A New Approach for the Production of a

Hydrogen - Rich Gas from Biomass (AER-GAS)

- Absorption Enhanced Reforming -

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BIO-ENERGY
ENLARGED PERSPECTIVES

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Main Goal of AER - GAS

New and Efficient Steam Gasification for Clean Conversion of Solid Biomass in a Single Step Fluidised Bed Reactor Generating a Product Gas with > 80 vol.-% Hydrogen.

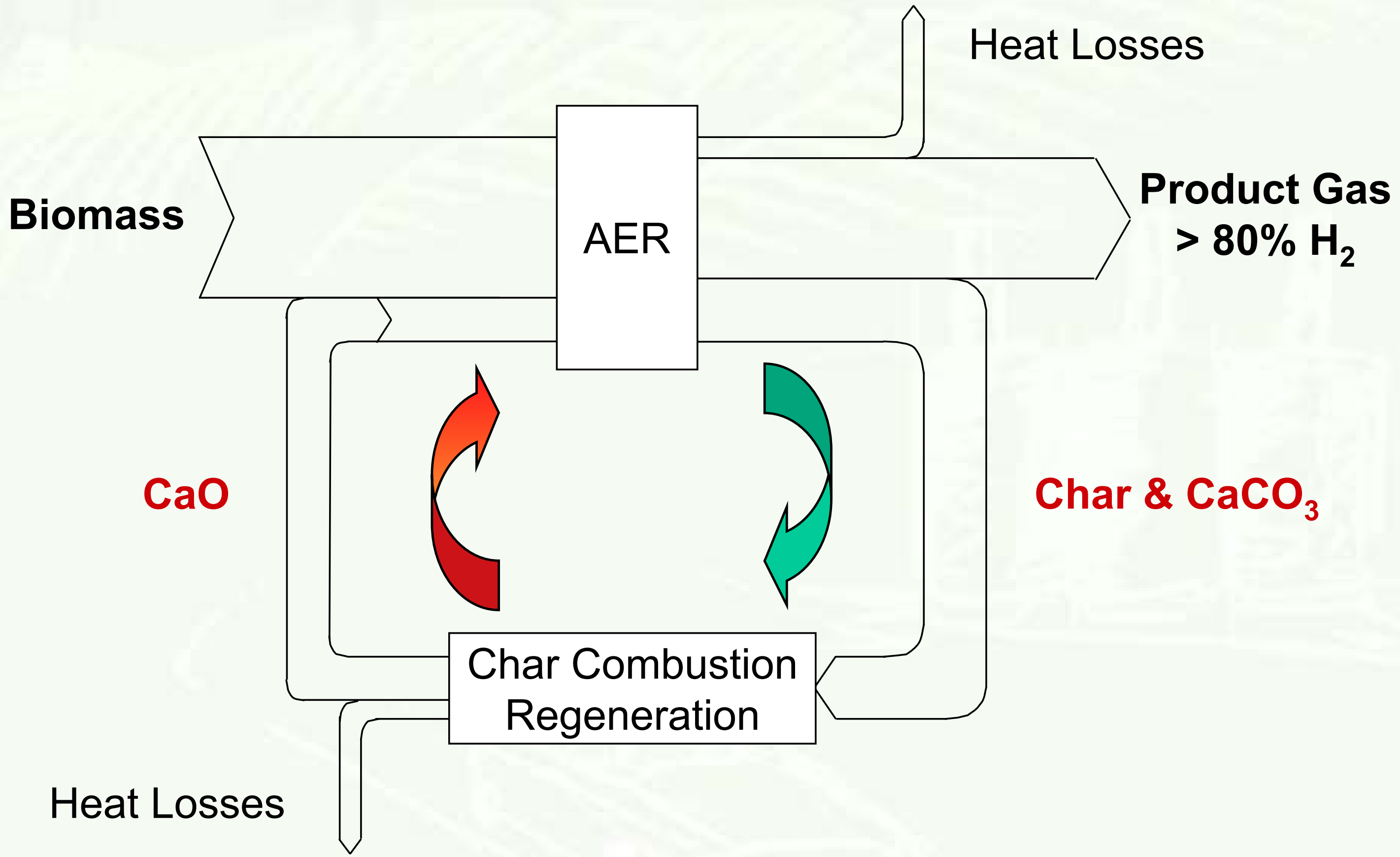
Formal Information on AER-GAS

Project Start:	1. 1. 2002
Duration:	3 years
Partners (8):	D, A, EL, CY, CH
Project No:	ENK5-CT-2001-00545

