Gasification 2010 – Feedstock, Pretreatment and Bed Material
Gothenburg, Sweden, October 28th 2010

AER* - Technology and SNG from AER - Gas

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ZSW – Centre for Solar Energy and Hydrogen Research, Stuttgart, Germany

*AER: Absorption Enhanced Reforming

Centre for Solar Energy and Hydrogen Research (ZSW): New Energy Technologies

- Applied Research & Development
- Close Cooperation with Industry and Universities
- 22 Million € Turnover, 170 Employees (Full-time Staff)

- Photovoltaic – Thin Film Technologies (CIS-PV) & Application Systems
- Renewable Fuels and Processes
- Fuel Cells – Technology, Systems, Test Centre
- Batteries – Materials, Systems, Qualification
- Systems Analysis and Policy Consulting

Stuttgart

Widderstall

Ulm

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AER Principle

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Primary Objectives of "Biomass for Energy" and "AER-Process"

- Wide biomass resource basis (residues)
- Utilization of biomass for **energy storage** in the form of SNG, generation of transport fuel and electricity
- High overall energy efficiency
- Closed material cycles (ash → fertilizer)
- Decentralized biomass utilization

AER-Lighthouse-Project: Intention

- Link of **ecology** (biosphere reserve "Swabian Alb" → utilisation of biomass residues) and **technology** (thermo-chemical conversion to a H_2-rich syngas (> 60 Vol.%), adapted for downstream SNG synthesis)
- Link of **investor concept** and **R&D-platform "BtG" (Biomass-to-Gas)**

Principle of AER (Absorption Enhanced Reforming)

Steam reforming of biomass decomposition products

$$CH_xO_y + (1-y)\,H_2O \rightarrow CO + (0.5x + 1 - y)\,H_2 \qquad \Delta H_R >> 0$$

CO shift reaction

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad \Delta H_R < 0$$

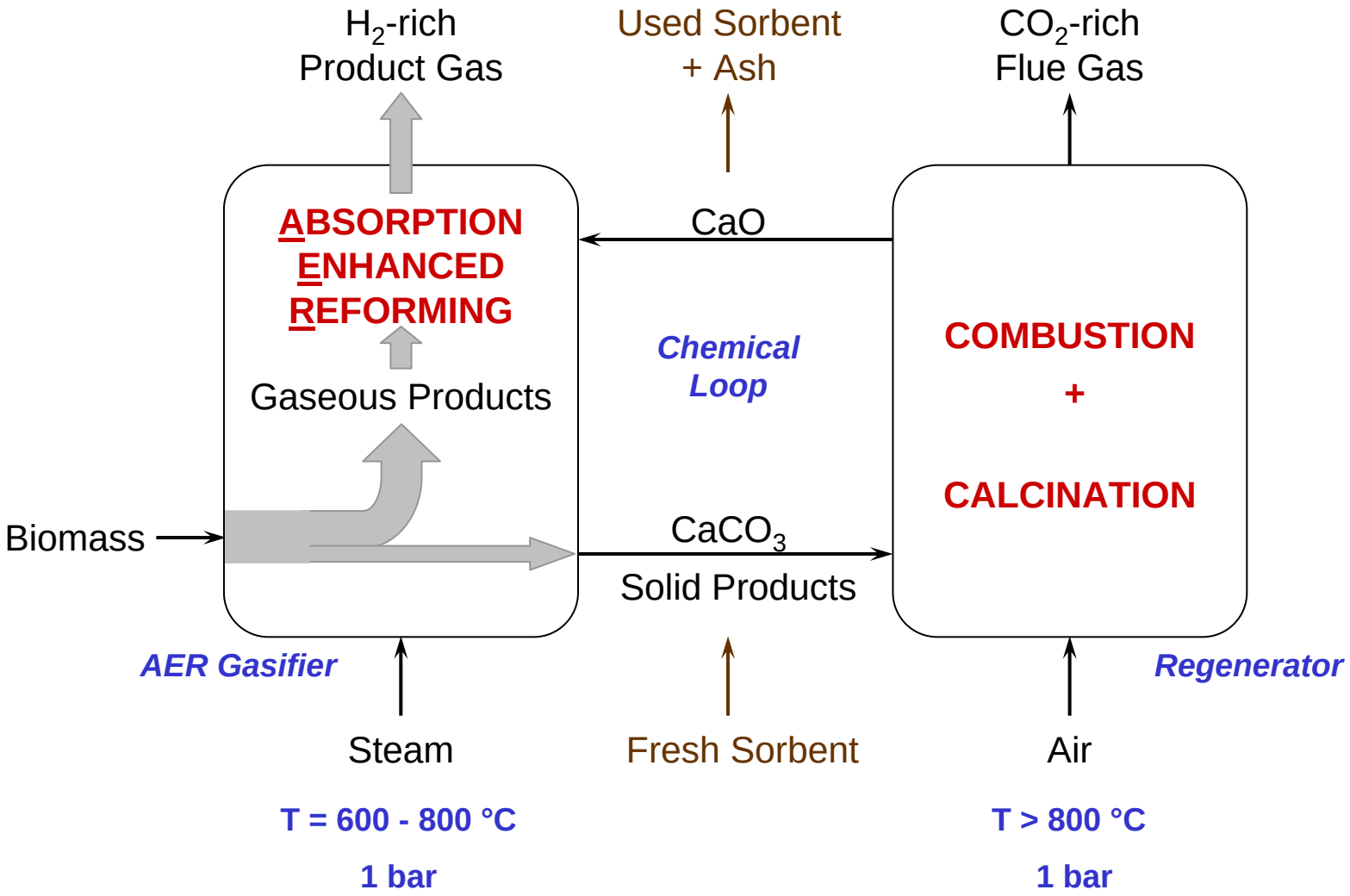
Combined with a HT-CO_2 absorption

$$CO_2 + CaO \rightarrow CaCO_3 \qquad \Delta H_R << 0$$

Overall (600 – 800 °C, 1 bar)

$$CH_xO_y + (2 - y)\,H_2O + CaO \rightarrow CaCO_3 + (0.5\,x + 2 - y)\,H_2 \qquad \Delta H_R \approx 0$$

Principle of AER: Dual Fluidised Bed (DFB) Gasifier with *in situ* CO_2 Removal



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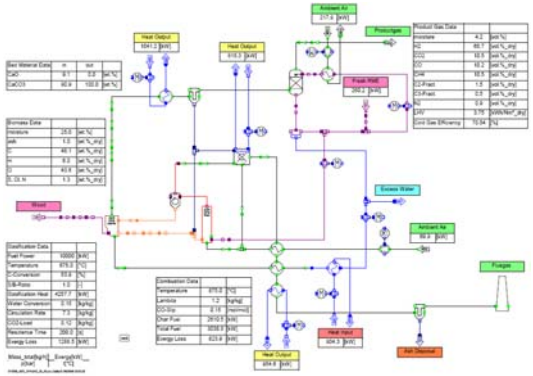
Thermo-chemical Biomass Conversion via AER: Fluidised Bed Material Development (Core of Process)

