clogging due to sudden thermal expansion. **Risks:** Particle attrition due to repeated usage may be a potential risk.

6. Team

Michigan State University: James Klausner, Joerg Petrasch, Kelvin Randhir, Philipp Schimmels, Michael Hayes. **Oregon State University:** Nicholas AuYeung, Juvenal Ortiz, Lei Fuqiong. **Mississippi State University:** Like Li, Wei Huang, David Korba. **Purdue Northwest University:** Nesrin Ozalp, Assaad Al Sahlani

Visuals

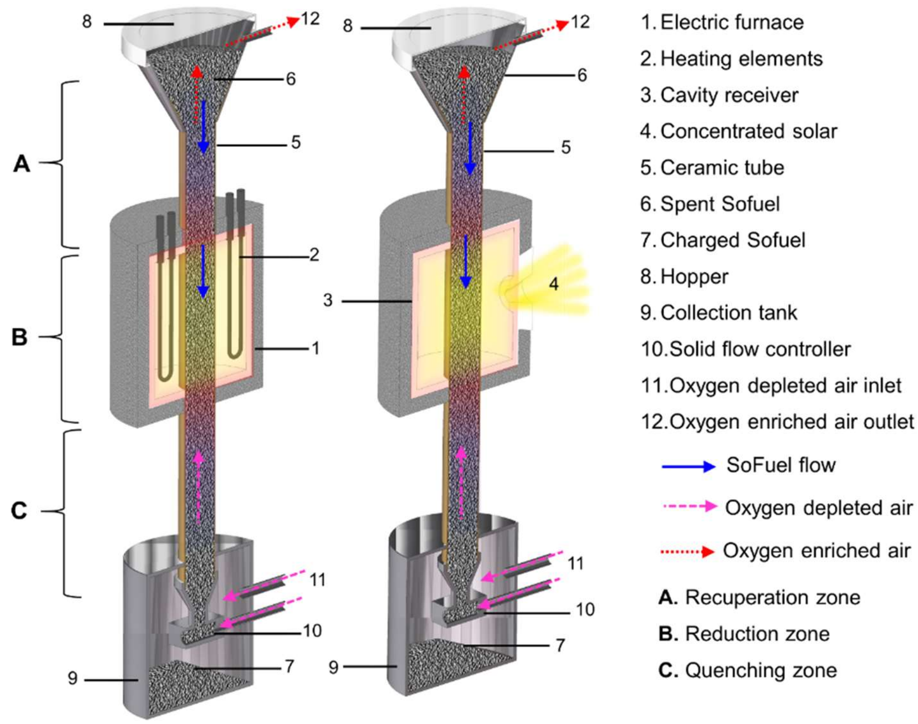

Figure 1. The layout of a SoFuel production facility a) powered by renewable electricity and electrically heated furnace b) powered by concentrated solar furnace

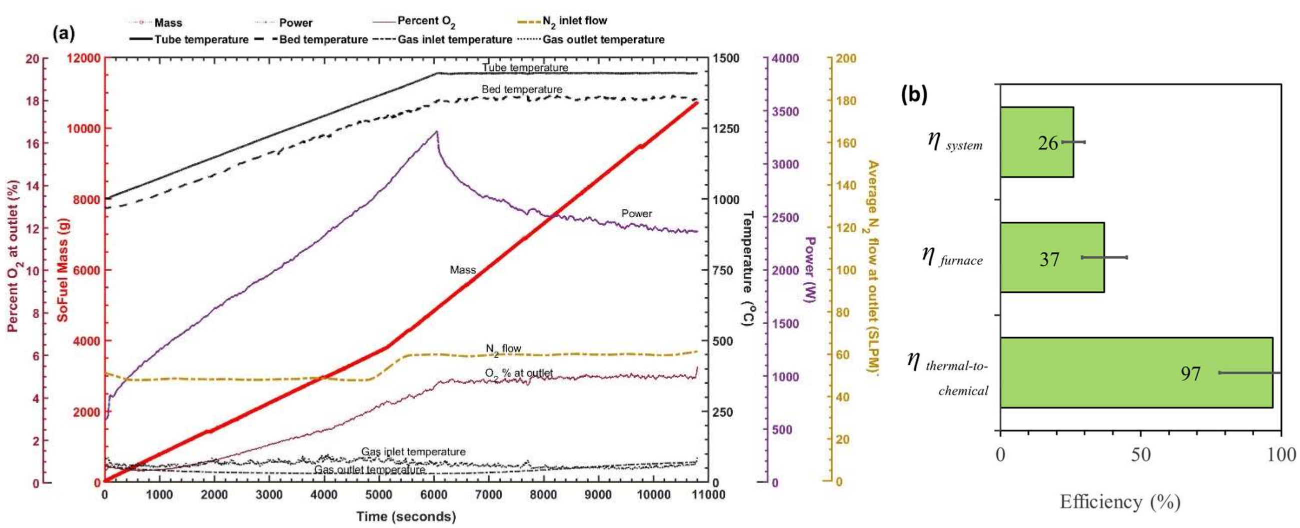

Figure 2. (a) Experimental data for SoFuel pellet reduction at 1450 °C flowing at 1.25 g/s through a 50 mm diameter alumina tube with 300 mm heated zone (b) Overall system efficiency, efficiency of the lab scale furnace and the thermal to chemical conversion efficiency if heat loss from furnace walls to ambient is excluded.