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Chemical Looping gAsification foR sustainAble production of biofuels

CLara

2. German Doctoral Colloquium Bioenergy, Nürnberg, 30.9 - 1.10.2019

Agenda

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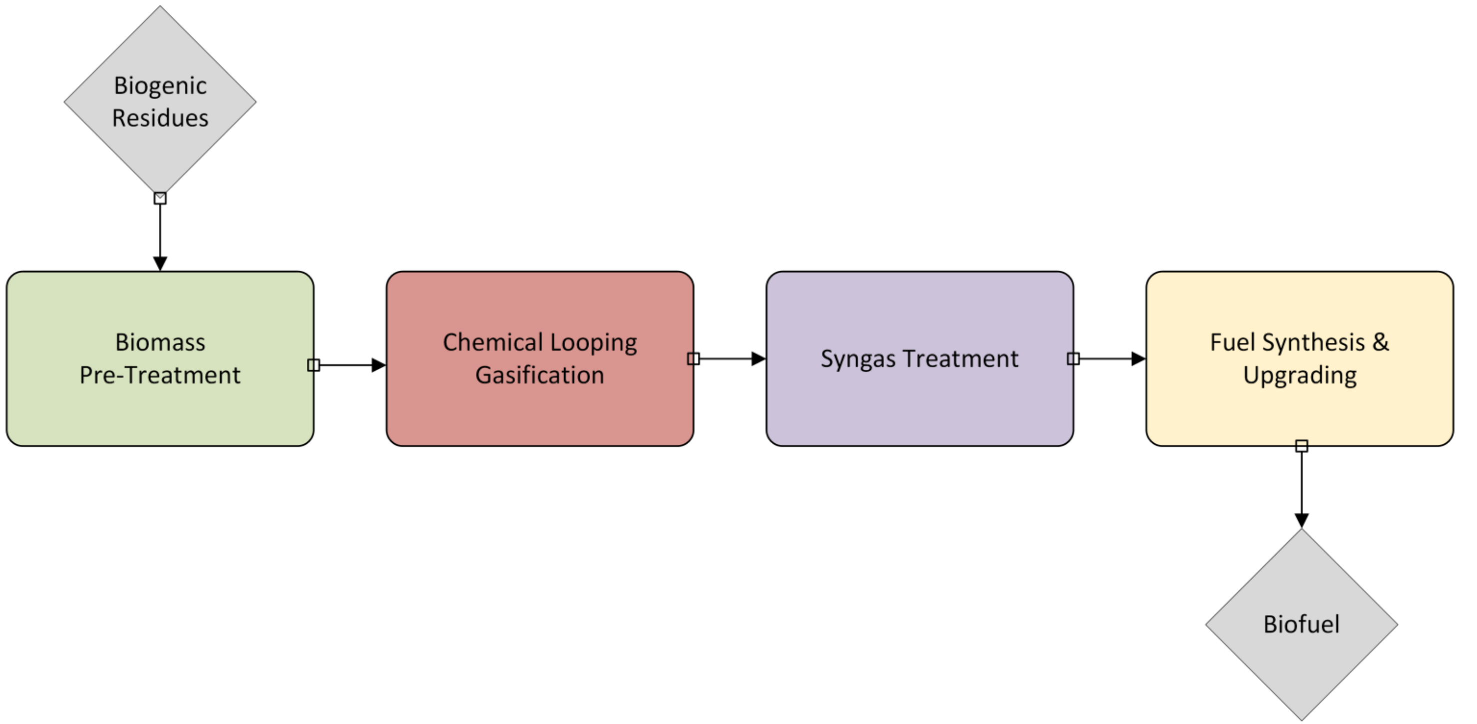
- Basic Concept
- Description of Technology
- Full Process Chain
- Summary & Outlook

Concept (I)

