Concentrated Solar Radiation
More than just a power source

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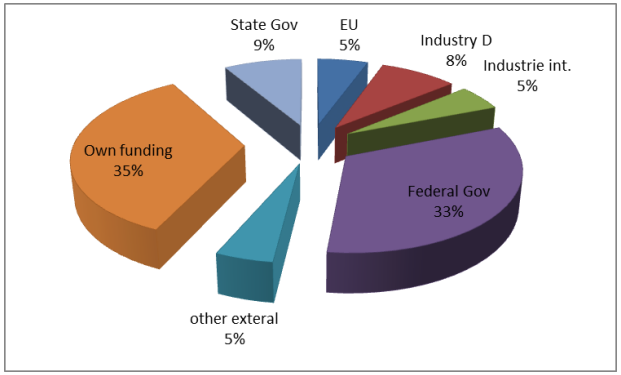
Prof. Dr. Christian Sattler
Christian.sattler@dlr.de

DLR Institute of Solar Research

Mission

- 1/3 fundamental scientific questions to enable next generation technology for electricity, heat, fuel and water using concentrating solar power
- 2/3 applied development task for/with industry to optimize products and technologies



Key data

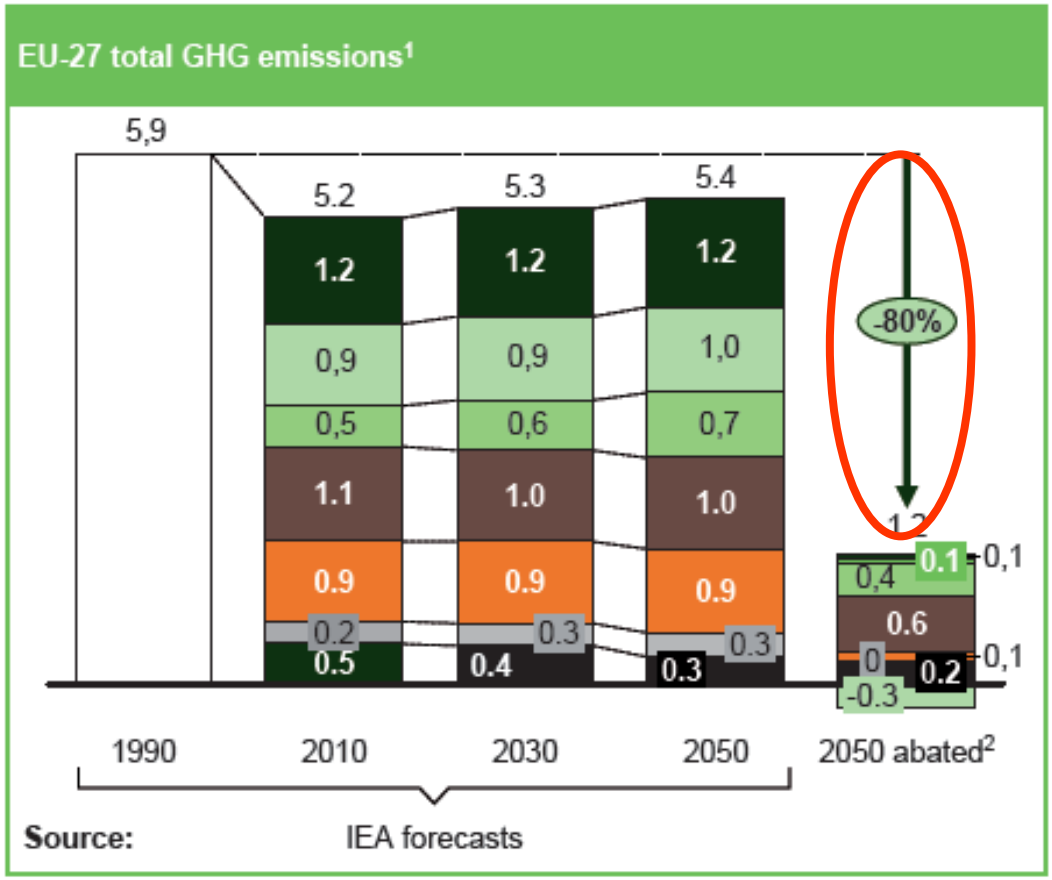
- Annual turnover ~ 20 Mio€ (in CSP and Solar Fuels related activities)
- More than 160 people (among Top 5 worldwide)
- Teams in Germany (Cologne, Stuttgart, Jülich) and Spain (Almería)
- Unique Infrastructure
- Active coordination of national and international networks in CSP and solar fuels

