Fuel Production from Concentrated Solar Radiation

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Introduction

- Motivation: Political, Economical, Ecological, Technical
- Concentrating Solar Systems
- Solar fuels technology developments and demonstrations
- R&D needs and networks
Political Drivers: Examples – EU Sustainable Energy Technology Plan (SET-Plan 2007) G7 Goals (2015)

- **Goals of the EU until 2020 (20/20/20)**
  - 20% higher energy efficiency
  - 20% less GHG emission
  - 20% renewable energy

- **Goal of the EU until 2050:**
  - 80% less CO₂ emissions than in 1990

- **G7 Goals, Elmau, Germany**
  - 100% Decarbonisation until 2100
  - 100 bln $/year for climate actions in developing countries, large share by industrial investment
Development of EU GHG emissions [Gt CO$_2$e]

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total abatement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>95-100%</td>
</tr>
<tr>
<td>Road transport</td>
<td>95%</td>
</tr>
<tr>
<td>Air &amp; sea transport</td>
<td>50%</td>
</tr>
<tr>
<td>Industry$^3$</td>
<td>40%</td>
</tr>
<tr>
<td>Buildings</td>
<td>95%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>20%</td>
</tr>
<tr>
<td>Waste</td>
<td>100%</td>
</tr>
<tr>
<td>Forestry</td>
<td>-0.25 Gt CO$_2$e</td>
</tr>
</tbody>
</table>

1. Large efficiency improvements are already included in the baseline based on the International Energy Agency, World Energy Outlook 2009, especially for industry.
2. Abatement estimates within sector based on Global GHG Cost Curve.
3. CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries).

SOURCE: www.roadmap2050.eu
Solar Hydrogen

Solar Energy

Heat

Thermochemical Cycles

Metal oxide cycles: HYDROSOL (800-1200°C)

Other Thermochemical Cycles

Thermolysis >2000°C

Mechanical Energy

Electricity

Conversion

Photolysis

Electrolysis

Biomass

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Temperature Levels of CSP Technologies

**Paraboloid:** „Dish“

**Solar Tower** (Central Receiver System)

**Parabolic Trough / Linear Fresnel**
Solar Towers

- PS10, Ivanpah, Torresol
- PSA CRS, CESA-1,
- Solar-Two, Daggett,
Technical Optimization in all Dimensions necessary

10^4 – 10^2 m
Solar Plant

Site
Solar field
Simulation
Environmental impact

10^2 – 10^1 m
Receiver

Design
Simulation
Construction
Testing
Next-Generation-Development

10^1 – 10^{-2} m
Receiver-components

Materials
Design
Heat and Mass transport
Simulation
Testing and Development

10^{-2} – 10^{-8} m
Reactive Systems

Simulation
Synthesis
Chemical Characteristics
Physical Characteristics

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Solar Field Development

The field has to be designed for its application:

- Location
- Concentration ratio to achieve the Process temperature
- At high concentration (1000 suns) secondary optics have to be taken into account


Receiver – Concepts for Solar Chemistry

• Challenges:
  • Temperature
  • Corrosion
  • Abrasion
  • Process operation

• Goals:
  • Efficiency
  • Durability
  • Cost

German Project
Solar heated rotary kiln, DLR

European Project
Solar heated Cavity-Gas Receiver with porous Ceramic structure
A. Steinfeld et al., ETH Zürich

DoE Project with DLR participation
Solar heated Particle-Receiver
I. Ermanoski et al., Sandia Natl. Lab.
Scale evolution

TGA  →  Lab-scale furnace test rig  →  Solar receivers
Comparative testing of three SiC receivers (190 slm)

SiSiC honeycomb
90 cps; Schunk
Weight ≈1404 g
Length = 15 cm

3 SiSiC foams
10 ppi; ERBICOL
Weight ≈ 246 g
Length = 12 cm

ReSiC honeycomb
90 cps; Stobbe TC
Weight ≈ 584 g
Length = 10 cm
Rationale for using ReSiC

- Possibility to exceed 1370° C on the front irradiated surface (m.p. > 2000° C).
- Temperature measurement with an IR camera (“matched” to TC1 indication for T < 1370° C).
Solar Receiver Components and reactive Systems


Reactive coated structures and structures made from reactive materials

Example how a technology is developed
The HYDROSOL concept

1. Water Splitting
$\text{H}_2\text{O} + \text{MO}_{\text{red}} \rightarrow \text{MO}_{\text{ox}} + \text{H}_2$

2. Regeneration
$\text{MO}_{\text{ox}} \rightarrow \text{MO}_{\text{red}} + \frac{1}{2} \text{O}_2$

Net Reaction: $\text{H}_2\text{O} \rightarrow \text{H}_2 + \frac{1}{2} \text{O}_2$
HYDROSOL Development

Hydrosol I
2002 – 2005
< 10 kW

Hydrosol II
2006 – 2009
100 kW

Hydrosol 3D
2010 – 2012
1 MW
Hydrosol Plant - Design for CRS tower PSA, Spain

- European FCH-JU project
- Partner: APTL (GR), HELPE (GR), CIEMAT (ES), HYGEAR (NL)
- 750 kW$_{th}$ demonstration of thermochemical water splitting
- Location: Plataforma Solar de Almería, Spain, 2016
- Use of all heliostats
- Reactor set-up on the CRS tower
- Storage tanks and PSA on the ground
H₂O/CO₂-Splitting Thermochemical Cycles

Solar Production of Jet Fuel

- EU-FP7 Project SOLAR-JET (2011-2015)
- SOLAR-JET aims to ascertain the potential for producing jet fuel from concentrated sunlight, CO₂, and water.
- SOLAR-JET: optimize a two-step ceria based solar thermochemical cycle to produce synthesis gas (syngas) from CO₂ and water, achieving higher solar-to-fuel energy conversion efficiency over current bio and solar fuel processes.

- First jet fuel produced in Fischer-Tropsch (FT) unit from solar-produced syngas!

http://www.solar-jet.aero/
Outlook
Specific Solar Fuel Demonstration Tower needed!

CRS Tower PSA, Spain
2008 and 2016

- High concentration > 1000
- Heliostats fit to receiver size
- Field control adapted to fuel production processes

Solar Fuels Tower, Location?
2020
Thank you very much for your attention!