Implementation with partners from energy sector



Delivery of 14 tons of FB material to biomass power plant in Güssing

From material development to technical test in 8 MW power plant in Güssing

Material development

Process development

System techniques

Simulation

Process realisation

Plant layout

Requirements on CO_2 Sorbent Fluidised Bed (FB) Material

- Sufficient CO_2 absorption capacity (g_{CO2} / g_{Oxide})
- High reaction rate for CO_2 absorption & release at specified operation conditions
- Chemical and thermal stability
- Mechanical stability
- Catalytic effects
- Availability at low cost; non-toxic

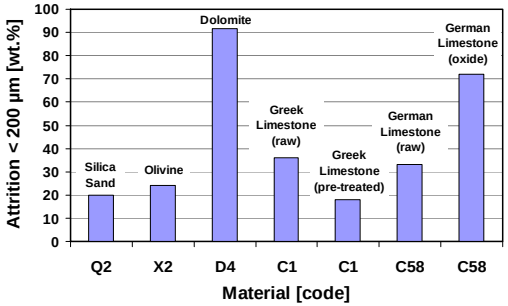
➡ **Recommendation of sorbents for FB gasification:**

- TGA screening of natural materials: Selection of suitable FB materials
- Mechanical stability under CO_2 cycling conditions in FB
- Screening of catalytic activity

REG Facilities for FB Material Testing

Milling test:

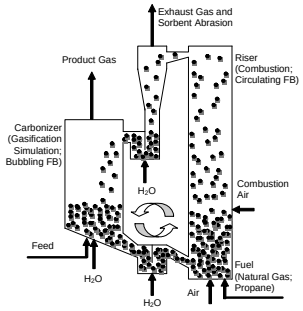
$$\text{Attrition} = \frac{m_{\text{material}}(d < 200\ \mu m)}{m_{\text{material, total}}}$$



Thermogravimetric analysis:

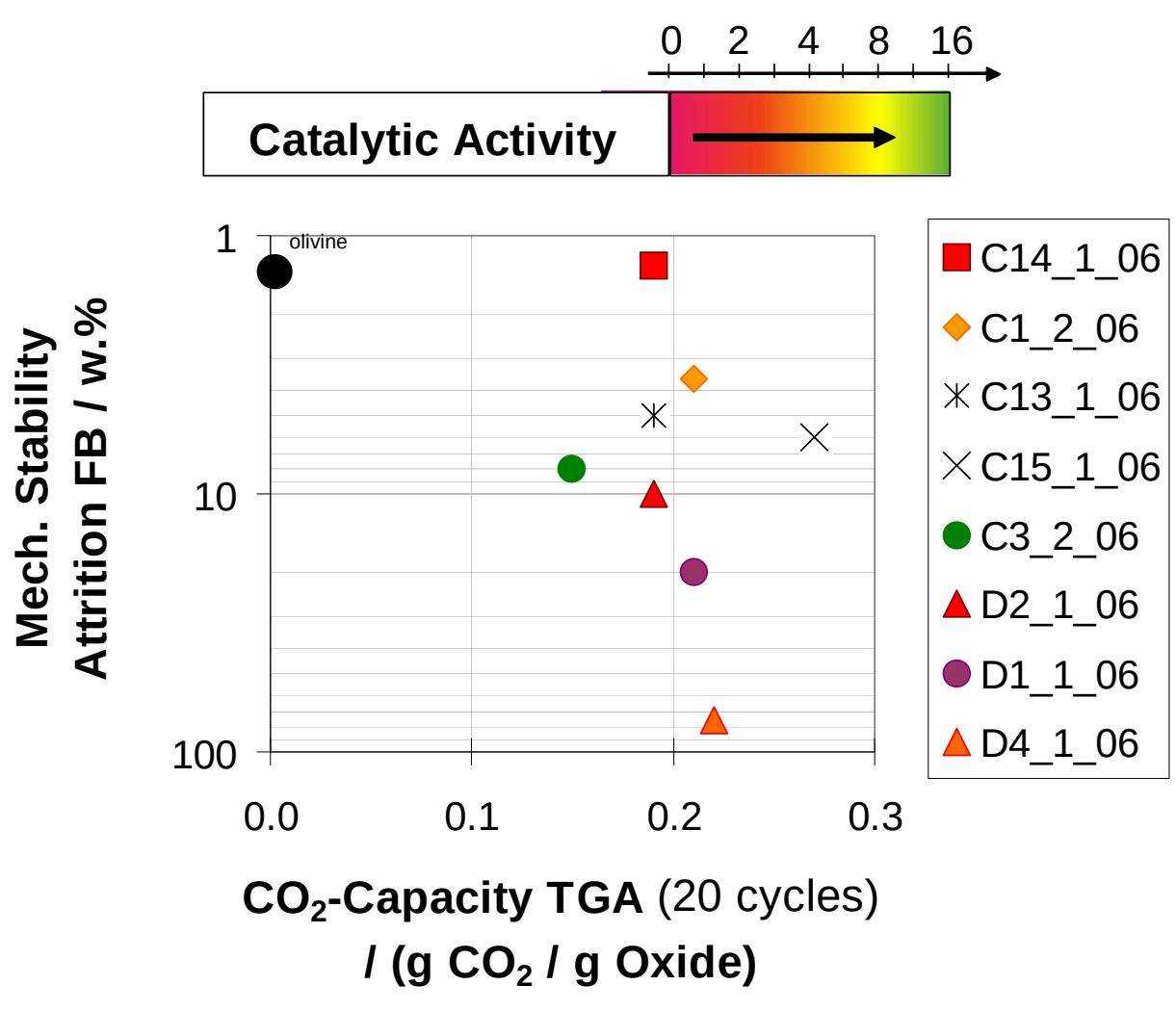
- Atmospheric TGA
- High pressure TGA + MS

DFB reactor / Pilot plant:

