

# Decentralized hydrogen production from diesel and biodiesel

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für Luft- und Raumfahrt  
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**NEMESIS2+ (New Method for Superior Integrated Hydrogen Generation System)** received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under Grant Agreement No 278138.

# H<sub>2</sub> production: Which options are available?

## A) Conventional H<sub>2</sub> production

(mainly steam reforming of natural gas)

Worldwide: ~600\*10<sup>9</sup> m<sup>3</sup><sub>N</sub> H<sub>2</sub>/year

70 % chemical industry (ammonia, methanol)

30 % fuel and heating purposes



### Linde-steam reformer

Location: Texas/USA

Feed: natural gas

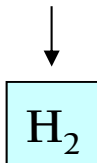
Capacity: 110,000 m<sup>3</sup><sub>N</sub>/h

Purity: 99.99 %

## B) Biomass



Biological / Thermochemical conversion

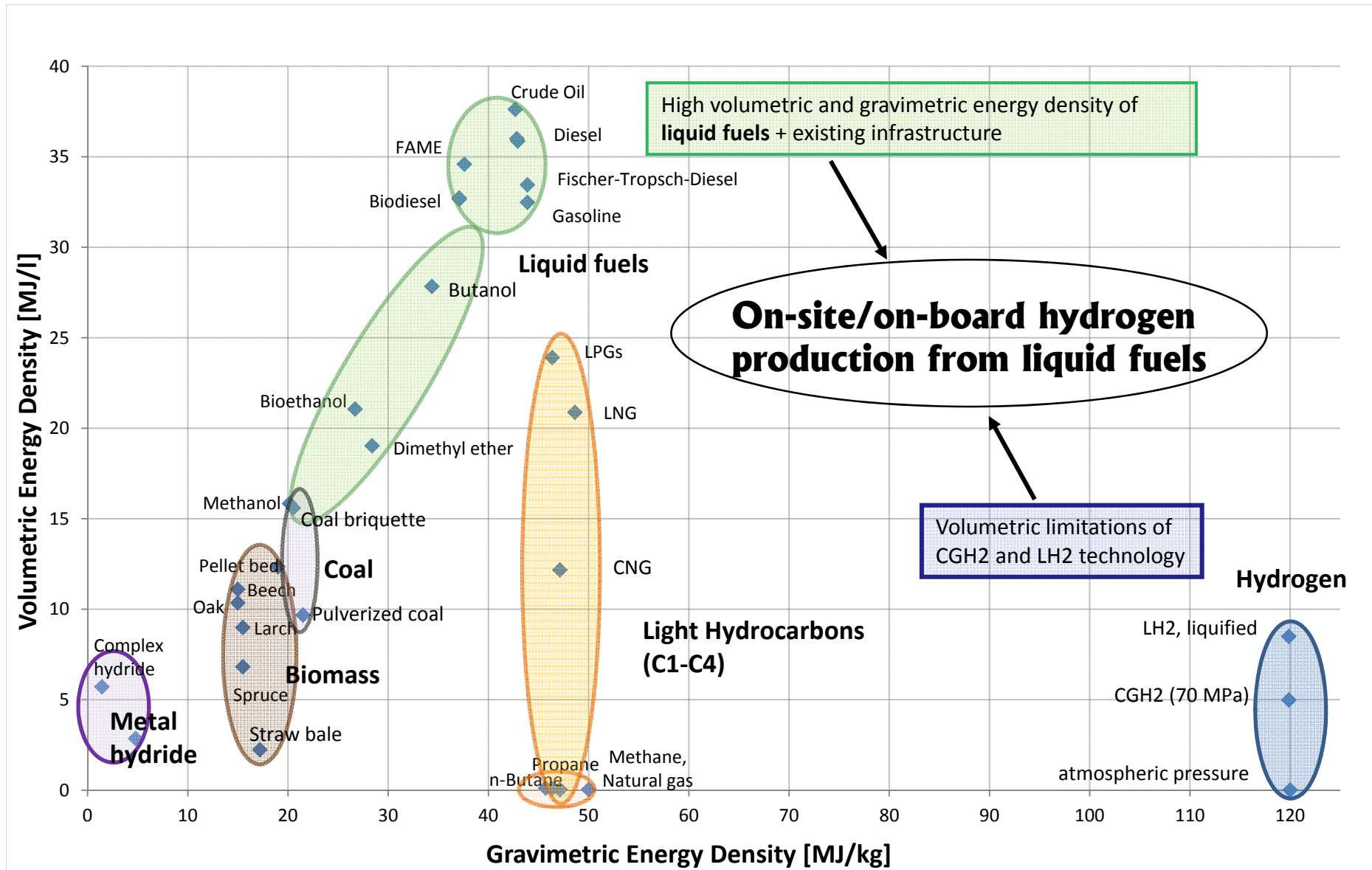


## C) Renewable electricity



Water  
Electrolysis →

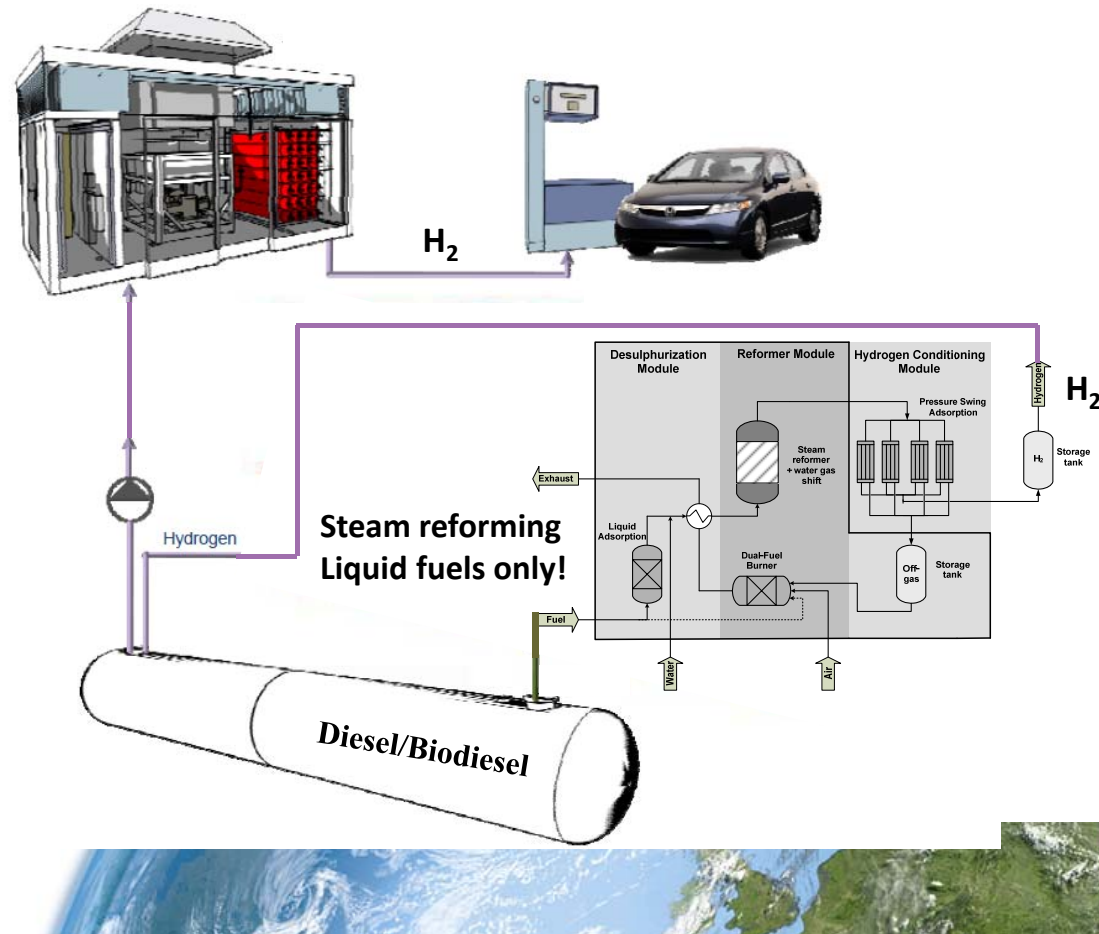






## NEMESIS2+: Project Objectives

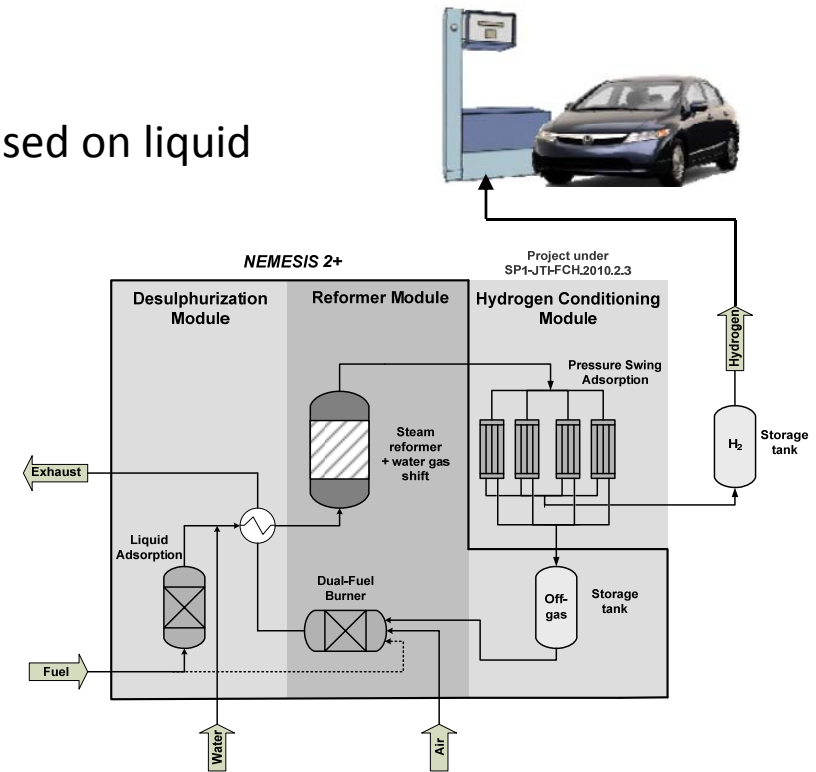
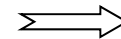
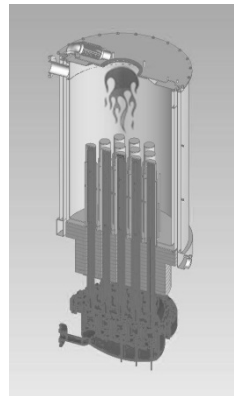
On-site hydrogen production at refuelling stations from diesel and biodiesel





## NEMESIS2+: Project Targets

- Development of a pre-commercial hydrogen generator (50 Nm<sup>3</sup>/h)
- System efficiency > 65 % (>70 %), stable long-term operation testing for at least 1000 hours, H<sub>2</sub>-purity 5.0
- Total hydrogen production costs < 4 € per kg
- Show feasibility of desulphurization concept based on liquid phase adsorption
- Development of improved reformer and WGS catalyst formulations