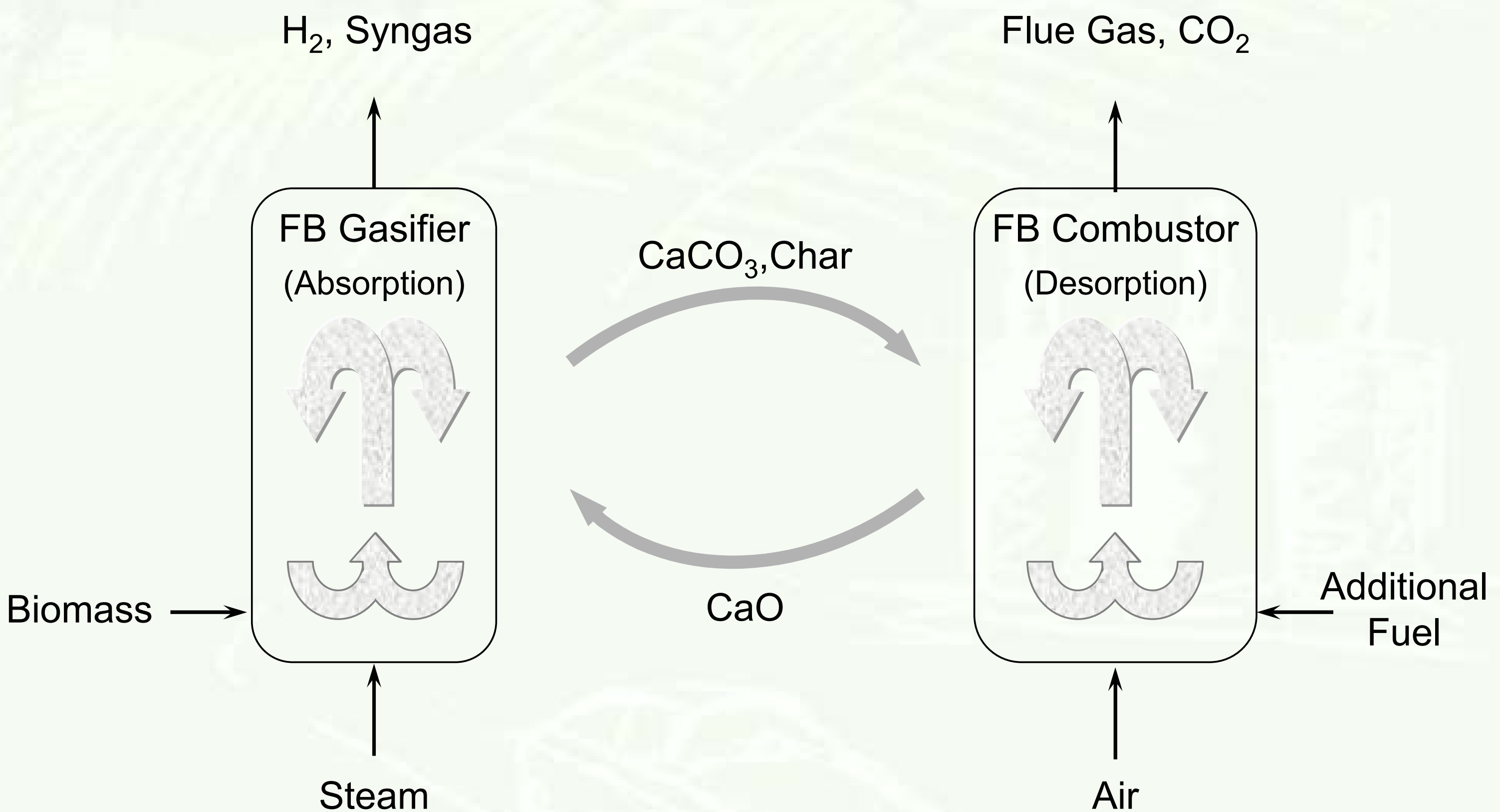
Further information:

Homepage:	www.aer-gas.de
Contact:	Co-ordinator ZSW
	Technical officer Dr. Garbine Guiu