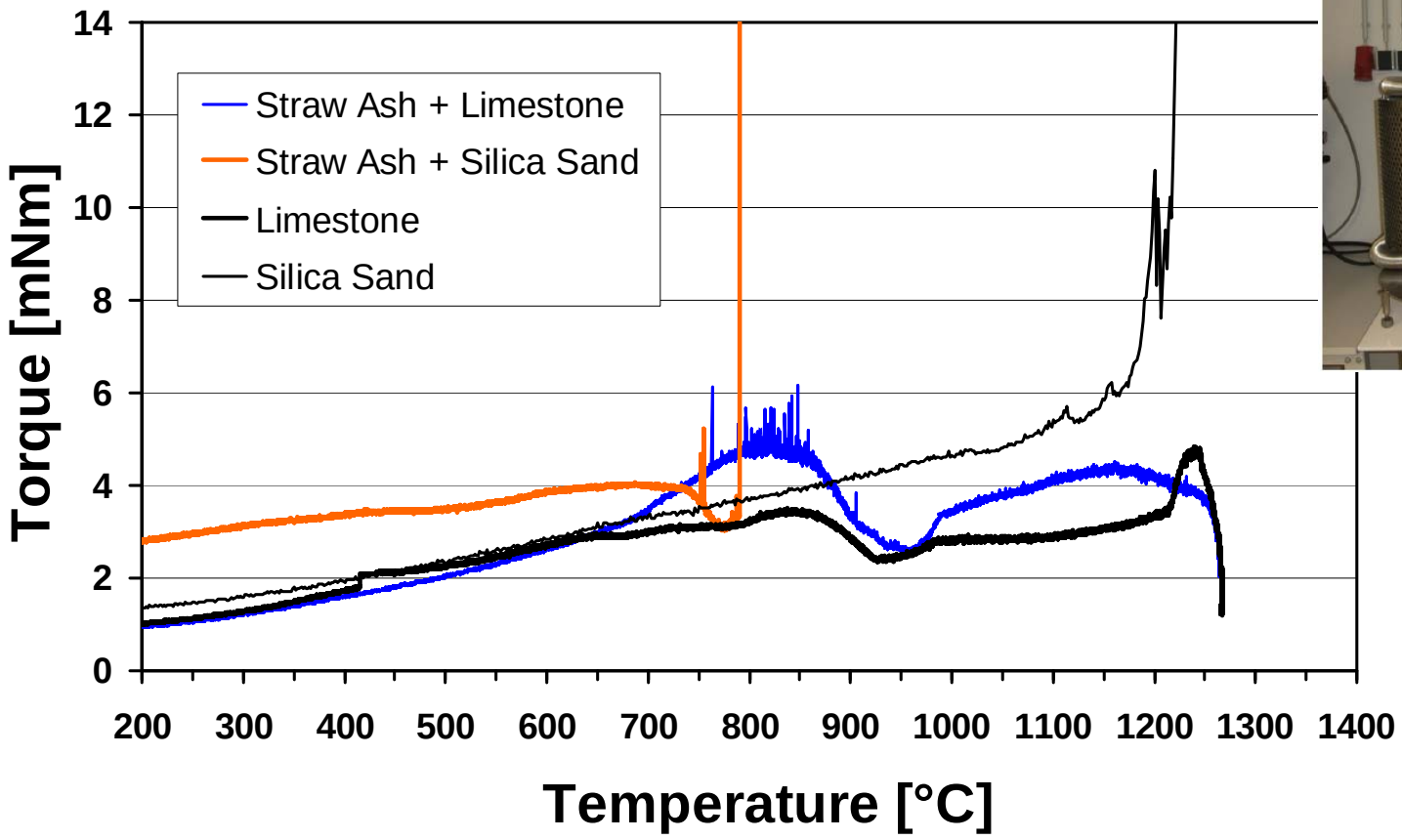


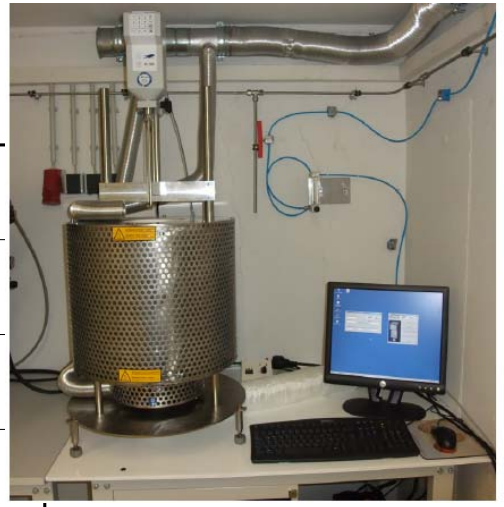
Rotational viscosimeter:

Characterisation of the Sorbents for FB Operation: Mechanical Stability / CO_2 Capacity / Catalytic Activity