# NEMESIS2+: Scientific Approach

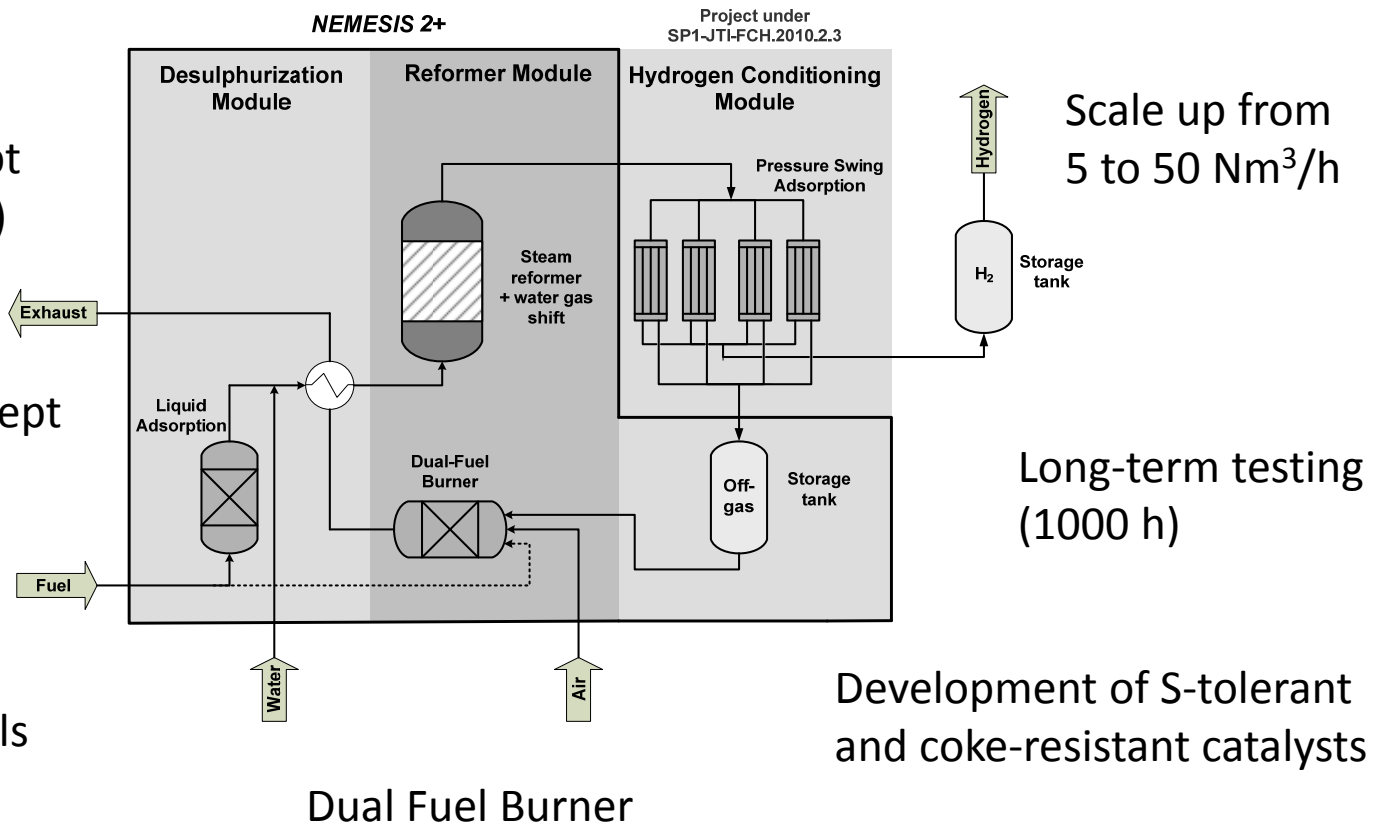
Elaborated heat management (Pinch-Analysis)

Pressurized steam reforming  
(13 bara)

„One-reformer“-concept  
(without pre-reforming)

Innovative desulph. concept  
(liquid phase adsorption)

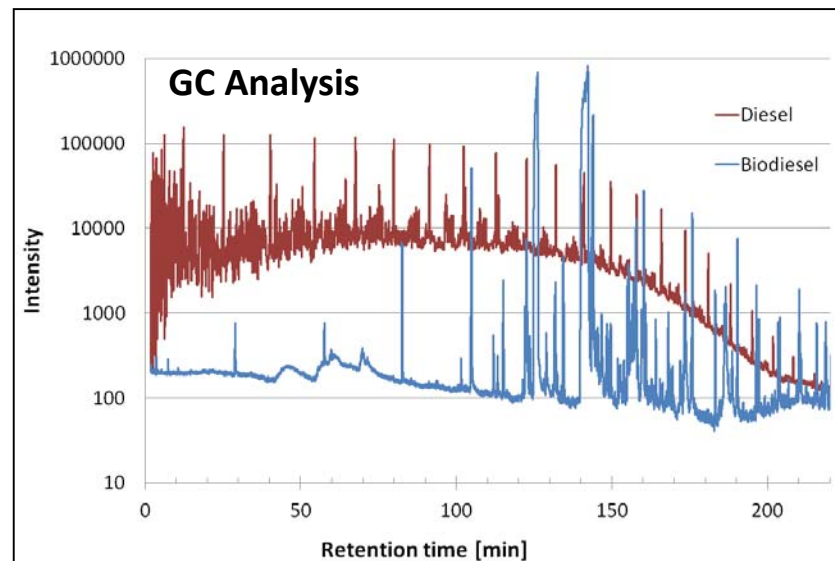
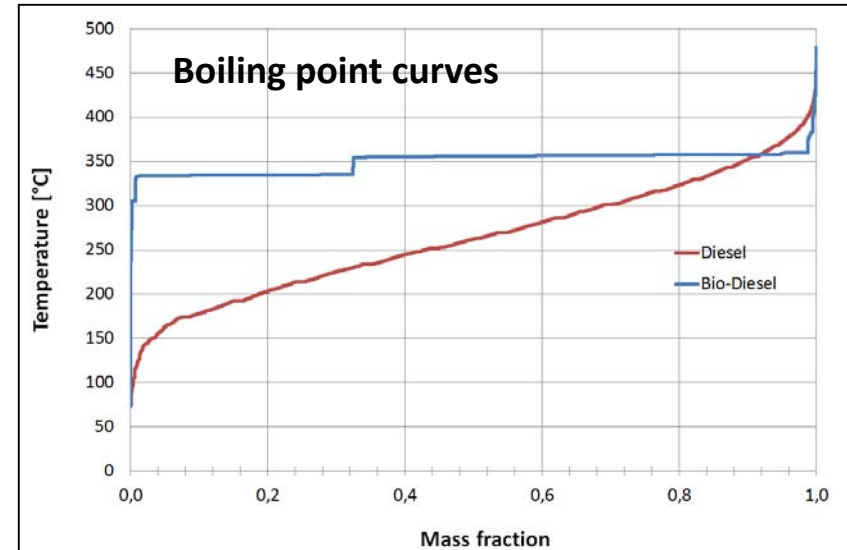
Focus on liquid fuels  
(diesel, biodiesel)



