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SUNgas: Thermochemical Approaches to Solar Fuels

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Solar energy offers an intelligent solution to reduce anthropogenic emissions of greenhouse gases and to meet an expanding global demand for energy. A transformative change from fossil to solar energy requires collection, storage, and transport of the earth's most abundant but diffuse and intermittent source of energy. One intriguing approach for harvest and storage of solar energy is production of clean fuels via high temperature thermochemical processes. Concentrated solar energy is the heat source and biomass or water and carbon dioxide are the feedstocks. Two routes to produce fuels using concentrated solar energy and a renewable feed stock will be discussed: gasification of biomass or other carbonaceous materials and metal oxide cycles to produce synthesis gas. The first and most near term route to solar fuels is to gasify biomass. With conventional gasification, air or oxygen is supplied at fuel-rich levels to combust some of the feedstock and in this manner generate the energy required for conversion to H_2 and CO. The partial-combustion consumes up to 40% of the energetic value of the feedstock. With air combustion, the product gas is diluted by high levels of CO_2 and N_2. Using oxygen reduces the product dilution, but at the expense of adding an oxygen plant. Supplying the required heat with concentrated solar radiation eliminates the need for partial combustion of the biomass feedstock. As a result, the product gas has an energetic value greater than that of the feedstock and it is not contaminated by the byproducts of combustion. The second promising route to solar fuels splits water and carbon dioxide. Two-step metal-oxide redox cycles hold out great potential because they the temperature required to achieve a reasonable degree of dissociation is lower than direct thermal dissociation and O_2 and the fuel are produced in separate steps. The 1^{st} step is the endothermic thermal dissociation of the metal oxide to the metal or lower-valence metal oxide. The 2^{nd} exothermic step is the hydrolysis of the reduced metal to form H_2 and the corresponding metal oxide. Two promising options for 2-step cycles, the Zn/ZnO and non-stoichiometric ceria redox cycles, will be compared with a focus on efficiency and state of the art achievements.