Track record

- Awarded as DLR Centre of Excellence 2006, 2009 and 2013
- Several license agreements with industry on DLR Patents (Receivers, measurement technology)
- 3 Spin-off companies founded in the last 7 years
- CSP Component Qualification Centre QUARZ™ is market reference

http://www.dlr.de/sf/en/desktopdefault.aspx

Goals: Development of EU GHG emissions [Gt CO_2e]



Sector	Total abatement
Power	95-100%
Road transport	95%
Air & sea transport	50%
Industry[3]	40%
Buildings	95%
Waste	100%
Agriculture	20%
Forestry	-0.25 Gt CO_2e

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

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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 – Germany **34%** 2015!
- **Goal of the EU until 2050:**
  - **80%** less CO_2 emissions than 1990
- **G7 Goals, Elmau, Germany**
  - **100%** Decarbonisation until 2100
  - ***100 bln $/year*** *for climate actions in developing countries, large share by industrial investment from 2020*

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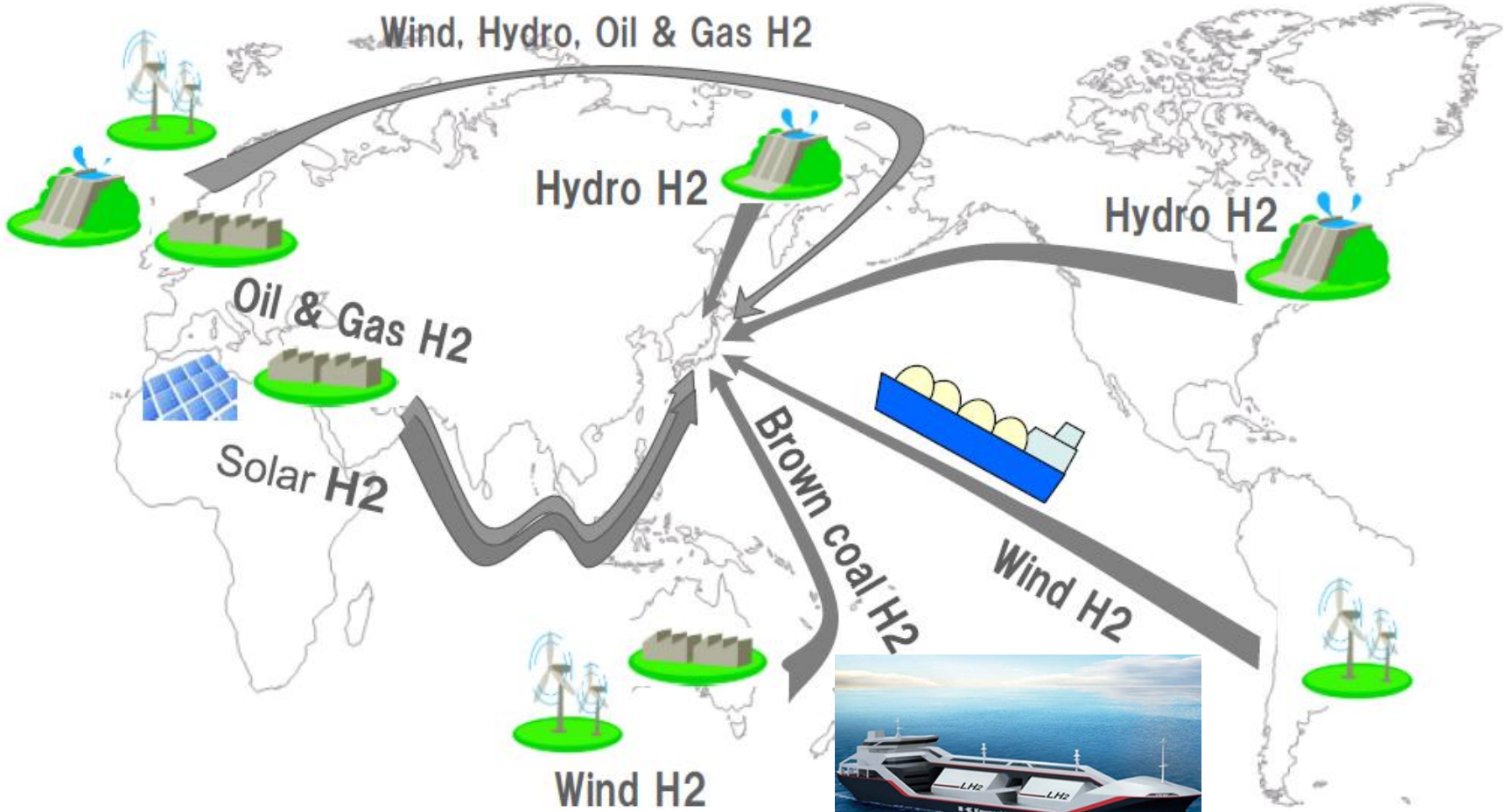
Industrial Driver: Kawasaki vision for the cryogenic liquid hydrogen market – team-up with Shell (March 15, 2016)