AER Process, Principal & Energy Flow



AER Combined FB Gasification



AER Reaction

Steam Reforming of Biomass:

$$C_xH_yO_z + (2x - z)\ H_2O \rightarrow x\ CO_2 + (2x - z + 0.5y)\ H_2$$

Combined with a HT-CO_2-Absorption:

$$x\ CaO + x\ CO_2 \rightarrow x\ CaCO_3$$

Overall (in the Temperature Range 700 - 1000 K):

$$C_xH_yO_z + (2x-z)\ H_2O + x\ CaO \rightarrow x\ CaCO_3 + (2x-z+0.5y)\ H_2$$

Advantages of AER Reaction

- Hydrogen Content > 95 % in a Single Step Process (Fixed Bed)
- Complete CO_2 Separation (Hydrogen Production) or Partial CO_2 Separation for Stoichiometry Adjustment (Synthesis Gas Production)
- Equilibrium Shift toward H_2 (away from CO, CH_4, Soot)
- Autothermal Reactor (Since the Absorption Reaction is Exothermic, it Supplies the Energy Necessary for the Endothermic SR Reactions)
- Gas Cleaning/CO Removal via Methanation
- Combustion Energy of Residual Solids (e.g. Char) is Used for Absorbent Regeneration

AER - GAS Consortium

ZSW	Center for Solar Energy and Hydrogen Research, Germany Department: Renewable Fuels and Processes
ICE/HT	FORTH – Foundation for Research and Technology Hellas, Greece Institute of Chemical Engineering and High Temperature Processes
UOC	University of Cyprus, Cyprus Department of Chemistry
PSI	Paul Scherrer Institute, Switzerland General Energy Research Department
IVD	University of Stuttgart, Germany Institute of Process Engineering and Power Plant Technology
TUV	Technical University of Vienna Institute of Chemical Engineering, Fuel and Environmental Technology
IVE	IVE-Weimer, Germany Energy Processes and Technology
PROPLAN	Proplan Ltd. (PROPLAN), Cyprus

Main Tasks

WP 1: Catalytic Absorbent Bed Material (ICE/HT, UOC, ZSW)

Investigation of absorbents; lab scale fixed bed exp.

Investigation & improvement of absorbent materials

Investigation & development of *in situ* tar removal

WP 2: Fluidised Bed Experiments (IVD, PSI)

Mechanical stability of materials, “tar” reforming exp.

Biomass AER gasification, absorbent regeneration

WP 3: Fast Internally Circulating Fluidised Bed Reactor, FICFB (TUV)

Combination of gasification and absorbent regeneration

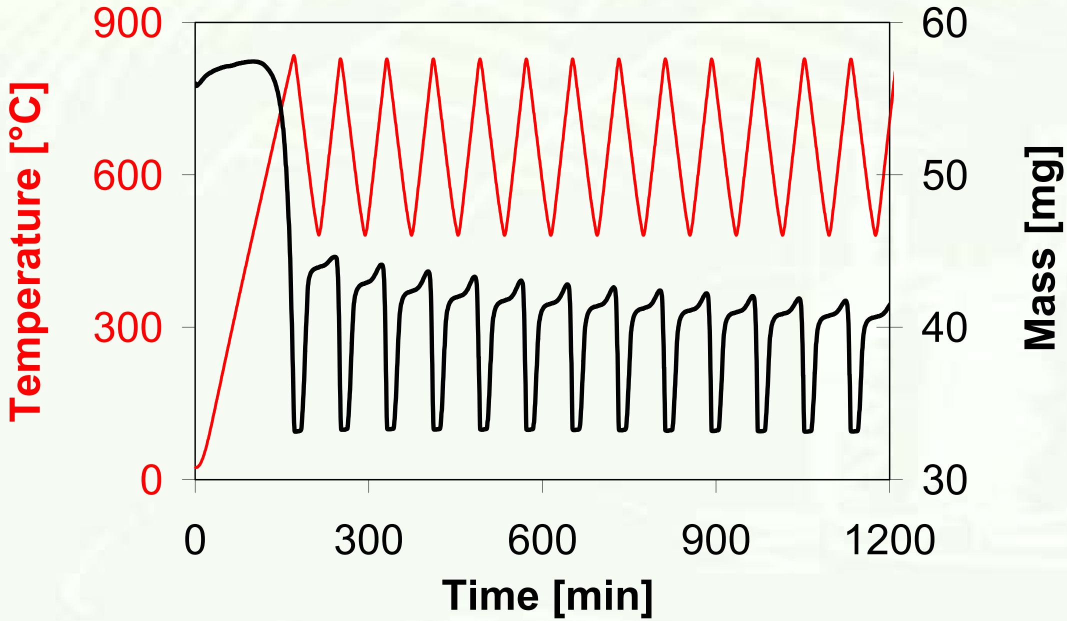
WP 4: Plant Design, Efficiency & Economical Calculation (IVE, PROPLAN)