# Fuel characterization

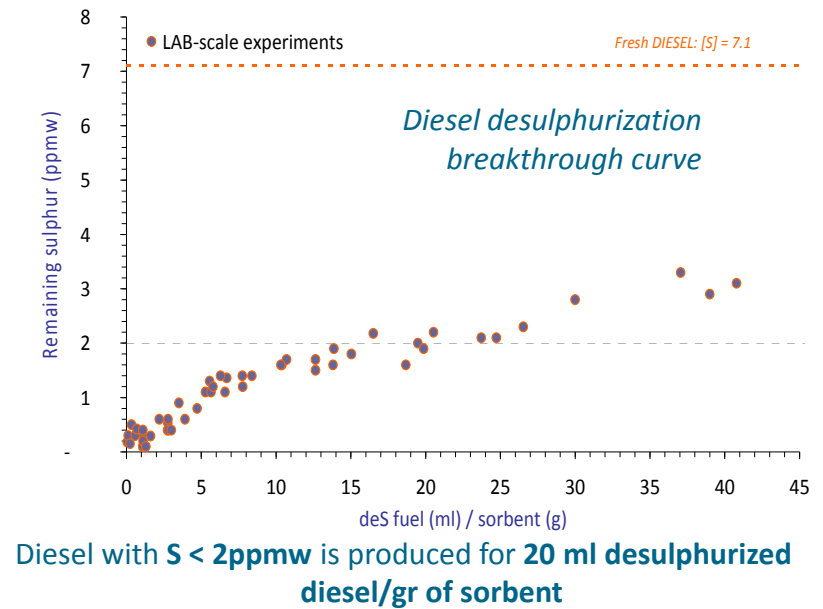
- Fossil diesel (Shell)
- Biodiesel (Abengoa Bioenergy)

	Biodiesel	Diesel
Chemical formula	$C_{18.3}H_{34.8}O_2$	$C_{13.3}H_{24.7}$
S content (ppmw)	1.5	7.1
LHV (kJ/kg)	37,790	42,930



# Liquid Desulphurization

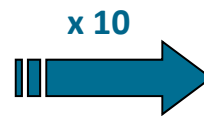
...achieved in an **adsorption bed of activated carbon** (lab scale) with **low particle size** and **high surface area**



Process scaling up:



Lab-scale deS reactor



Pilot-scale deS unit

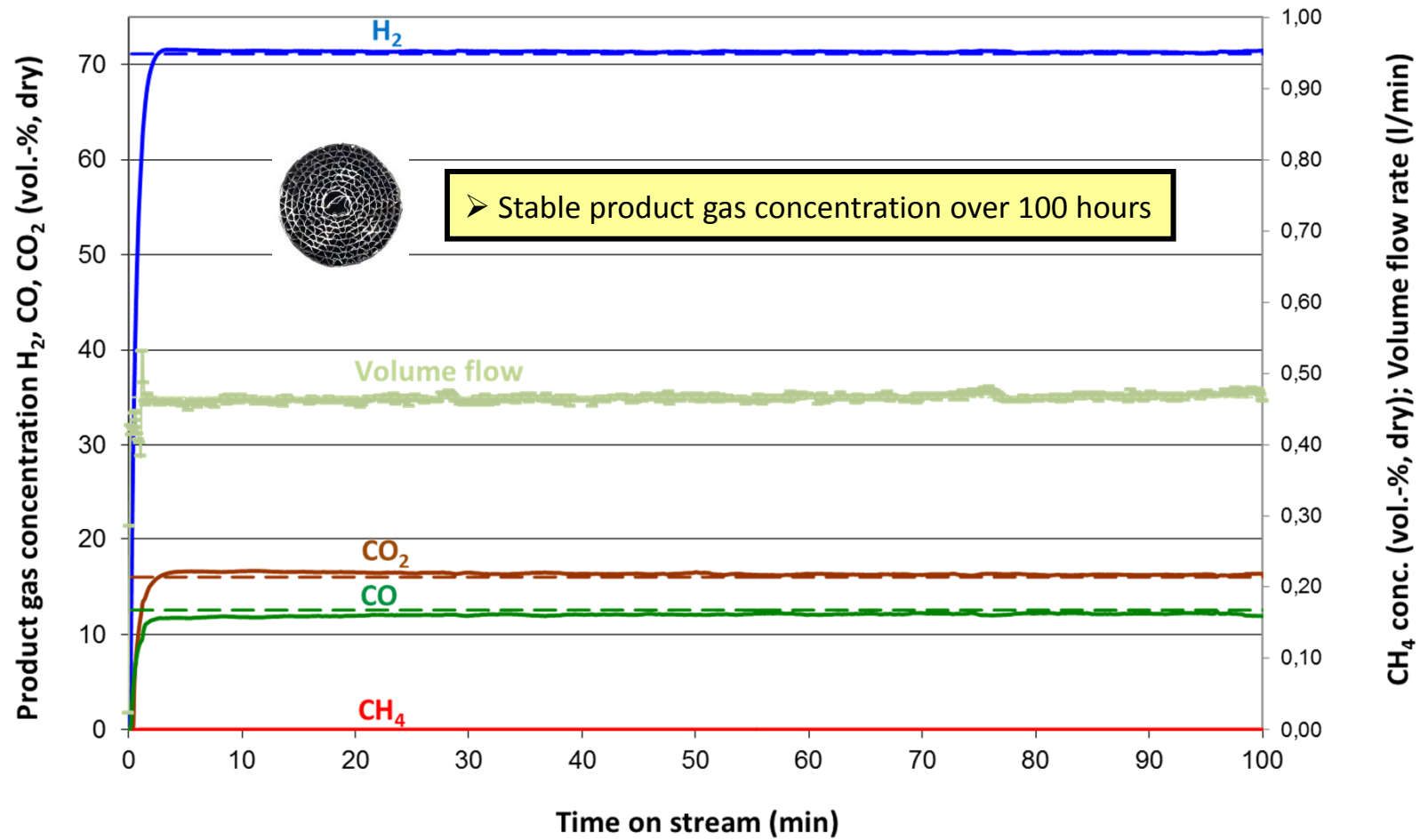
Production of 1.5-2 l/h of desulphurized fuel





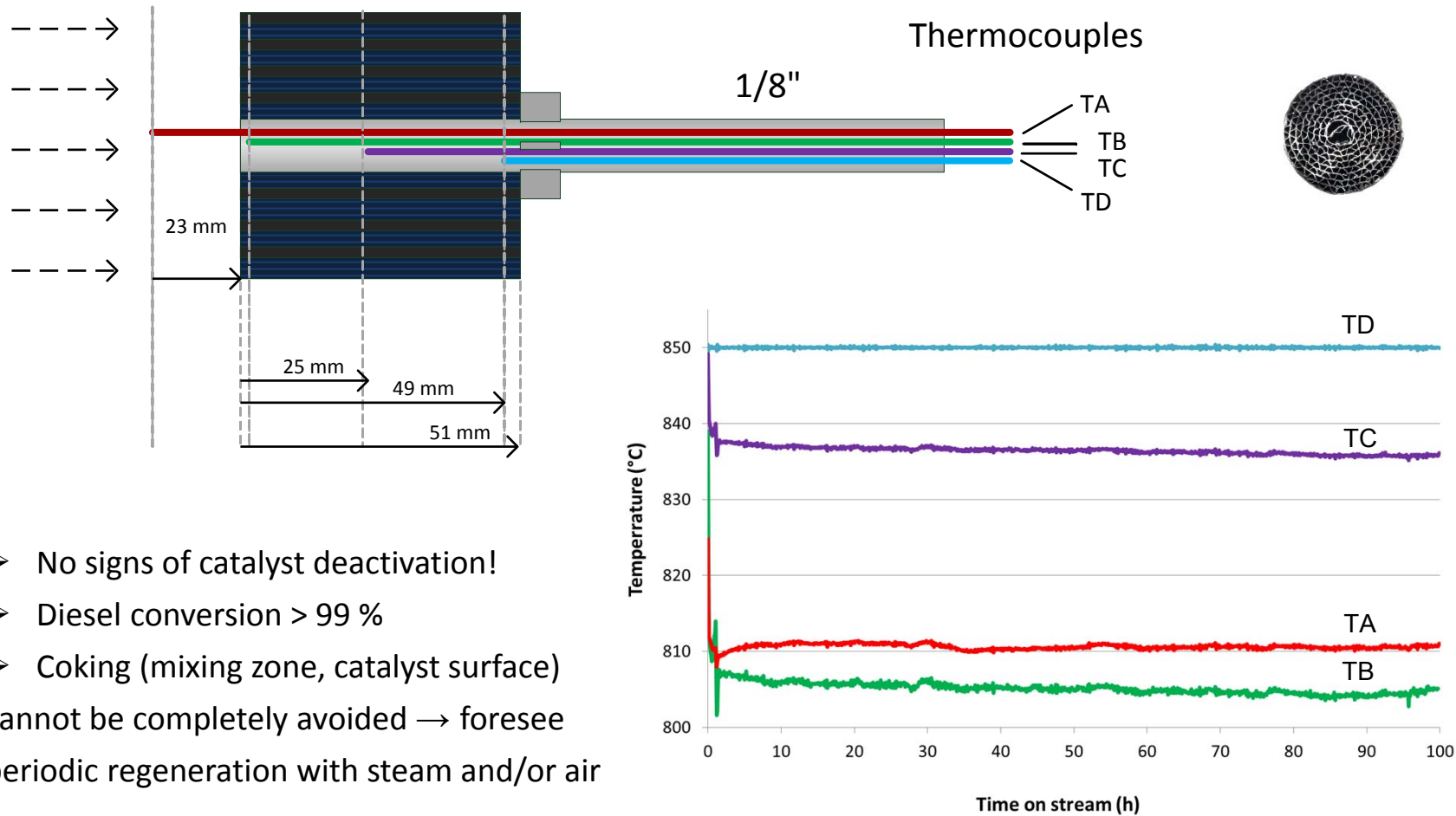
# Lab scale steam reforming of desulphurized B7 Diesel