http://global.kawasaki.com/en/stories/hydrogen/

Example Funding Scheme: Private Public Partnership

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

http://www.fch.europa.eu/

- **Why a public-private partnership?** The **scale and scope of the research and market entry** agendas for developing and deploying FCH technologies goes beyond the capacity of single companies or public research institutions in terms of financial commitment, resources and capability.
- **Overcoming barriers to deployment**: A concentrated effort of all players is necessary, because the research needed to develop the technologies is often so complex that **no single company or public research institution can perform it alone**.
- **Pooling together resources:** EU Framework Programmes (FPs) , national programmes and the significant investment by industry and research institutions shall be better coordinated.
- In FP7 (7 years) € 0,94 billion were jointly contributed by the members (50% by industry and research partners).
- In H2020 (7 years) > € 1,33 billion, at least 50% investment from industrial and research partners.
- In reality industrial investment is already much higher, presently > € 0,3 billion/year

Example Funding Scheme: Private Public Partnership

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

http://www.fch.europa.eu/

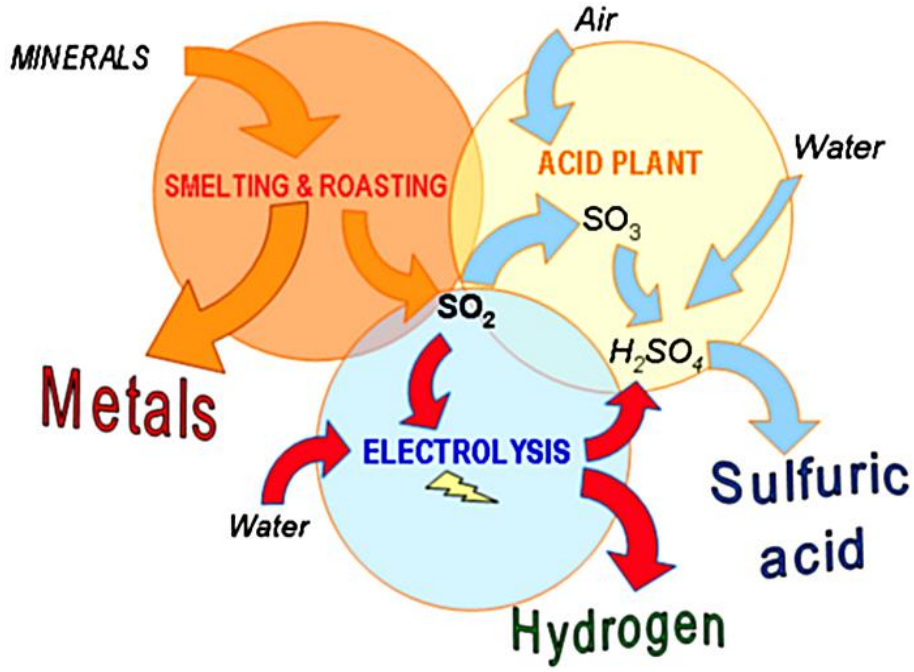
- **Market focus:** Without a consumer market, no technology can have a major impact. **Industry's leading role in defining priorities and timelines** will ensure that the agenda is focused on market introduction.
- **Tackling the market failure:** **Substantial investment is needed**, in R&D, transport, storage and refuelling infrastructures to make FCH competitive.
- The fossil resources-based energy economy is untenable for environmental reasons and due to the lack reserves in the medium to long term.
- No single company has the resources to make the transition alone, because **mass-market volumes are too distant, as is return on investment**.
- The FCH JU's model of sustained public-private partnership is expected to help **overcome this dilemma and bring the technologies to the point of market breakthrough**.

https://sol2hy2.eurocoord.com

SOL2HY2 – Solar To Hydrogen Hybrid Cycles

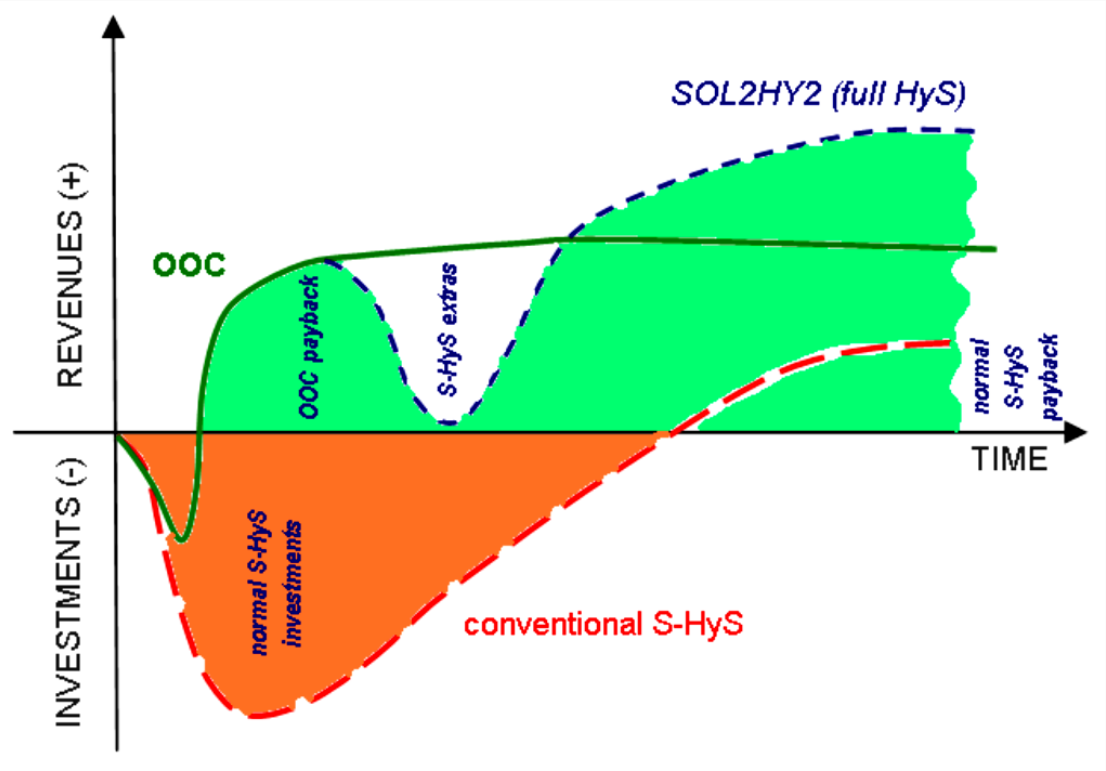
- FCH JU project on the solar driven Utilization of waste SO_2 from fossil sources for co-production of hydrogen and sulphuric acid
- Hybridization by usage of renewable energy for electrolysis
- Partners:
  - **Industry: EngineSoft (IT), Outotec (FI), Erbicol (CH), Oy Woikoski (FI)**
  - Research: Aalto University (FI), DLR (DE), ENEA (IT),