Application and implementation of AER in industry; efficiency

Plant design for CHP system, market study

Absorbent Characterisation by TGA

Typical Cyclic Behaviour of Dolomites (Dolomite Hufgard) in Thermal Gravimetric Analysis (TGA)



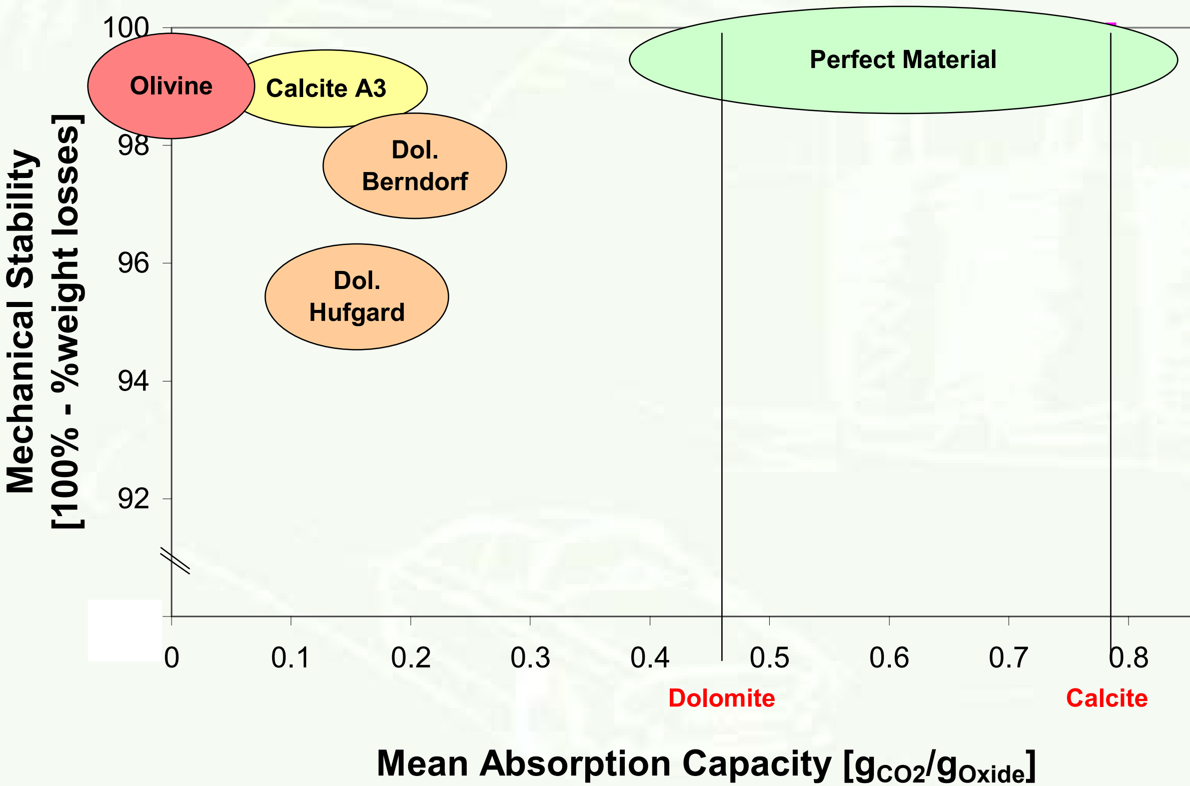
- Temperature: T_{min} = 475 °C, T_{max} = 875 °C; 10 K/min
- Particle size: $d_P \leq 20$ µm
- Atmosphere: 70 vol.-% N_2, 20 vol.-% H_2O, 10 vol.-% CO_2

Overview: Material Investigation

Testing the mechanical stability of materials in bubbling fluidised bed reactor

Reaction conditions: T_{abs} = 650°C, T_{des} = 900°C, 1 atm; Feed: 20 % CO_2 in Air