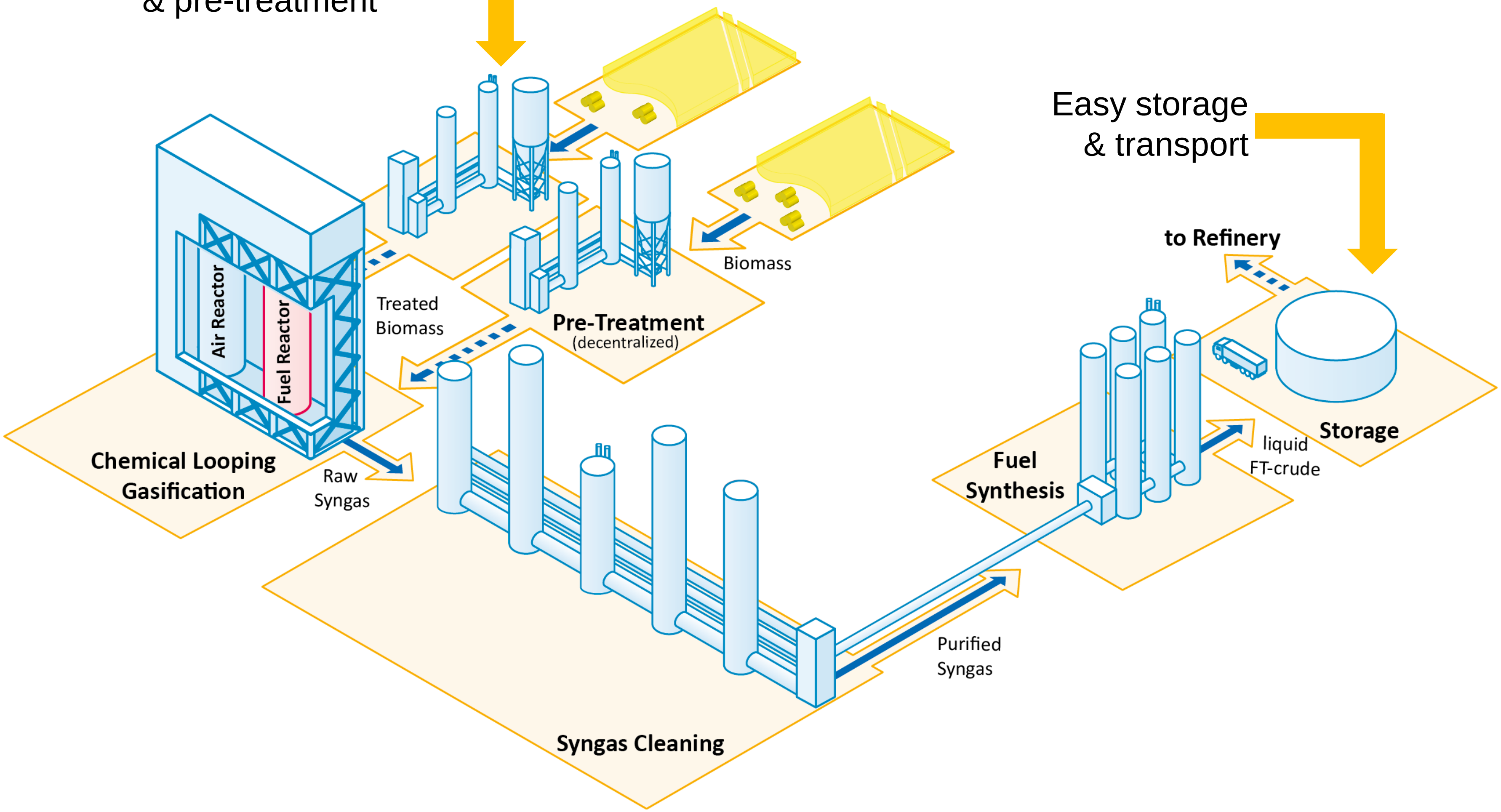


- Biomass-to-biofuel process chain
- Novel biomass pre-treatment, gasification and syngas treatment concepts
- Deployment of established fuel synthesis and upgrading technologies for the production of drop-in biofuels

Concept (II)