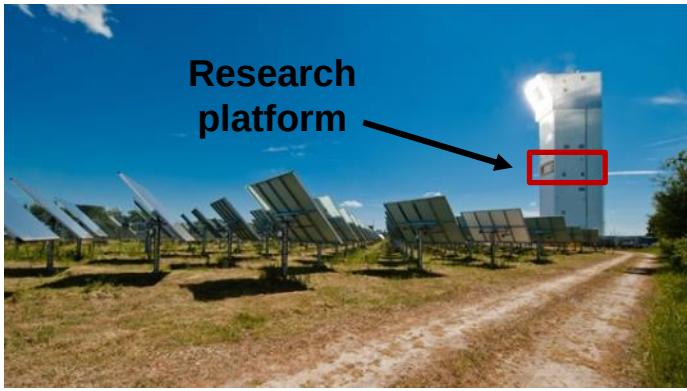
Outotec™ Open Cycle (OOC)



- Utilization of waste SO_2 from fossil sources
- Co-production of hydrogen and sulphuric acid
- Hybridization by renewable energy for electrolysis

Investments vs. revenues





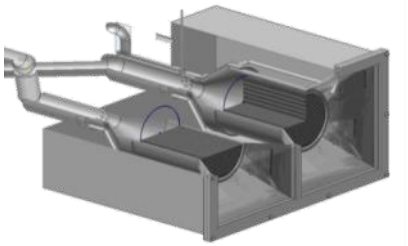
Demonstration on the Solar Tower Jülich
~100 kW total thermal power

- Reduction of initial investments
- Financing of HyS development by payback of OOC
- Increase of total revenues

HYDROSOL Development

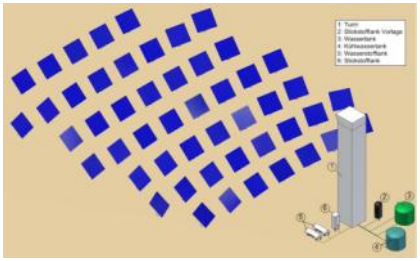
Long term development, substatial industrial contribution by Total (F), Johnson Matthey (UK), Helpe (GR), HyGear (NL), StobbeTech (DK)