Absorption capacity after 10 cycles; Particle size: 0.16 - 0.315 mm

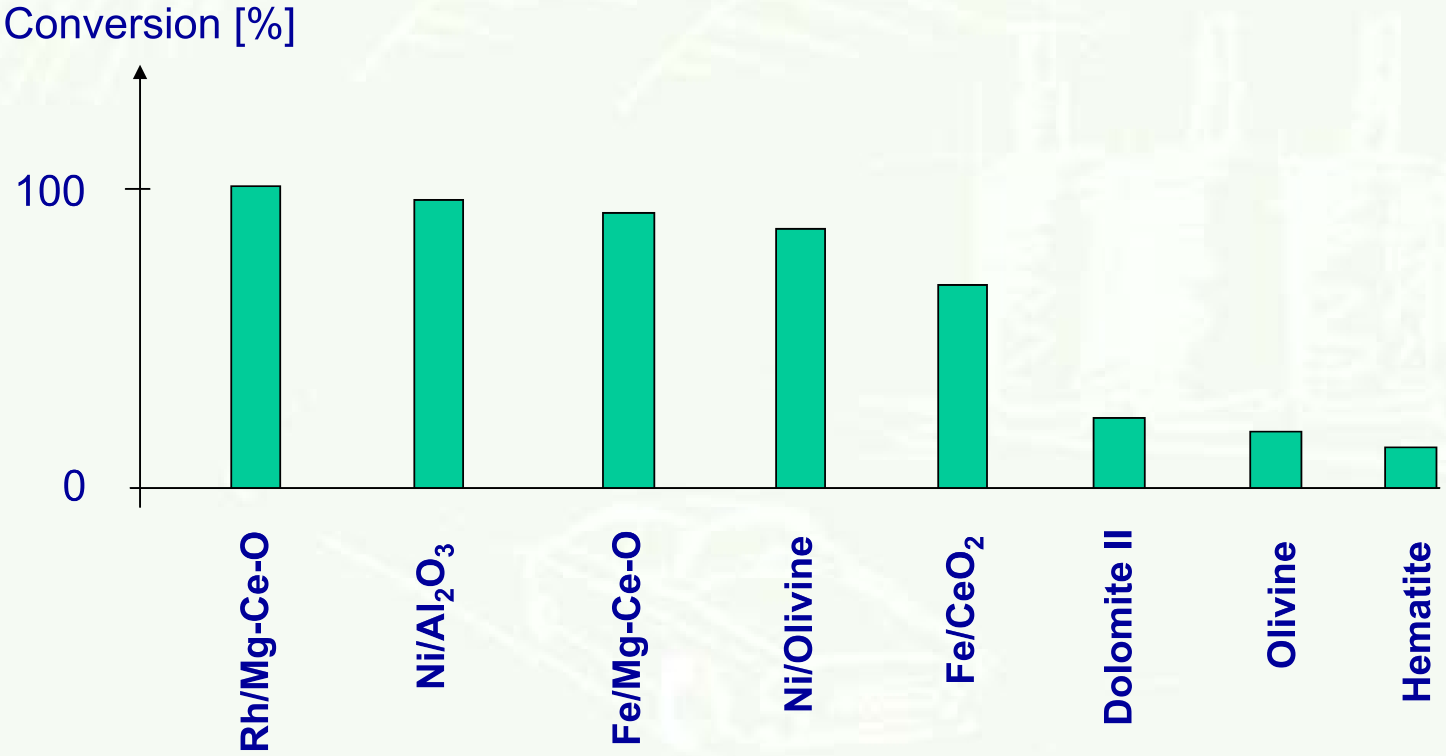


Tar (Phenol) Removal Experiments

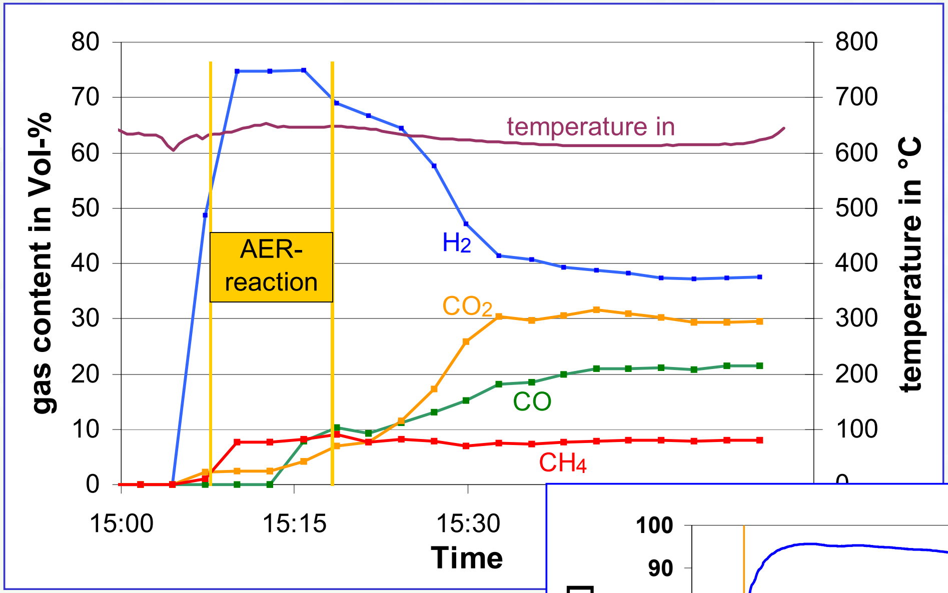
Employing different catalysts for tar reforming in lab scale fixed bed reactor