Local feedstock sourcing
& pre-treatment

Easy storage
& transport

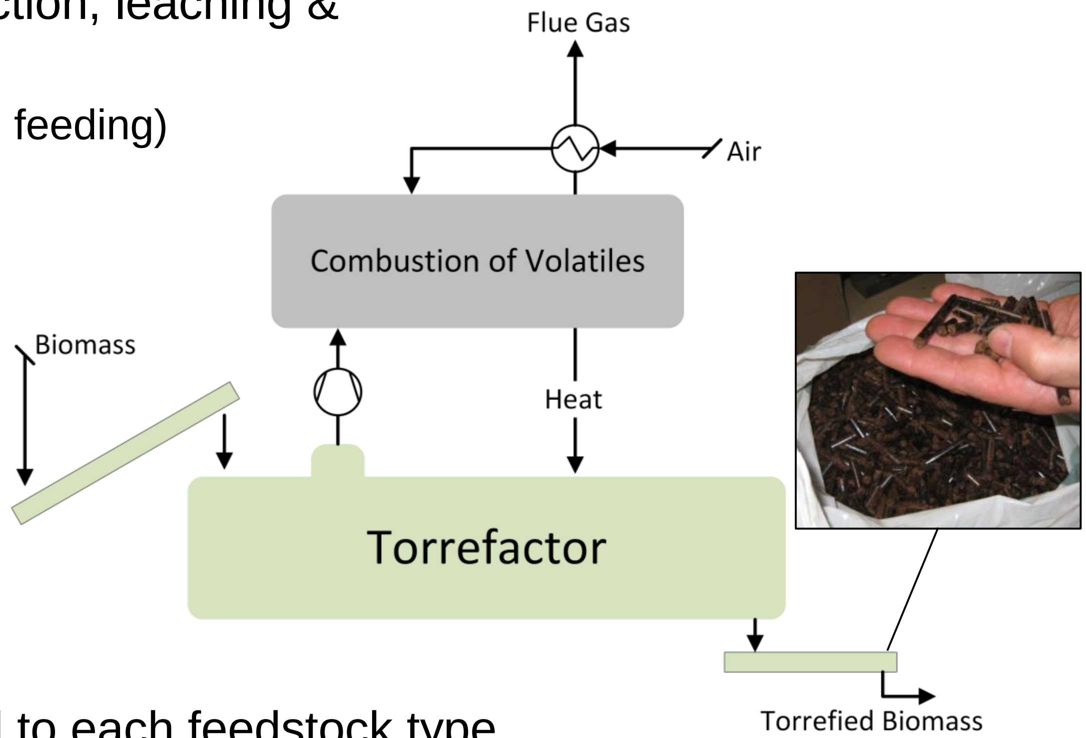


➢Cost competitive and environmentally compatible fuels for road transport

Biomass Pre-Treatment

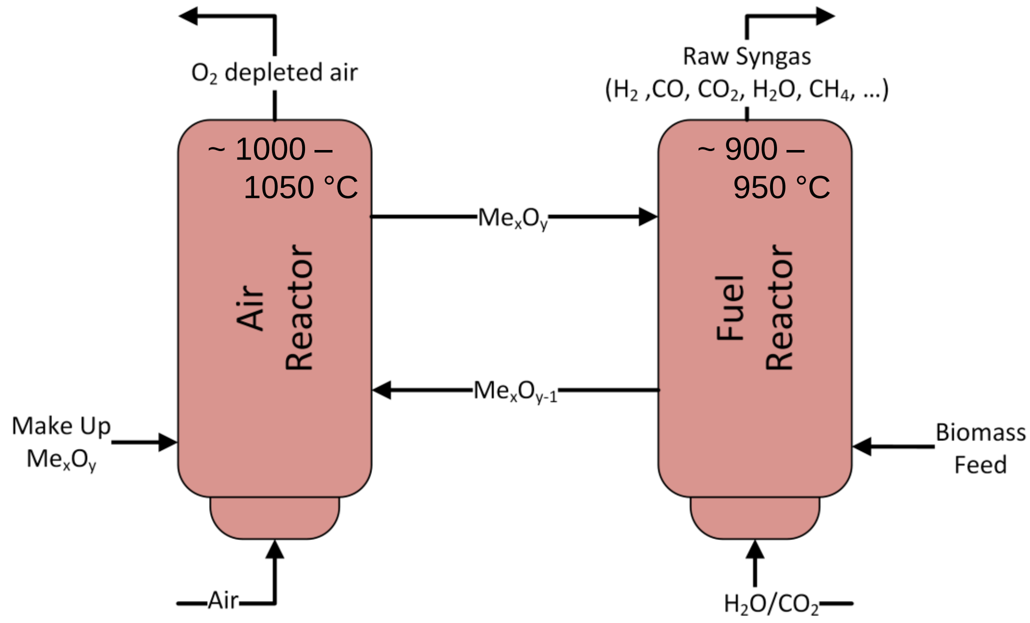
- Pre-Treatment of “difficult” feedstocks (e.g. straw)
  - Large amount of contaminants (Cl, Alkali)
  - Low volume specific heating value
  - Low ash melting temperature

- Concept: Combination of torrefaction, leaching & pelletization
  - Better handling (transport, storage, feeding)
  - Better fluidized bed characteristics
  - Larger heating value



➢ Pre-treatment concept tailored to each feedstock type

Chemical Looping Gasification (CLG) - Overview



- Feedstock gasification with H_2O/CO_2 assisted by solid phase oxygen
- Circulation of Me_xO_y for oxygen & heat transport between reactors
  - No air separation required → cost-efficient
  - CO_2 concentrated in syngas → facilitation of net negative CO_2 emissions
- Low λ (~0.3 - 0.5) to achieve partial fuel oxidation → formation of synthesis gas
- Oxygen carriers: Fe_2O_3/Fe_3O_4, $Fe_2TiO_5/FeTiO_3$