( $T=850\text{ }^{\circ}\text{C}$ ,  $p=5\text{ bar}$ ,  $S/C=5$ )



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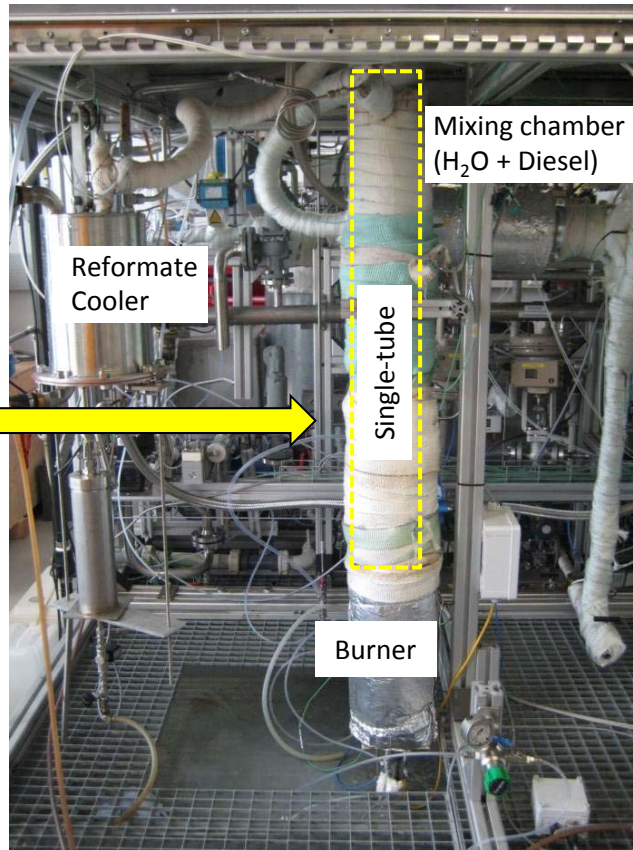
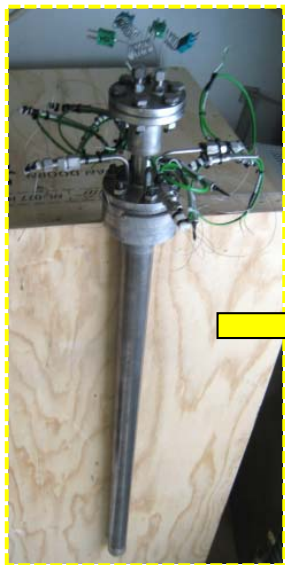
- No signs of catalyst deactivation!
- Diesel conversion > 99 %
- Coking (mixing zone, catalyst surface) cannot be completely avoided → foresee periodic regeneration with steam and/or air