Reaction conditions: T = 700°C, s/c = 13.3, SV = 80,000 $\frac{1}{h}$

Feed: 0.25% C_6H_5OH / 20% H_2O / He



Experimental Results AER Reaction



Biomass Gasification

Fluidised Bed Reactor

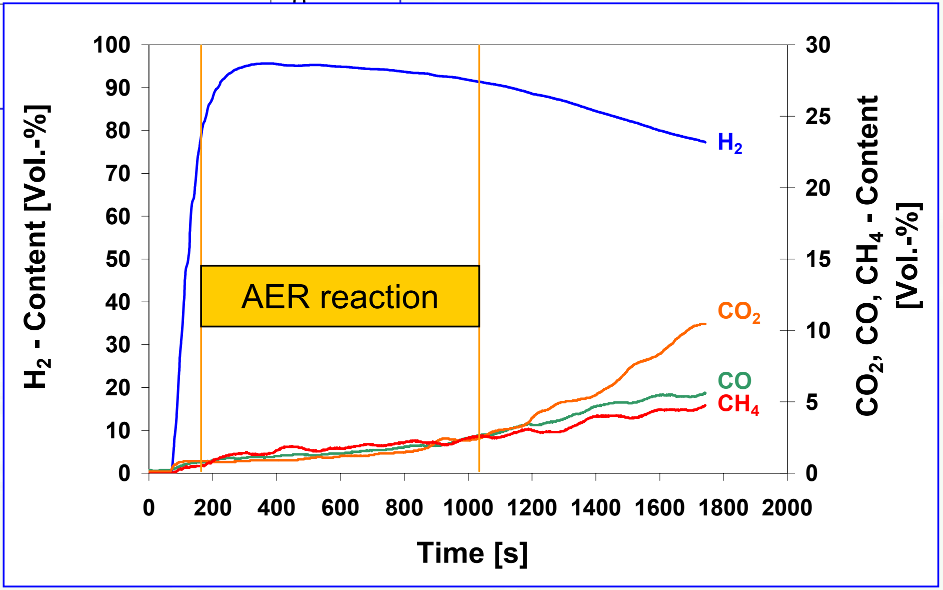
T ≅ 650 °C; s/c = 2.5

CH_4 Reforming

Fixed Bed AER Reactor

T ≅ 630 °C; s/c = 3.5;