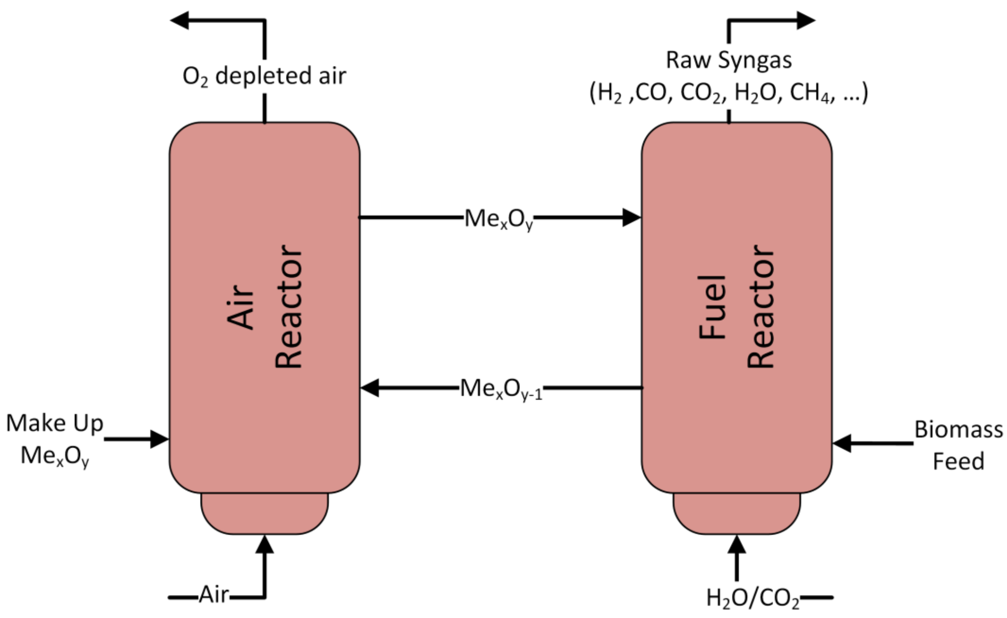
Chemical Looping Gasification (CLG) - Reactions

- Air Reactor (T~1000 – 1050 °C)
  - re-oxidation of oxygen carrier

$$Me_xO_{y-1} + 0.5\ O_2 \rightarrow Me_xO_y$$

  - Combustion of unconverted char

$$C + O_2 \rightarrow CO_2$$



- Fuel Reactor (T~900 – 950 °C)
  - Gasification of biomass

$$C + CO_2 \rightarrow 2\ CO$$
$$C + H_2O \rightarrow CO + H_2$$

  - Heterogeneous Me_xO_y – gas reactions

$$4\ Me_xO_y + CH_4 \rightarrow 4\ Me_xO_{y-1} + 2\ H_2O + CO_2$$
$$Me_xO_y + CH_4 \rightarrow Me_xO_{y-1} + 2\ H_2 + CO$$
$$Me_xO_y + CO \rightarrow Me_xO_{y-1} + CO_2$$
$$Me_xO_y + H_2 \rightarrow Me_xO_{y-1} + H_2O$$