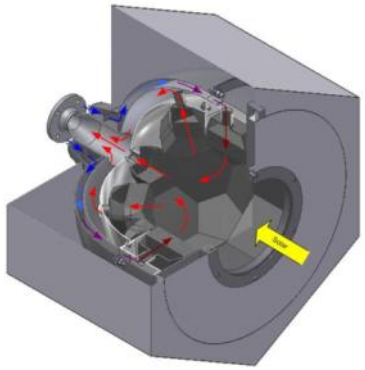
Hydrosol I
2002 – 2005
< 10 kW



Hydrosol II
2006 – 2009
100 kW

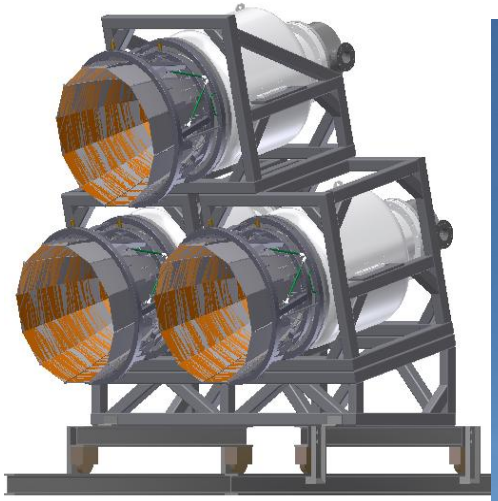
Hydrosol 3D
2010 – 2012
1 MW

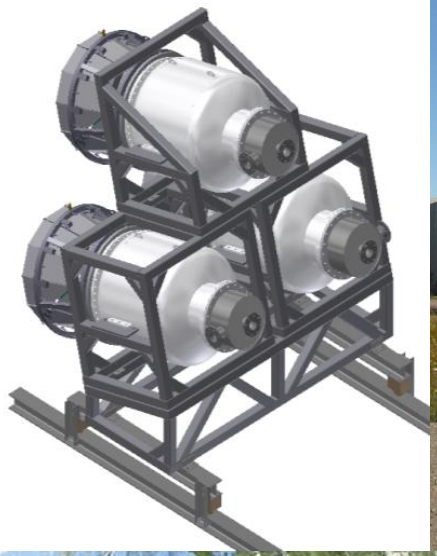




Hydrosol Plant - Design for CRS tower PSA, Spain

- European FCH-JU project
- Partner:
  - Industry: HELPE (GR), HYGEAR (NL)
  - Research: APTL (GR), CIEMAT (ES), DLR (DE)
- 3 * 750 kW_{th} demonstration of thermochemical water splitting
- Location: Plataforma Solar de Almería, Spain, 2016
- Reactor set-up on the CRS tower
- Storage tanks and PSA on the ground



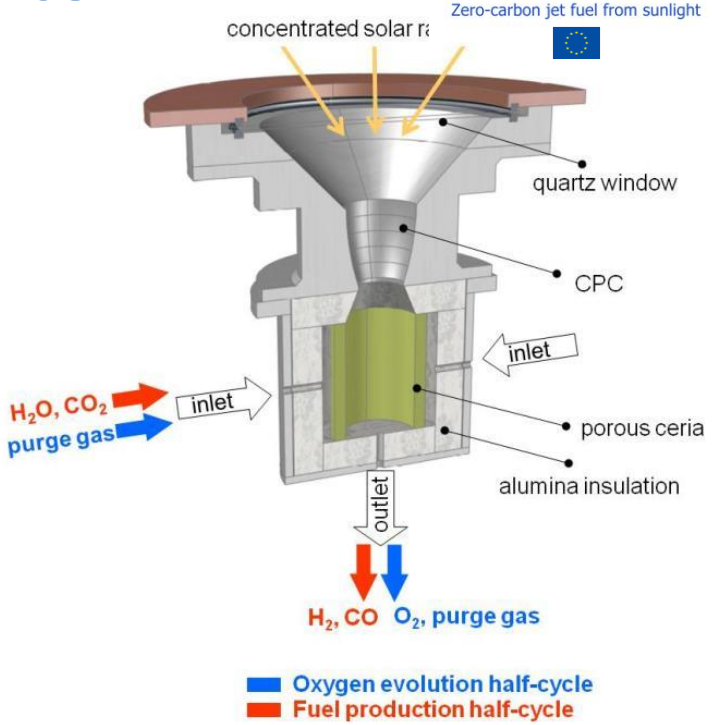


H_2O/CO_2-Splitting Thermochemical Cycles

SOLAR-JET
Zero-carbon jet fuel from sunlight

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, CO_2, and water.
- SOLAR-JET optimized a two-step solar thermochemical cycle based on ceria redox reactions to produce synthesis gas (syngas) from CO_2 and water, achieving higher solar-to-fuel energy conversion efficiency over current bio and solar fuel processes.
- **First jet fuel produced in the Fischer-Tropsch (FT) unit of Shell from solar-produced syngas!**



Int. J. Heat & Fluid Flow 29, 315-326, 2008.
Materials 5, 192-209, 2012.