$$SV = 1250 \quad \frac{Nl_{CH_4} + Nl_{steam}}{Nl_{reactor} \cdot h}$$



Interim Results at Midterm

1. Feasibility proof of AER concept with different fuels

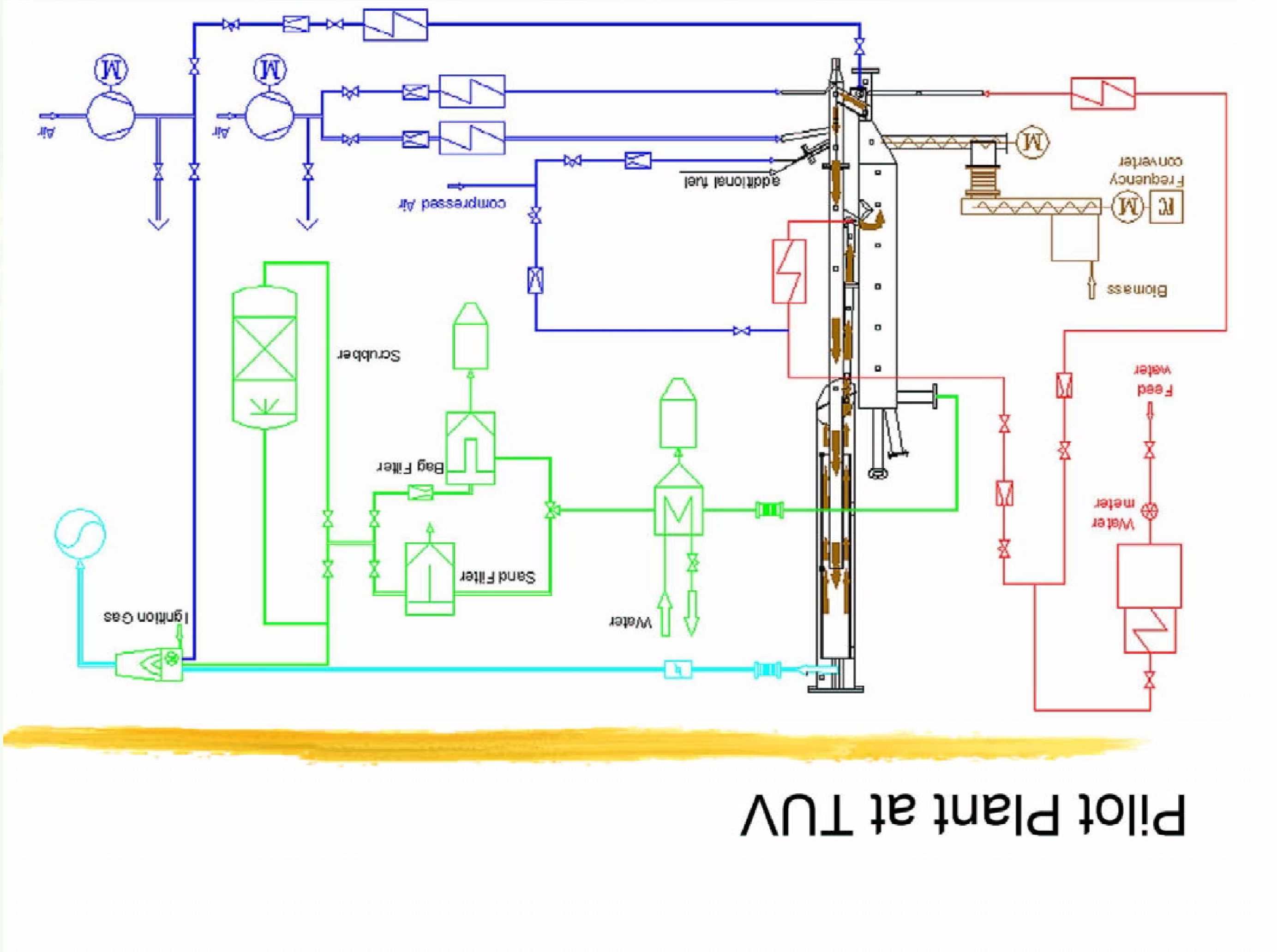
- Fixed bed experiments with hydrocarbon and alcohol fuels: H_2 > 90 %
- Fluidised bed experiments with biomass: H_2 > 75 %

2. Favoured absorbents for AER process are CaO containing natural materials

- T-range for gasification: 620 - 700°C (1 bar)
- Selection of natural CaO containing materials: compromise of mechanical and chemical cycle stability
- Selected materials show a CO_2 uptake of about 0,05 - 0,15 g CO_2/g Oxide (cycle number 100)
- Attrition resistance of bed material seems to be dependent on mechanical material pre-treatment
- Kinetics for CO_2 absorption and desorption: residence time for absorption/ desorption are sufficient for FB

3. Catalysts for tar conversion (e.g. Rh for downstream unit or natural minerals for *in situ* conversion)

Combined Process



Proposal for Future Collaboration

1. **Absorbent Material Development**

   - Fundamental research with view to the requirements of the different reactor types
   - Production of improved materials in bulk quantities for AER gasification experiments

2. **Hydrogen and Syngas Generation for Automotive Fuels**

3. **AER Gasification in Rotary Kiln Reactor**

   - AER gasification at lower mechanical stresses, longer residence time and larger particle sizes