  - Tar cracking

e.g. $C_8H_{18} \rightarrow C_3H_6 + C_5H_{12}$

  - Steam methane reforming

$$CH_4 + H_2O \leftrightarrow 3H_2 + CO$$

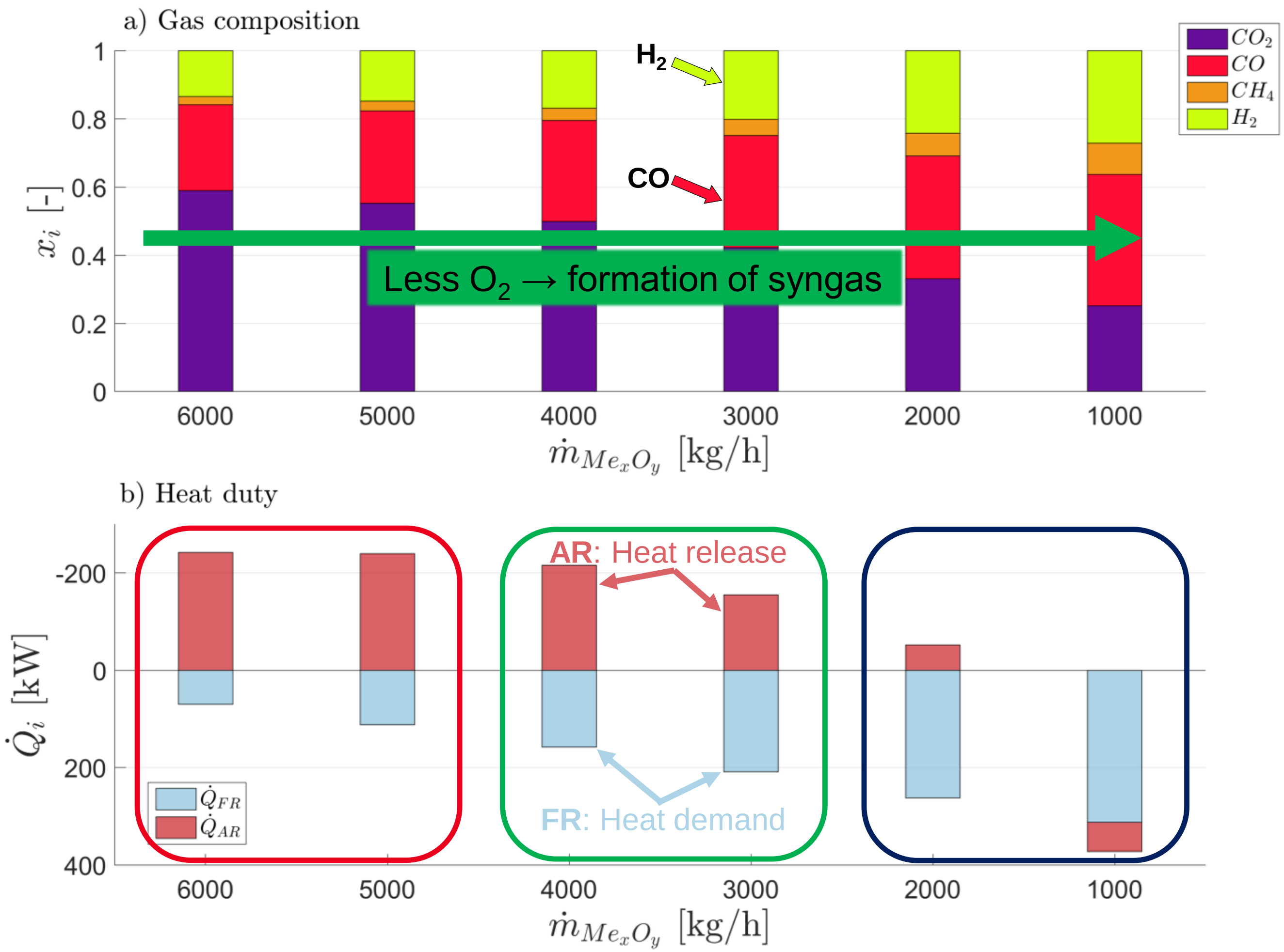
  - Water gas shift reaction

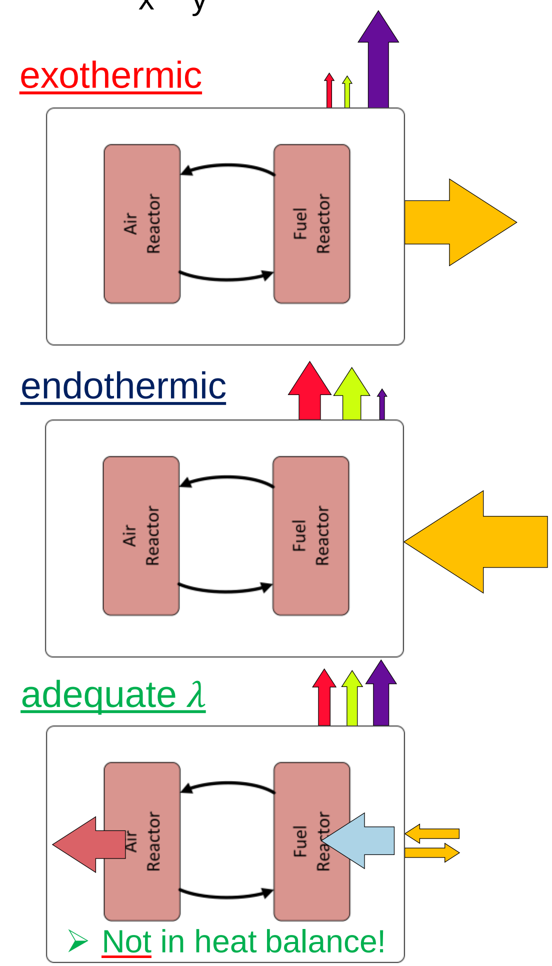
$$CO + H_2O \leftrightarrow H_2 + CO_2$$

➢ Continuous conversion of feedstock to syngas without N_2-dilution

Chemical Looping Gasification (CLG) – Mode of Operation (I)