Partners: Bauhaus Luftfahrt (D), ETH (CH), DLR (D), SHELL (NL), ARTTIC (F)
Funding:EC

http://www.solar-jet.aero/

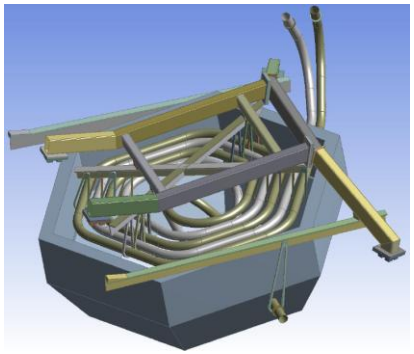
Near-term: Solar Production of Syngas (H_2 and CO)

Solar pilot plants demonstrated in the power range of 200-600 kW_{th}

Solar steam reforming of natural gas / methane

SOLGAS (200 + 600 kW_{th})

CSIRO, Australia



SOLREF (400 kW_{th})
Johnson Matthey, UK
DLR, Germany

Solar steam gasification of carbonaceous feedstock

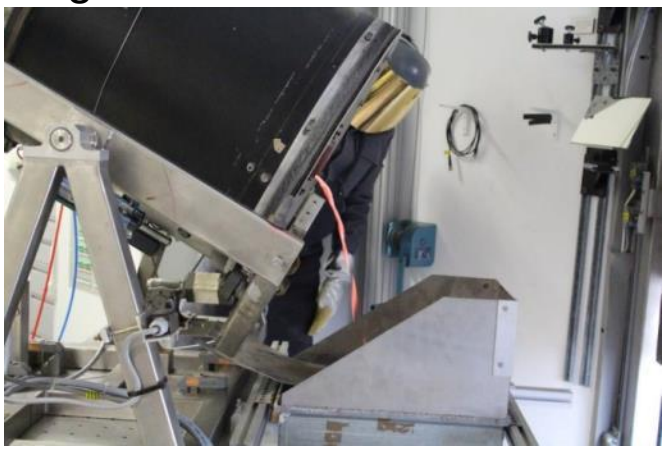
SYNPET (500 kW_{th})
PDVESA, Venezuela
CIEMAT, Spain

SOLSYN (250 KW_{th})
HOLCIM, Switzerland
PSI, Switzerland

SOLAM

Solar Aluminium Melting in a Directly Heated Rotary Kiln

- **Aim**
- Demonstration of solar aluminium recycling in a 20 kW rotary kiln
- Develop process concept for a commercial pilot plant
- Driver: Reduce the electricity demand from the grid



South African partners

Industry:

Eskom – South African National Electricity Generator and Distributor

Research:

CSIR – Council for Scientific and Industrial Research

NFTN – National Foundry Technology Network

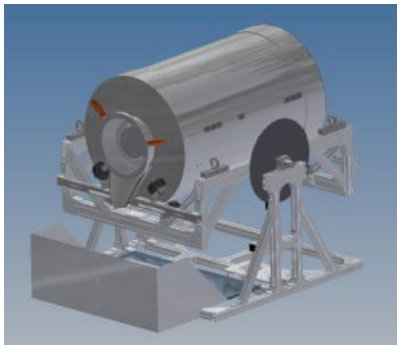
Government:

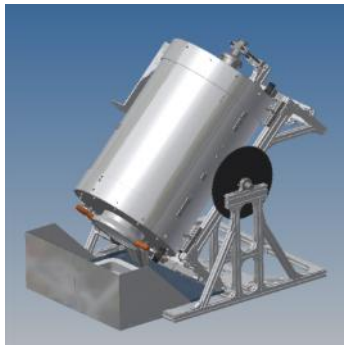
DST – Department of Science and Technology

German partners

Industry: Aixprocess

Research: DLR





Thank you very much for your attention!