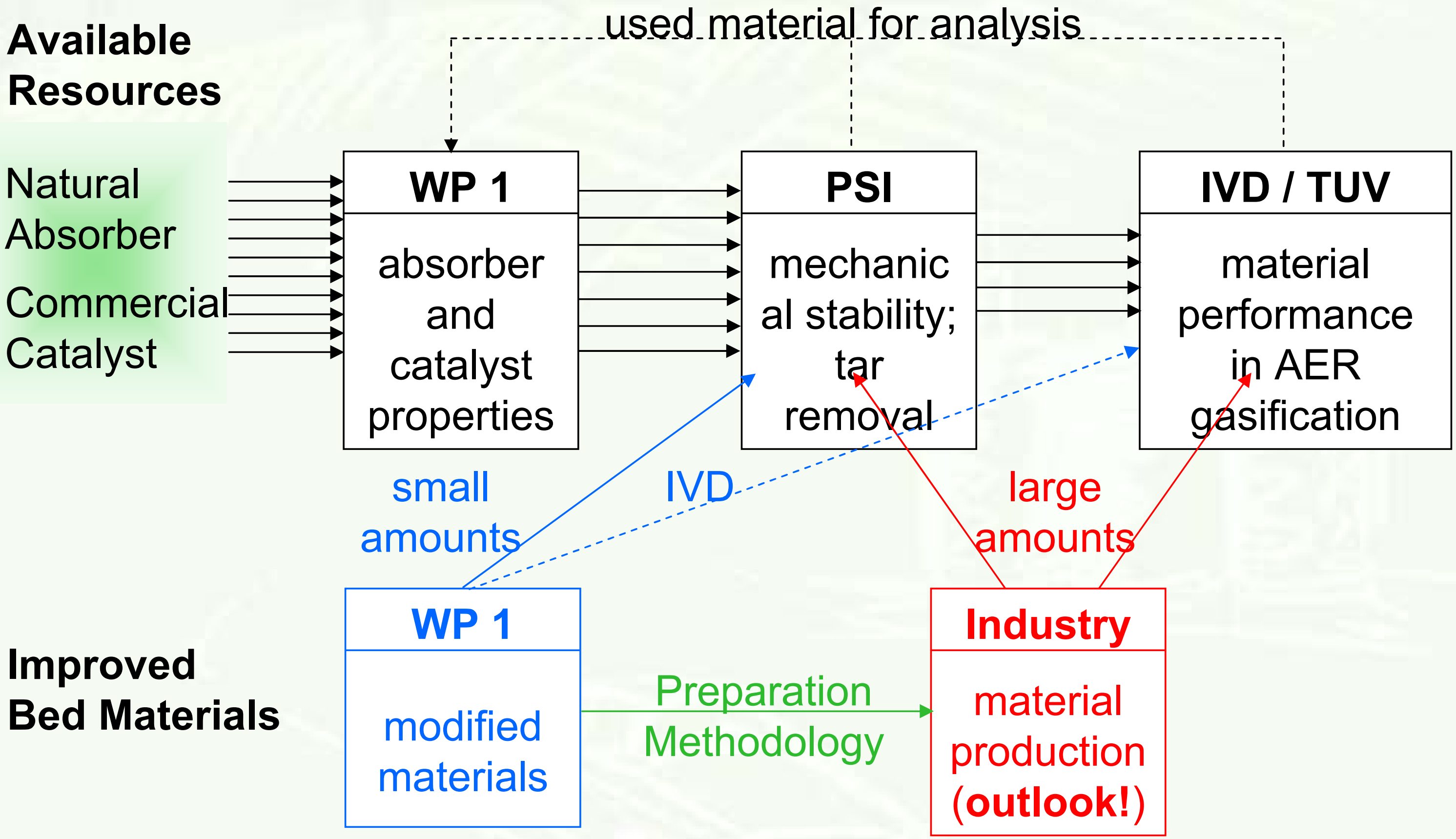
4. **Catalysts for *in situ* Tar Conversion**

5. **AER Gasification in Industrial Processes (e.g. cement, pulp)**

Future Application of AER Biomass Gasification

- Hydrogen Generation
- Fuel for Fuel Cells
- Syngas for Automotive Fuels

Investigation of AER Bed Material



Concepts to Improve & Deliver Material

Absorbent Material

1st Route (Supply):
Cheap improvement methods, bulk quantities → supply
- Slight modification (→ e.g. mech. pre-treatment)

2nd Route (Research):
Costly modification methods, small quantities, high quality
→ lab scale exp.

Catalytic Material

1st Route (Supply):
"Commercial" in-situ Fluidised Bed catalysts not available

2nd Route (Research):
Costly lab synthesis methods, small quantities, high quality for in-situ and downstream tar reforming