- Control of heat & oxygen transport through circulation rate of Me_xO_y





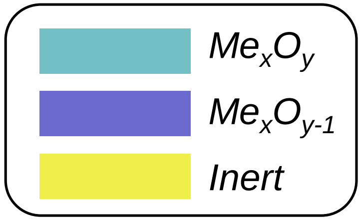
➢ Challenge: achieving adequate λ **and** sufficient heat transport

Chemical Looping Gasification (CLG) – Mode of Operation (II)

- Challenge: achieving adequate λ, while guaranteeing sufficient heat transport

a. Adjustment of reactor temperature gradient (lower T_{FR})

b. Decoupling of heat and oxygen transfer



- Approach I: **Dilution of metal oxide** with solid inert (e.g. Sand)
- ➢ Oxygen transport capability decoupled from heat capacity

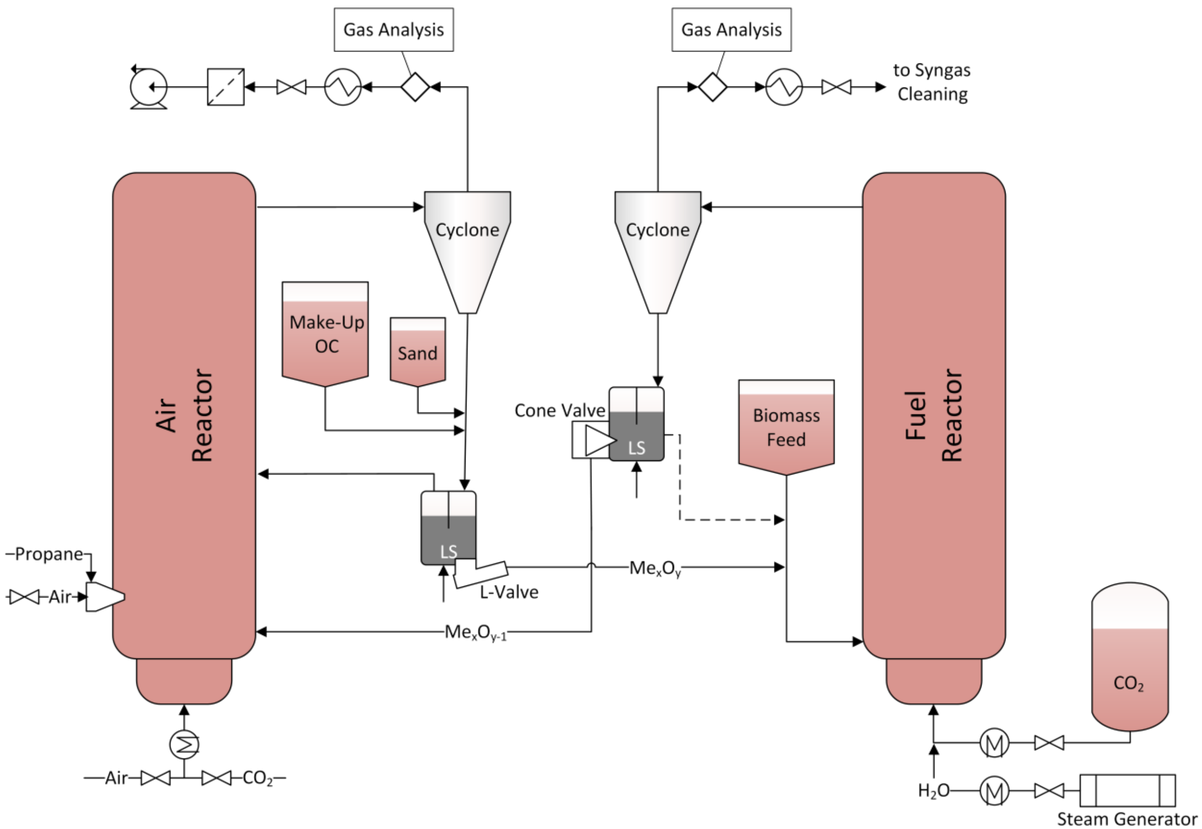
- Approach II: Metal oxide exhibiting **low O-transport capacity & high c_p**
- ➢ Oxygen & heat transport in the required “ratio”