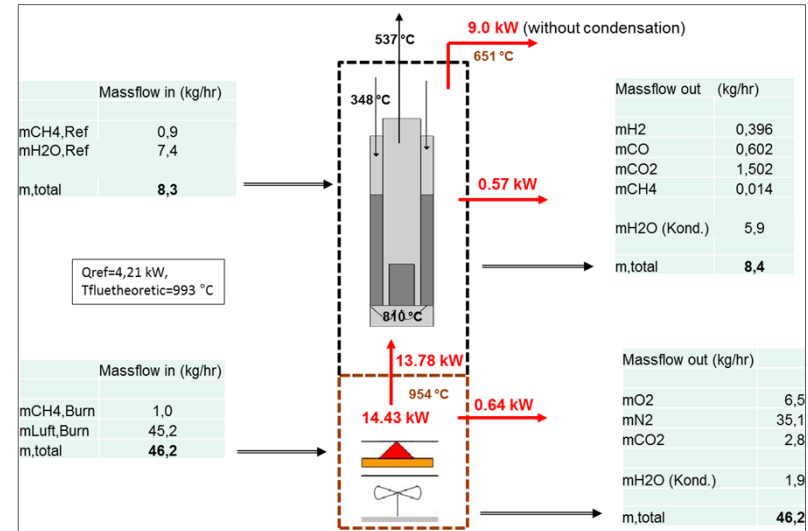
# Single-tube testing

Single tube integrated in LIFT test facility

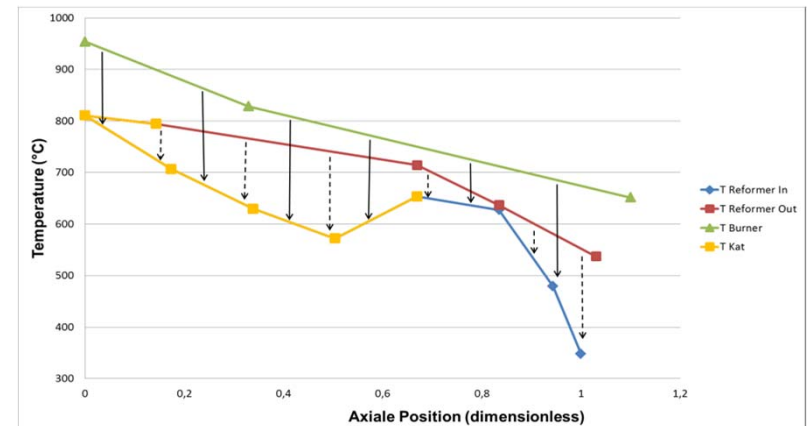
Single tube



## Mass and energy balance



## Axial temperature profile



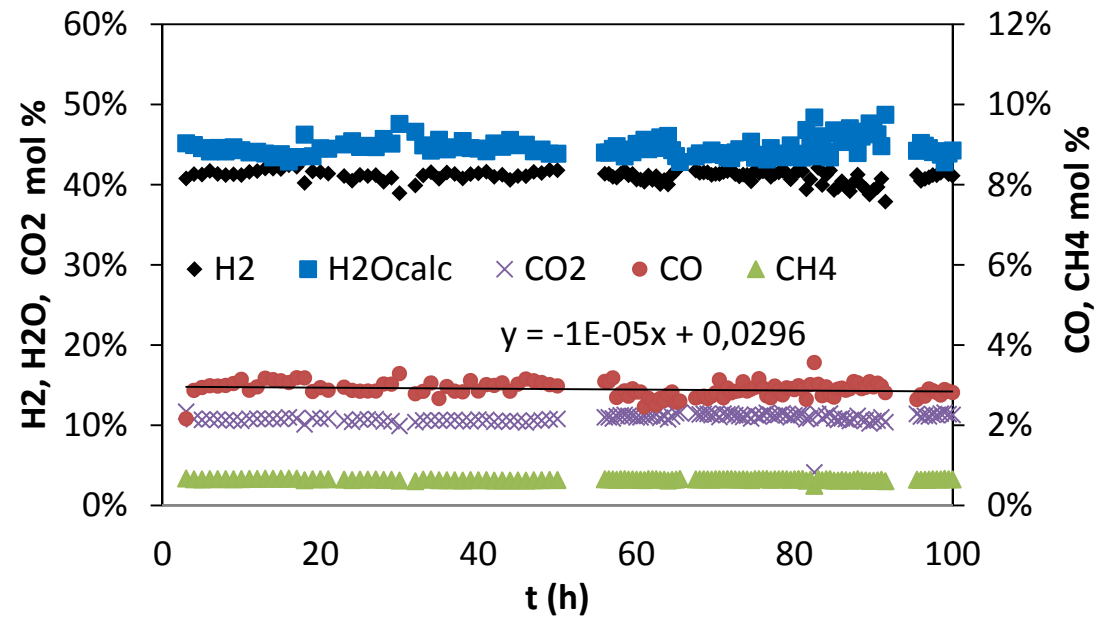
## Water gas shift durability testing (Lab scale)

100 hour continuous tests carried out with addition of 1 ppm H<sub>2</sub>S and 600 ppm of hydrocarbons (C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub>) → No degradation observed

R. C. Neto et al., Int. J. Hydrogen Energy 39 (2014) 5242-5247

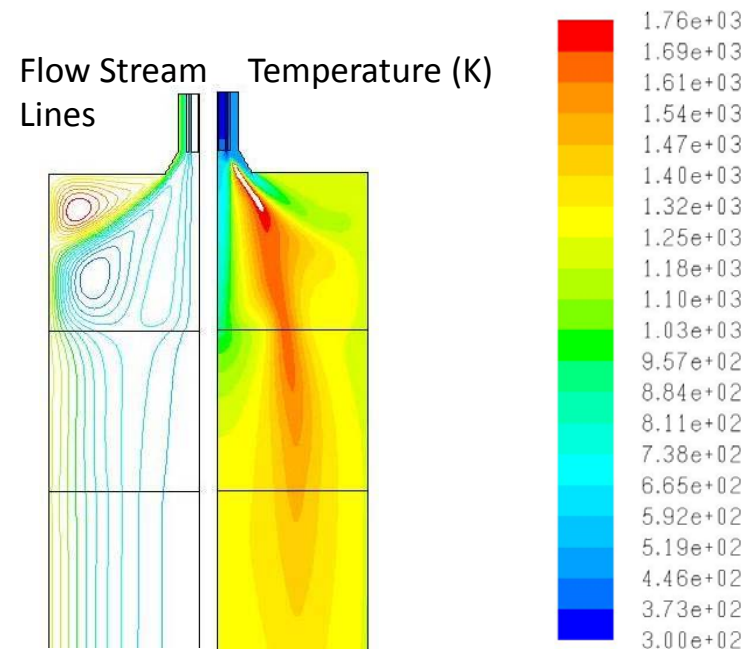
Assessment of operating conditions and reactor design:

- Steam to carbon ratio
- Temperature
- Gas Hour Space Velocity
- Dimension of reactor