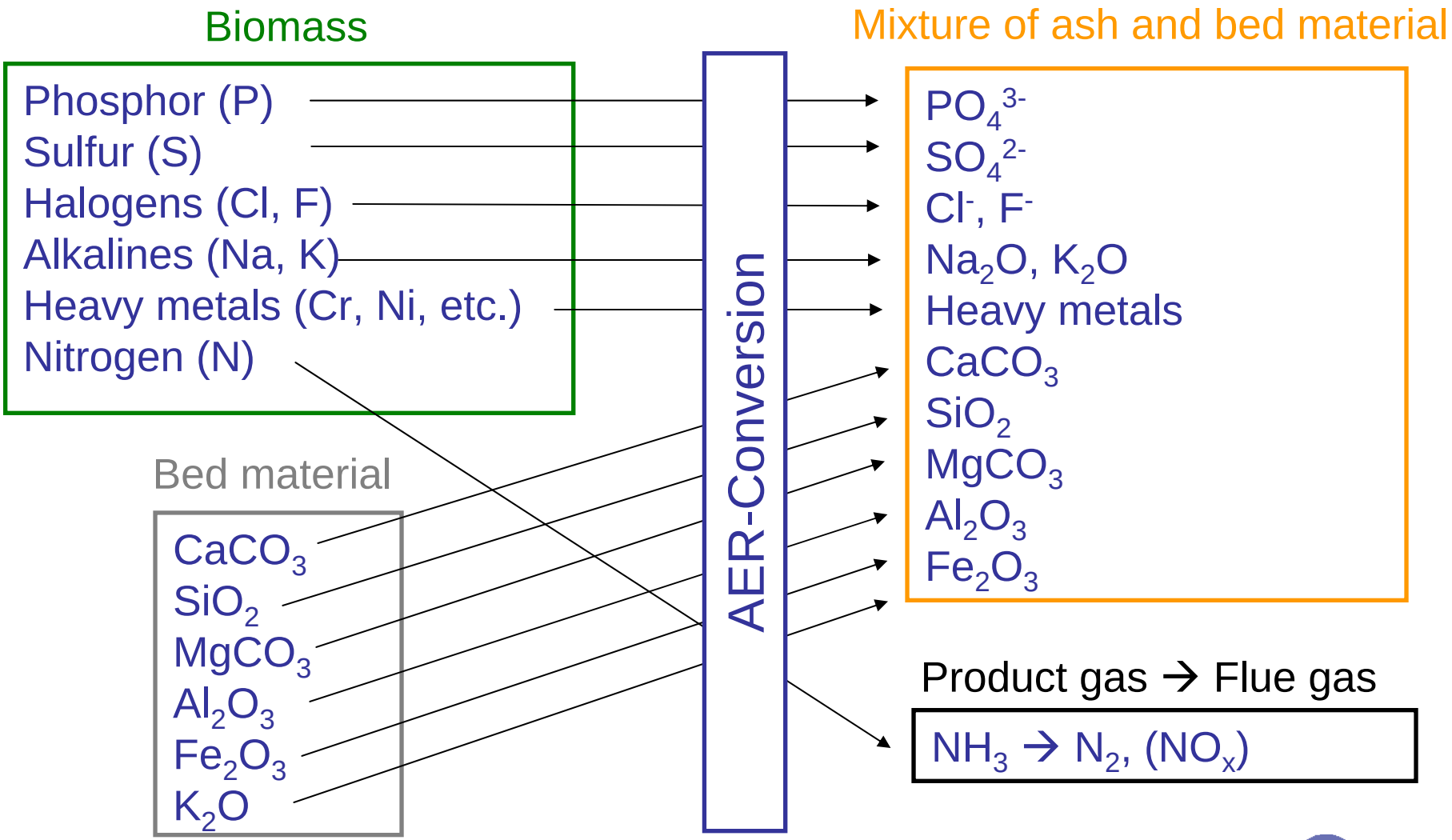


Experimental Investigation with Rotational Viscosimeter: Behaviour of Ash Melting





Mass Flow "Biomass/Bed Material → Ash/Attrition" of non-CHO-Components in AER-Process



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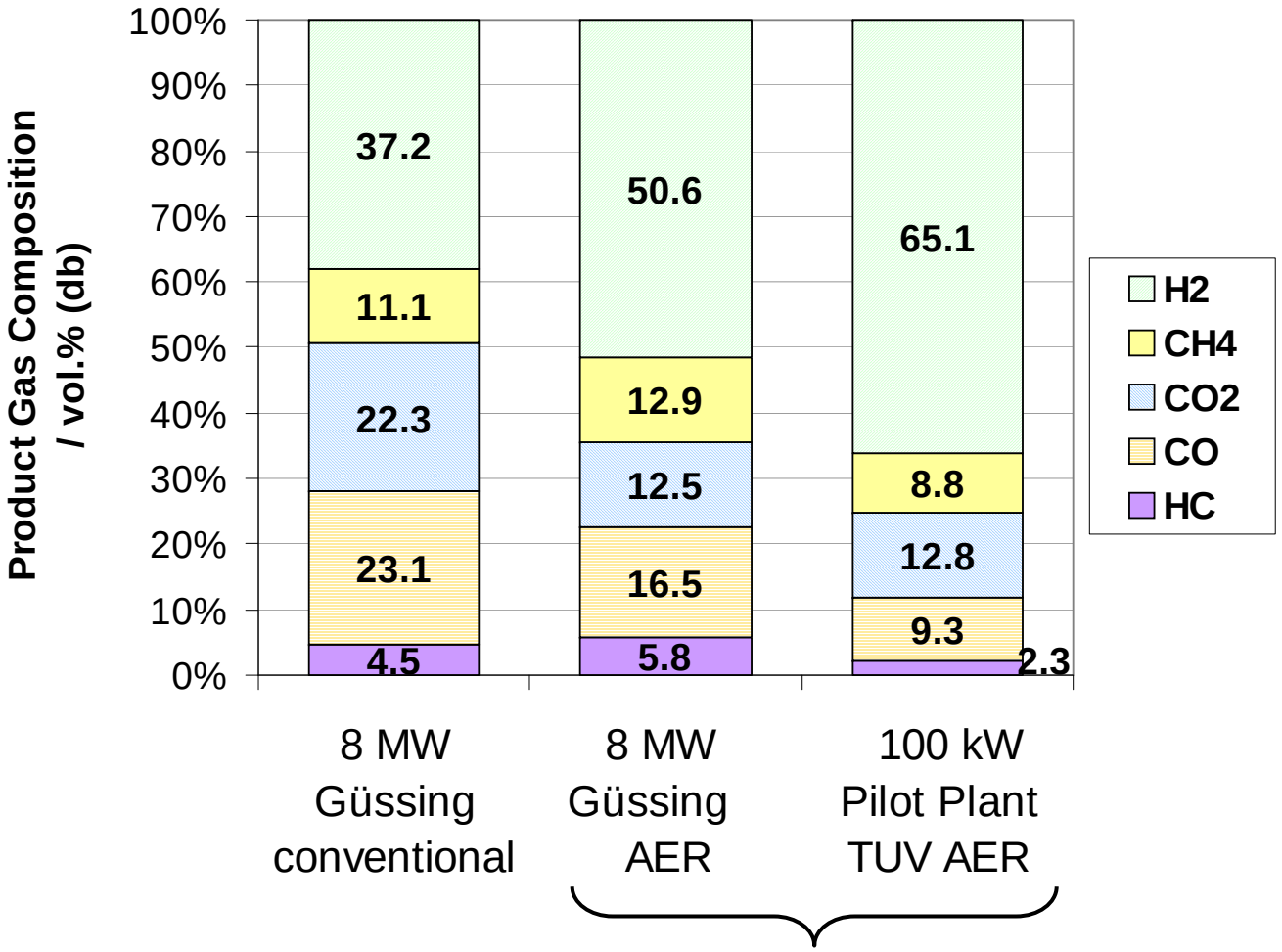
Product Gas Composition: Biomass Gasification in DFB Process