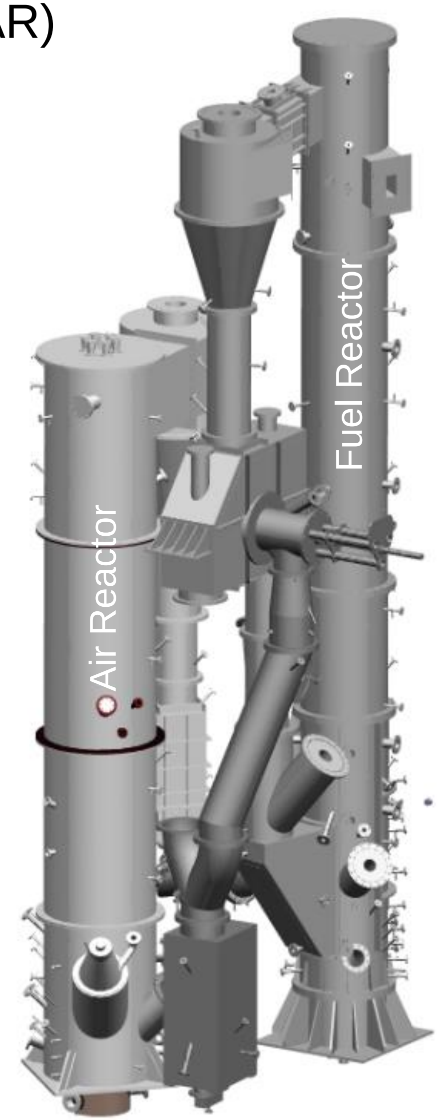
- Approach III: Operation of **air reactor in O_2 deficient atmosphere**
- ➢ Oxygen availability in fuel reactor controlled through air supply

➢ Different approaches are currently being investigated

Chemical Looping Gasification (CLG) – Plant Configuration

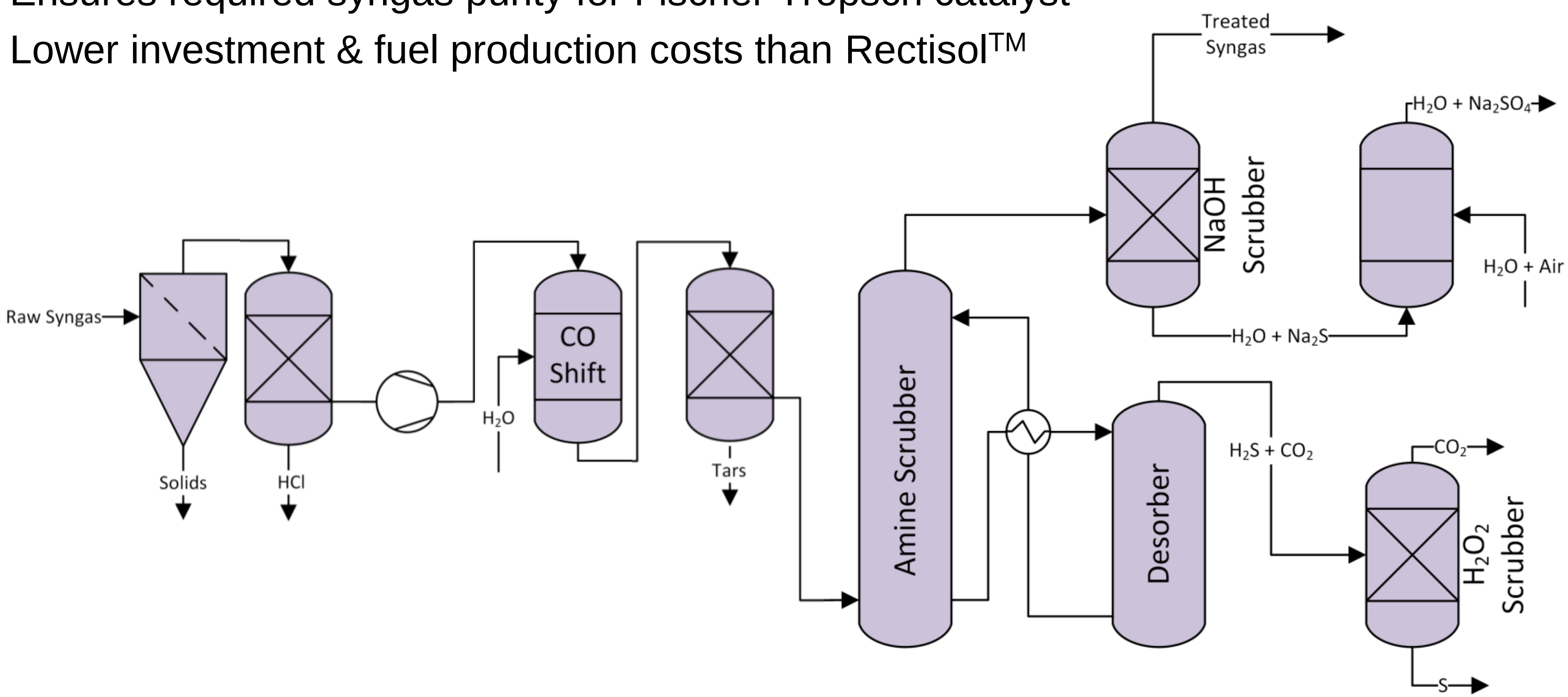
- Two coupled circulating/bubbling fluidized bed reactors (FR, AR)
  - Good heat & mass transfer characteristics
- Gas-solid separation via cyclones
- Loop seal (LS) as pressure seal
- Cone valve/L-valve for control of global solid circulation