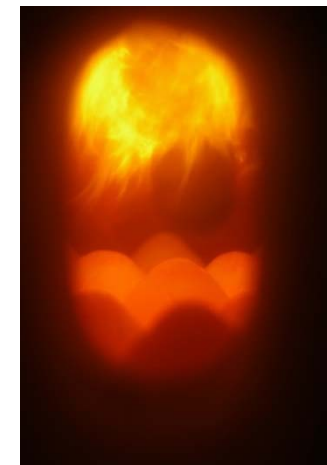
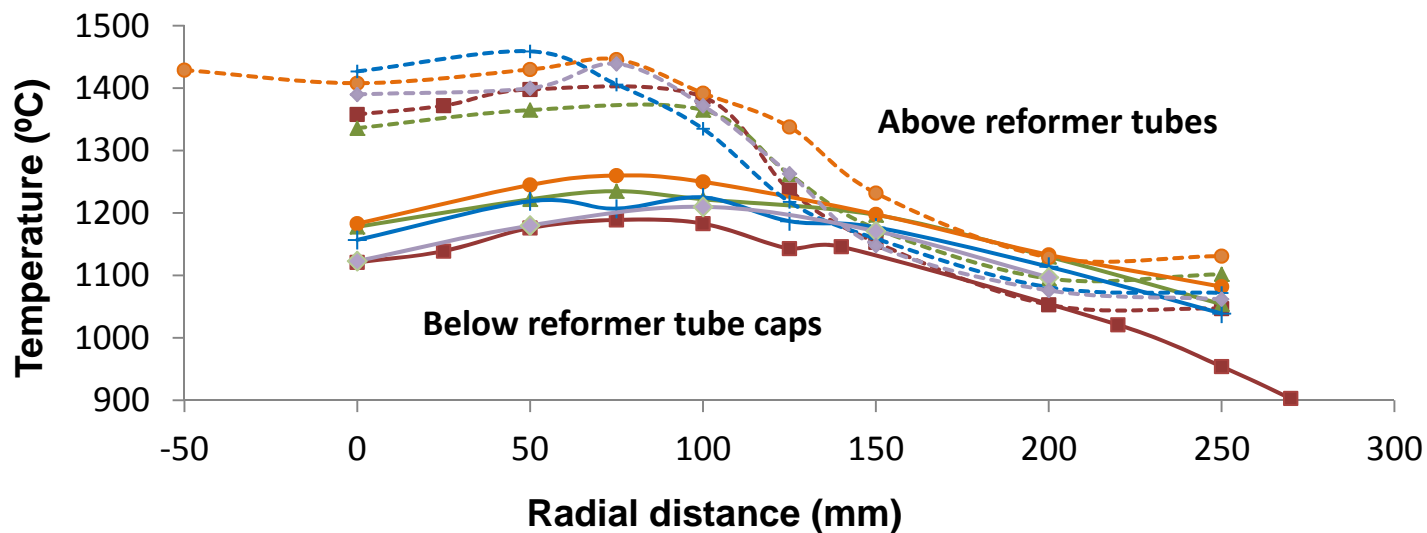
## Dual Fuel Burner Development: Simulation

- Challenges to use three different fuels alone or combined in a single burner: Biodiesel, Natural Gas and Off-Gas.
- Existing furnace with small volume and requirements to produce a short flame and distribute the gases uniformly through the multiple reformer tubes.
- Use of **CFD based numerical models** to evaluate effects of swirl number, air and fuel velocity on flame shape.
- Model also used to transpose the results from test work to the final furnace dimensions.



## Dual Fuel Burner Development: Experiments

- Tests on atomization and combustion were carried out to show relative advantages of atomizers:
  - Pressure atomizers: fine atomization but very sensible to flow rate
  - Air assisted atomizers: acceptable atomization but air mass flow restrictions
- **Final burner designed with high swirl and air assisted atomizer.**



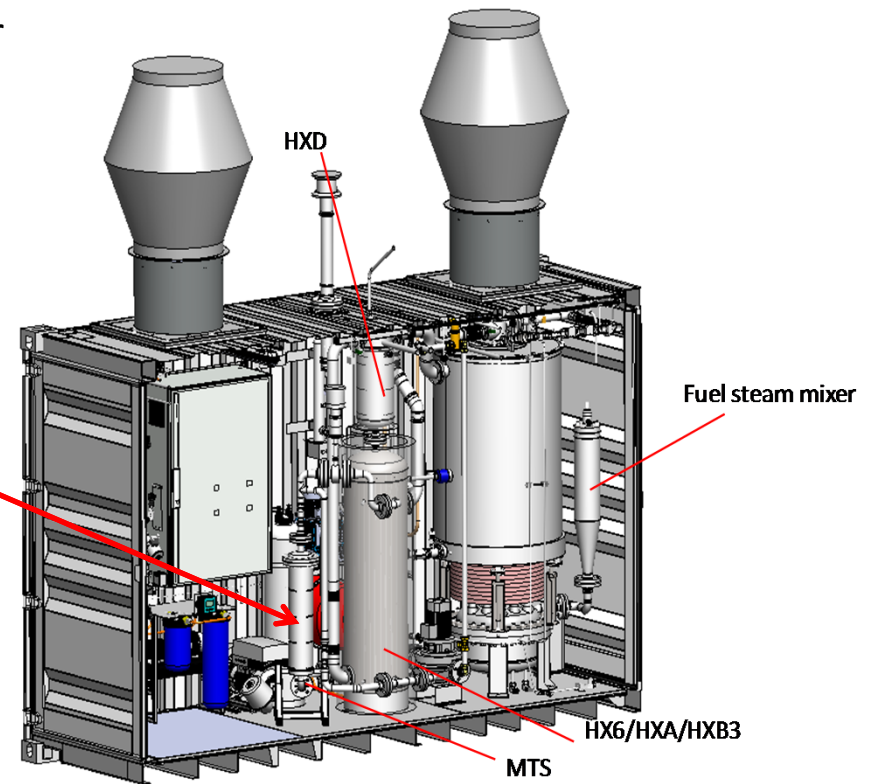
## Design Study NEMESIS2+ Hydrogen Generator

- System has been designed based on HyGear HGS-L system
- Additional hardware for water-gas-shift reactor and heat exchangers designed and built:
  - Control temperature of 300-350 °C in shift reactor
  - Increase steam temp. for biodiesel reforming
  - Vaporize and dose (bio)diesel feed



Newly designed water gas shift reactor

- Next steps: Build up system and test with
  - Biodiesel
  - Fossil diesel
  - GtL Diesel





# Thank you for your attention!

[www.nemesis-project.eu](http://www.nemesis-project.eu)

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