8 MW AER Test Campaign with Vienna Technical University and Biomass Power Plant Güssing

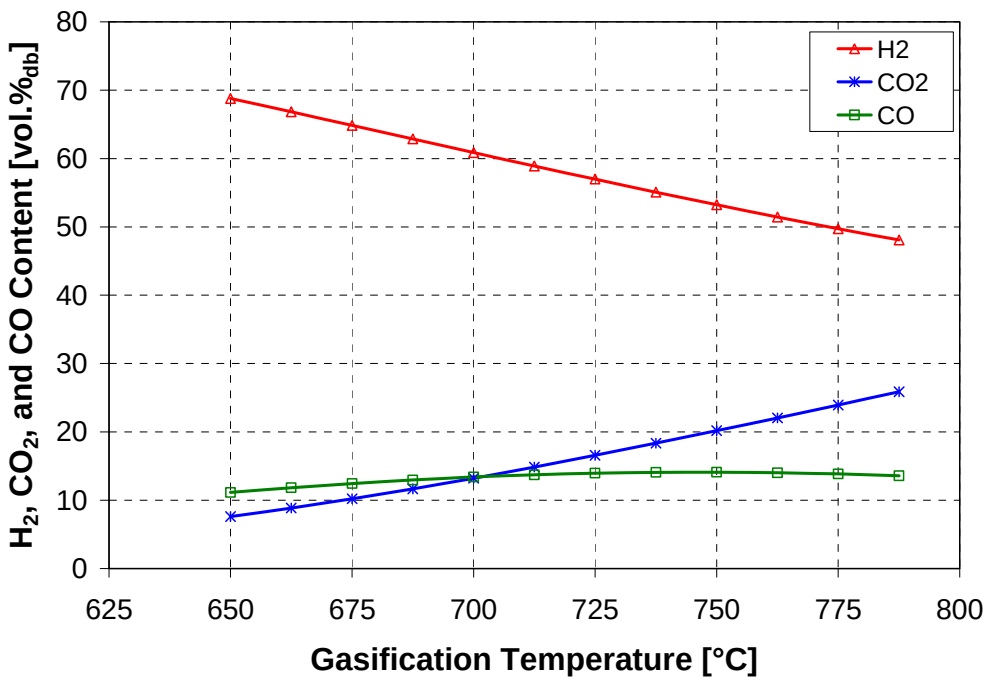
- Feasibility proof of scale-up: AER gasification at 8 MW_{th}
- In principle Guessing gasifier suitable for AER operation without major constructive changes
- High product gas quality:
  - Increased H_2 content (> 50 %)
  - Low CO_2 content (<12 %)
  - Low tar content: ca. 1 g / Nm^3 (like standard gasification)
- Pre-treated Ca-based sorbent as bed material:
  - No start-up problems
  - High reactivity towards CO_2 removal
  - No deposition in heat exchangers
  - Low attrition rate (comparable to Olivine)
- Efficiency similar to conventional mode

Product Gas Composition: Major Gas Components / Stoichiomety Adjustment

Measured data:

H_2	$vol.\%_{db}$	55 – 71
CO	$vol.\%_{db}$	5 – 11
CO_2	$vol.\%_{db}$	7 – 20
CH_4	$vol.\%_{db}$	8 – 13
C_2H_4	$vol.\%_{db}$	1.4 – 1.8
C_2H_6	$vol.\%_{db}$	0.3 – 0.6
C_3 fract.	$vol.\%_{db}$	0.1 – 1.0
H_2O	vol.%	51 – 65

Simulation:



Source:
- Brellochs et al. – "Stoichiometry Adjustment of Biomass Steam Gasification in DFB Process by in situ CO2 Absorption.", 1th International Conference on Polygeneration Strategies, Vienna, Austria, September 1-4, 2009
- Puchner et al. – "In-Situ CO2-Absorption in a Dual Fluidized Bed Biomass Steam Gasifier to Produce a Hydrogen Rich Syngas.", International Journal of Chemical Reactor Engineering, Vol5(A9), 2007

Advantages of AER Process for Biomass Gasification

- **Advantages of Ca-based FB material vs. Olivine**
  - Lower costs
  - No disposal of attrition/ash (option: fertilizer)
  - Various sources of supply
  - *in situ* gas cleaning (tars, S, Cl)
  - No agglomeration problems
  - CO_2 absorption
- **Fuel flexibility**
  - Forrest residues
  - Landscape conservation residuals
  - Straw
- **Product flexibility**
  - CHP
  - Adapted Syngas (SNG, H_2, ….)

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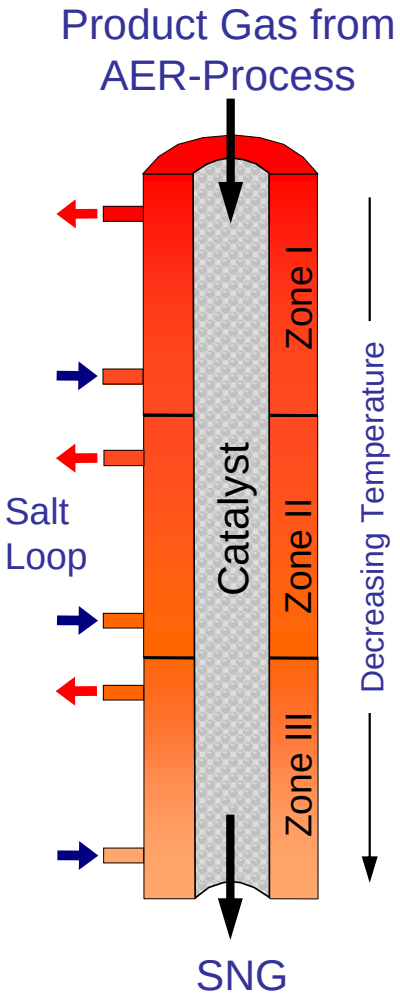
R&D-Topic: SNG Generation in Fixed Bed Molten Salt Cooled Reactor

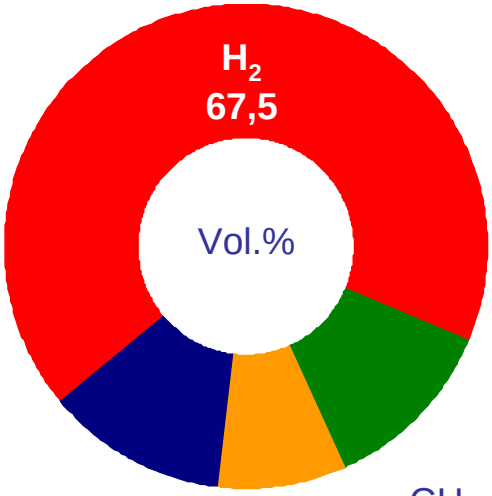


Goal:
SNG without Downstream CO-Shift and without CO_2 Separation due to *in situ* AER Adjustment of Syngas Stoichiometry

Demo-Plant:
50 - 100 kW_{SNG}

Concept Presented at ACHEMA Fair in May 2009 (Cooperation ZSW with MAN-DWE, Germany)

AER Producer Gas → SNG
Experimental Results

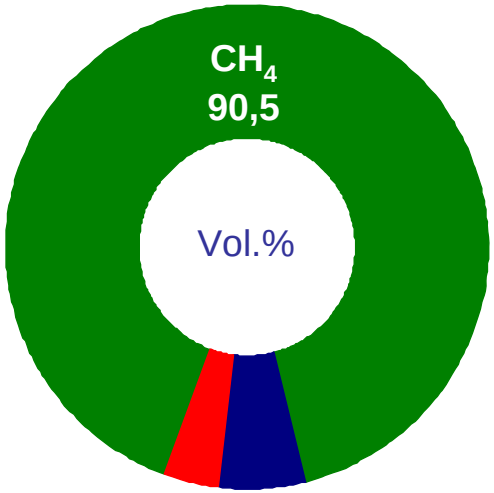


AER producer gas

Methanation

Parameter of methanation:

T = 250 - 500 °C
p_e = 6,5 bar
SV_{wet} = 3000 1/h



CH_4-rich product gas

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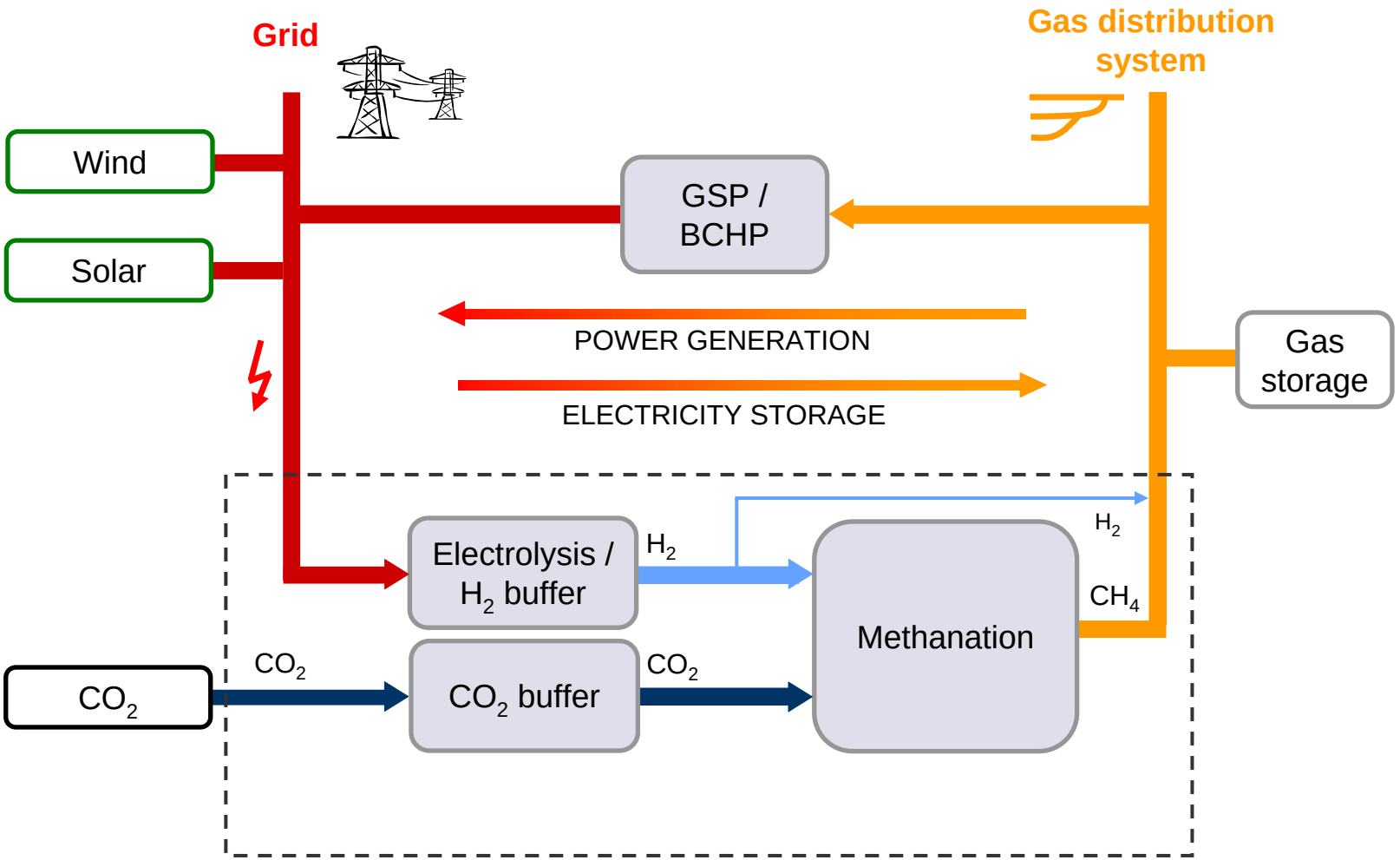
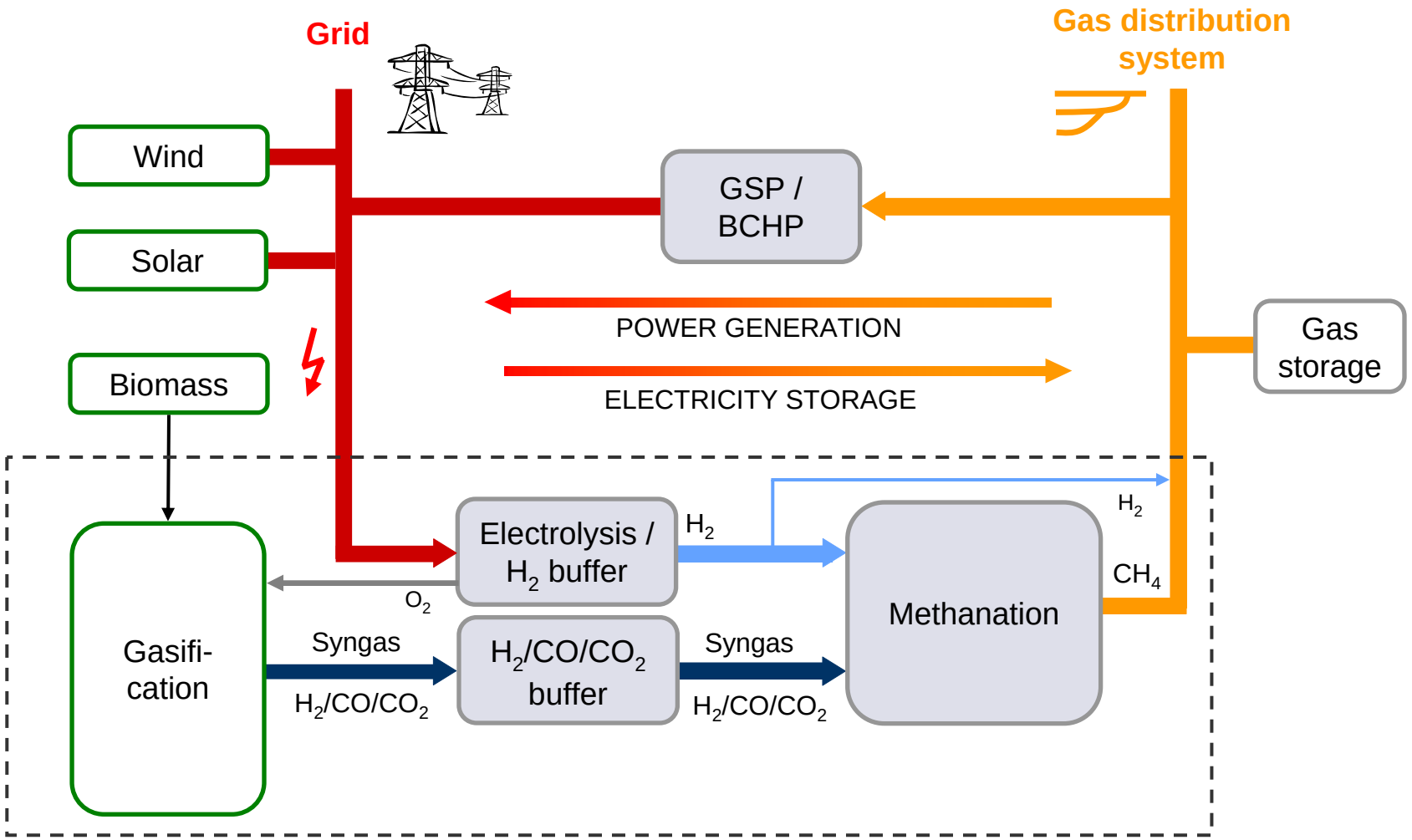
Power2Gas - Concept: Basic Layout



