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Solar Hydrogen via Steam-Gasification of Petcoke

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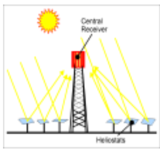
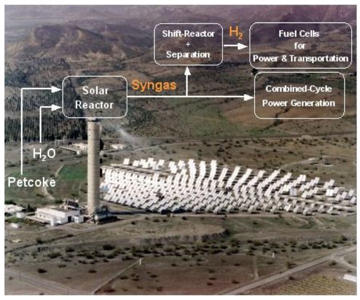
Motivation

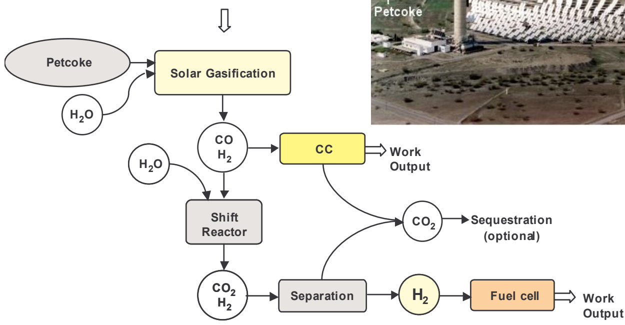
Hybrid solar/fossil endothermic processes, in which fossil fuels are used exclusively as the chemical source for H_2 production, and solar energy as the source of high-temperature process heat, offer viable and efficient routes for fossil fuel decarbonization and CO_2 mitigation. The advantages of the solar-driven process are three-folded:

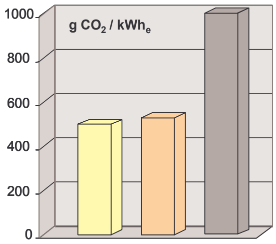
1) the discharge of pollutants is avoided;
2) the gaseous products are not contaminated; and
3) the calorific value of the fuel is upgraded.



Concentrated Solar Power



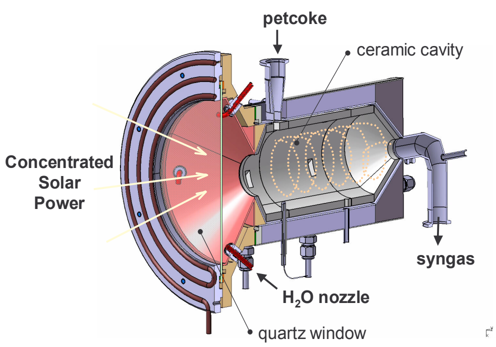


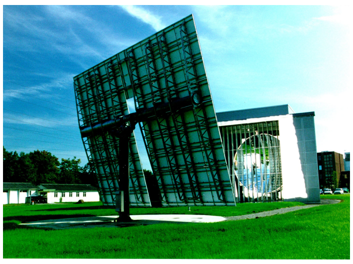


Specific CO_2 emission
(without sequestration)

- Petcoke-gasification to syngas + 55%-η CC
- Petcoke-gasification to H_2 + 65%-η fuel cell
- Petcoke-combustion + 35%-η Rankine cycle

Solar Chemical Reactor Technology

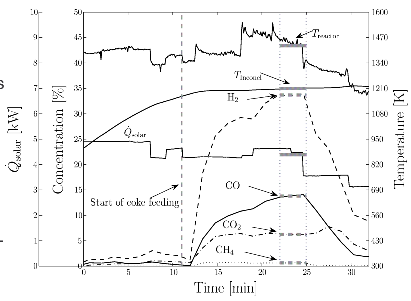




Schematic configuration of the solar chemical reactor, featuring a vortex flow of steam confined to a cavity-receiver and laden with petcoke particles that serve as radiant absorbers and chemical reactants. A 5-kW solar reactor prototype was tested at PSI's solar furnace.

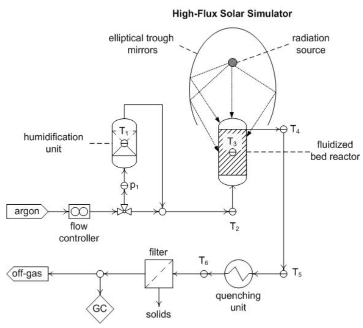
Solar Experimental:

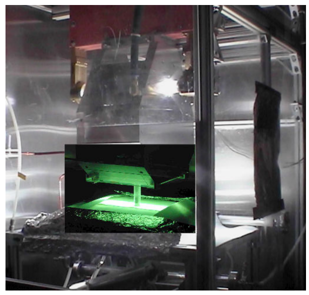
- Solar power input = 5 kW
- Solar flux concentration = 3000 suns
- Petcoke mass flow rate = 4 g/min
- Chemical conversion = 87 %
- Thermal efficiency = 19 %



Temperatures and product gas composition during a solar experimental run.

Kinetic Studies





$$CO_2 + C\langle * \rangle \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} CO + C\langle O \rangle$$

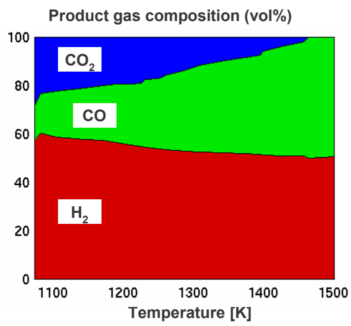
$$CO + C\langle * \rangle \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} C\langle CO \rangle$$

$$C\langle O \rangle \xrightarrow{k_3} CO + nC\langle * \rangle$$

$$H_2O + C\langle * \rangle \underset{k_{-4}}{\overset{k_4}{\rightleftharpoons}} C\langle OH \rangle + C\langle H \rangle$$

$$C\langle OH \rangle + C\langle H \rangle \xrightarrow{k_5} C\langle O \rangle + C\langle H_2 \rangle$$

$$H_2 + C\langle * \rangle \underset{k_{-6}}{\overset{k_6}{\rightleftharpoons}} C\langle H_2 \rangle$$



Outlook:

- 500 kW solar pilot plant at the *Plataforma Solar de Almeria*, Spain.
- Reactor modeling, validation, and optimization.
- 10-MW conceptual plant design

References:

- Trommer et al., *Int. J. Hydrogen Energy* 30, 605-618, 2005.
- v. Zedtwitz et al., *Ind. Eng. Chem. Res.* 44, 3852-3861, 2005.
- Z'Graggen et al., *Int. J. Hydrogen Energy* 31, 797-811, 2006.
- Trommer, Steinfeld, *Energy & Fuels*, in press

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