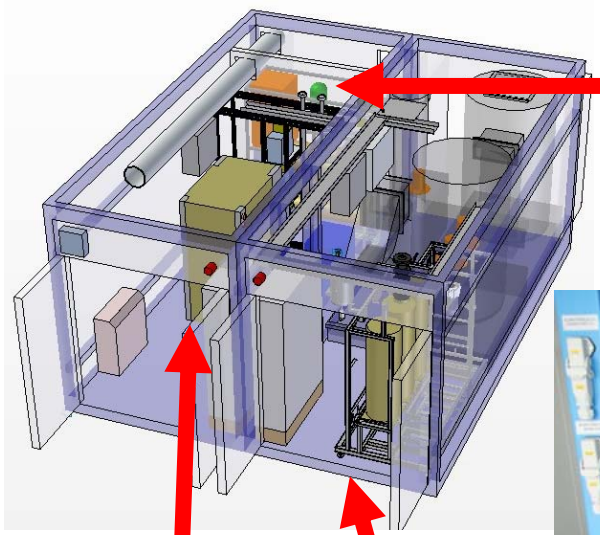
GSP: Gas and steam power plant; BCHP: Block-type combined heat and power station

Power2Gas - Concept: Interconnection with Biomass Gasification



GSP: Gas and steam power plant; BCHP: Block-type combined heat and power station

Power2Gas - Concept:
25 kW_e Technical Realisation for SOLARFUEL Company

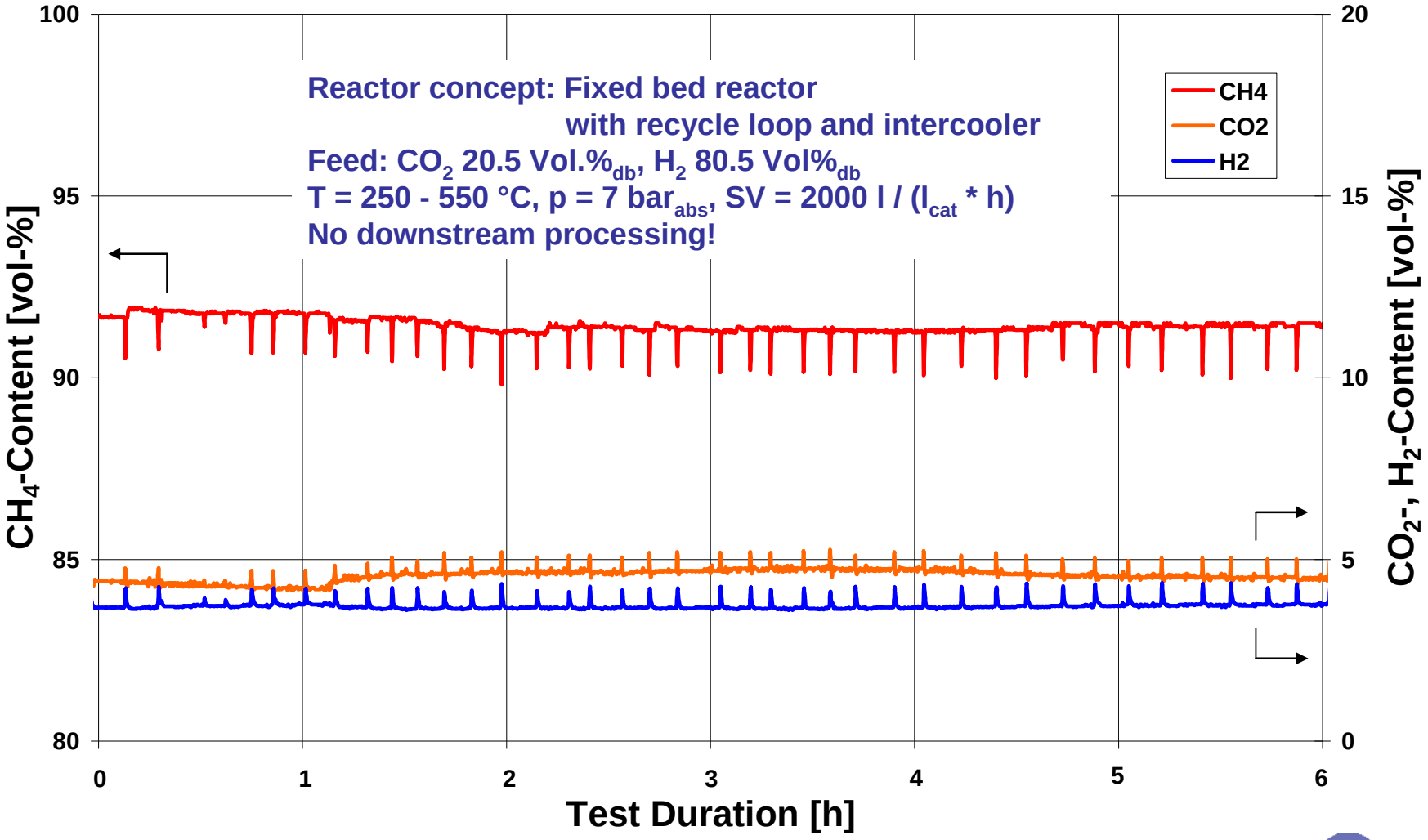


CH_4-Filling station
ca. 15 kg, 200 bar

CO_2-
Recovery

Electrolyser

Power2Gas - Concept: Experimental Results - SNG from H_2/CO_2



Power2Gas – Concept:
Nomination/Award for SolarFuel / ZSW / IWES

Nomination “Clean Tech Media Award” in the field “Energy”, 16.09.2010, Berlin

CLEAN TECH MEDIA AWARD

Award “ASUE” of the German Gas Industry in the field “Innovation and Climate Protection”, 29.09.2010, Berlin

PREIS DER DEUTSCHEN GASWIRTSCHAFT FÜR INNOVATION UND KLIMASCHUTZ 2010

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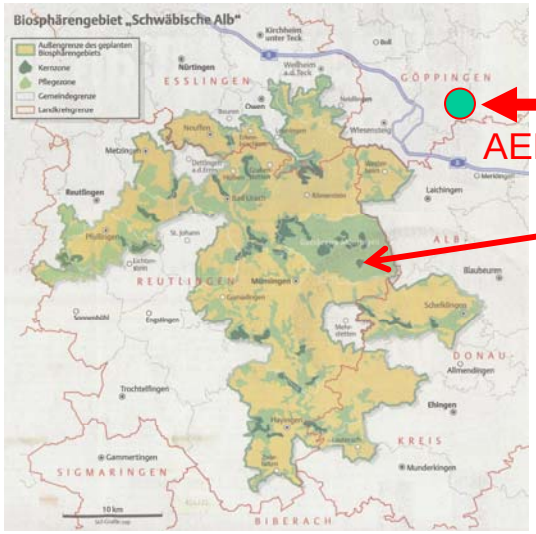
AER-Lighthouse-Project: Goals and Connection to the Biosphere Reserve “Swabian Alb”



UNESCO-Certification of the Biosphere Reserve since May 26th 2009

- Efficient conversion of biomass
- Fuel-flexibility (wood, woody biomass from biosphere reserve landscape conservation)
- Product-flexibility - poly-generation for electricity, heat and fuel
- Generation of Substitute Natural Gas (SNG) (partial flow)

- Transfer of AER-results to 10 MW_{th} power plant
- Co-operation with utilities, plant construction, ...
- Location in Geislingen (50 km southeast of Stuttgart)
- Heat for sewage sludge drying
- R&D-Platform „BtG“ at power station:
  → Scientific attendance
  → Innovative utilisation of AER product gas

AER-Lighthouse-Project: Operating Company

Operating Company:

TBM - **T**echnologieplattform **B**ioenergie
und **M**ethan GmbH & Co. KG (TBM),
Heidenheimer Str. 28, 73312 Geislingen

Project Management:
EVF - Energieversorgung Filstal GmbH & Co.KG
(Public Utility)

AER-Lighthouse-Project: Shareholder (Public Utilities) of the Operating Company TBM

Technologieplattform Bioenergie und Methan GmbH & Co. KG

Shareholder of TBM GmbH & Co. KG	Share [%]
Energieversorgung Filstal GmbH & Co. KG	21,1
Stadtwerke Geislingen a. d. Steige	21,1
Alb-Elektrizitätswerk e.G.	15,0
Stadtwerke Tübingen GmbH	10,0
Rationelle Energie Süd GmbH	5,0
Technische Werke Schussental GmbH & Co. KG	5,0
Stadtwerke Mühlacker GmbH	1,0
Stadtwerke Bietigheim-Bissingen GmbH	5,0
Universität Karlsruhe (TH)	1,8
Technische Werke Friedrichshafen GmbH	5,0
SWU Energie GmbH Ulm/Neuulm	5,0
Stadtwerke Heidenheim AG	5,0
Total	100,0

AER-Lighthouse-Project:
Technical / Design Data of the Biomass Power Plant

Gasification Process:	Dual Fluidised Bed (DFB); Gasifier: Bubbling Bed; Combustor: Circulation Bed
Gasification Temperature: Combustion Temperature:	600 - 800 °C 800 - 900 °C
Pressure:	Atmospheric
Gasification Agent:	Steam (0.7 – 1.4 kg_{H2O} / $kg_{fuel\ dry}$)
Fuel Power Input:	ca. 10 MW
Electrical Output:	ca. 3.5 MW_{el} (incl. ORC)
Thermal Output:	ca. 4 MW
Fuel: Fuel Requirement:	Wood Chips (up to 25 % from Landscape Conservation) ca. 15 000 $tons_{dry}$/a
Fluidised Bed Material: Circulation Rate: Fluidised Bed Material Purge Rate:	High Temperature CaO Based Sorbent 10 $kg_{sorbent}$/$kg_{fuel\ dry}$ < 100 kg/$t_{biomass}$
Product Gas Hydrogen Content (dry):	> 60 Vol.%
Investment:	ca. 25 Million EUR (incl. land, building, etc.)

AER-Lighthouse-Project: Status Quo / Procedure

Dec. 2007: Foundation of the operation company TBM GmbH & Co. KG;
Application for support (Ministry of Economics, Federal State of Baden-Württemberg, WM)

July 2008: Application for support at KfW-Bank in the frame of "Germany's Climate Protection Initiative" (Ministry of the Environment, Berlin, BMU)

Dec. 2008: → Grant from WM for plant investment (0,5 Mio. €)

April 2009: → Grant from BMU for BMU for plant investment (3,6 Mio. €)
→ Grant from WM for R&D-platform BtG (Biomass-to-Gas) (1,3 Mio. €)
→ Grant from BMU for R&D-platform BtG (Biomass-to-Gas) (1,1 Mio. €)

Apr. 2010: Tender procedure (lot-by-lot basis)

June 2010: Terminating of tender procedure (return inadequate)

July 2010: Annihilation of tender procedure
→ Private allocation of contracts (negotiations with general contractors ongoing)

Oct. 2010: Issue of construction approval

Nov. 2010: Building decision ("final GO")

Spring 2011: Start of construction

Acknowledgement

For Fruitful Collaboration:

Project Partners of R&D-Platform BtG

Project Partners of AER-GAS and AER-Gas II

TBM

For Funding:

Baden-Württemberg
WIRTSCHAFTSMINISTERIUM

Ministry of Economics of the Federal State of Baden-Württemberg, Stuttgart

Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Berlin

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

in the Frame of:

Germany's Climate Initiative – Climate protection pays off!

EUROPEAN COMMISSION

European Commission (ENK5-CT2001-00545, SES6-518309)

ZSW




An Interesting Discussion !

Thanks for Your Kind Attention.