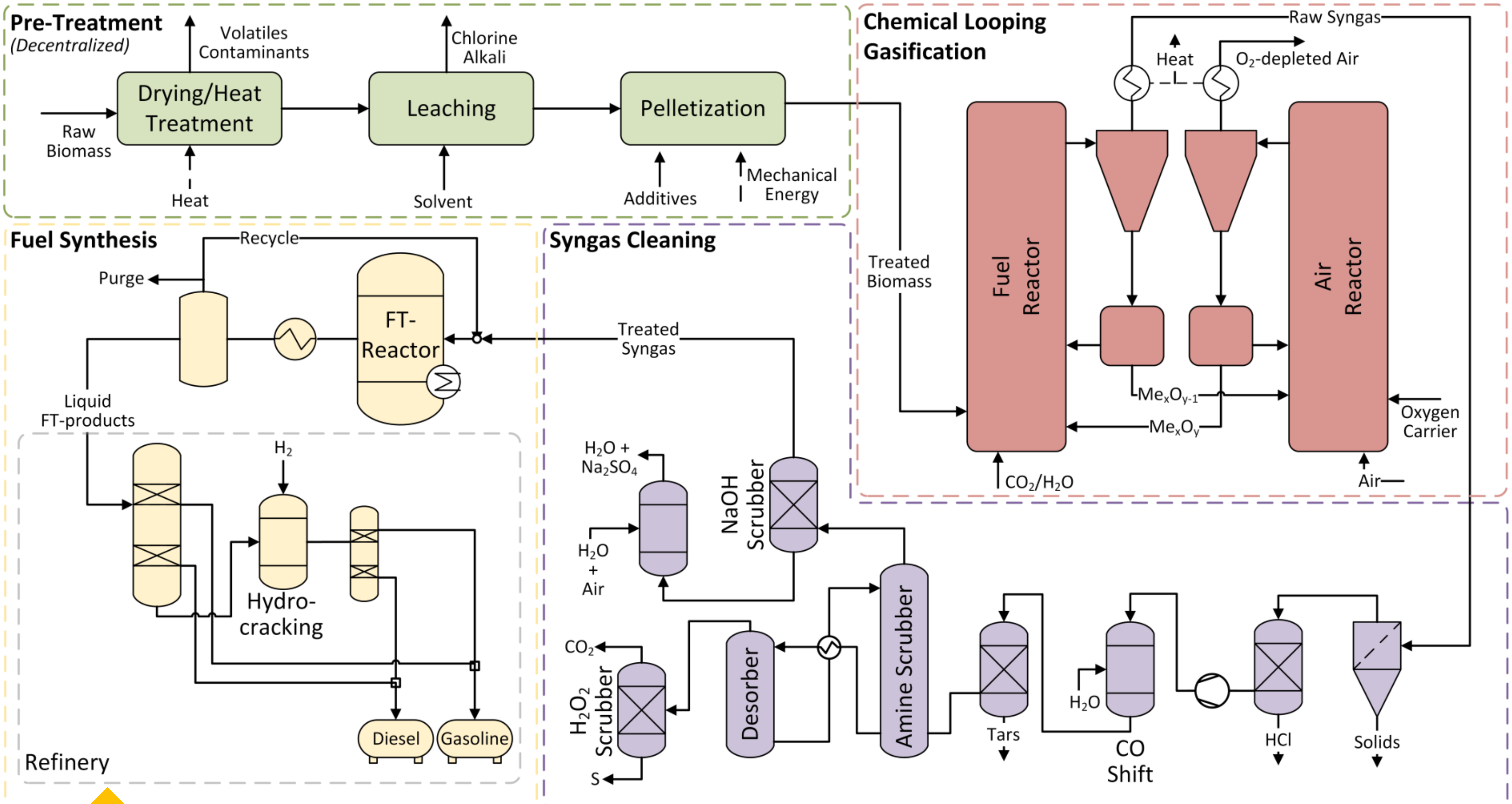


Syngas Treatment

- Hot gas filter for solids removal
- Scrubbing column (HCl removal)
- CO-Shift to adjust H_2/CO-ratio
- Efficient tar removal via biodiesel washing column
- Acid gas removal: Amine/NaOH/H_2O_2 scrubbers
  - Ensures required syngas purity for Fischer Tropsch catalyst
  - Lower investment & fuel production costs than Rectisol™



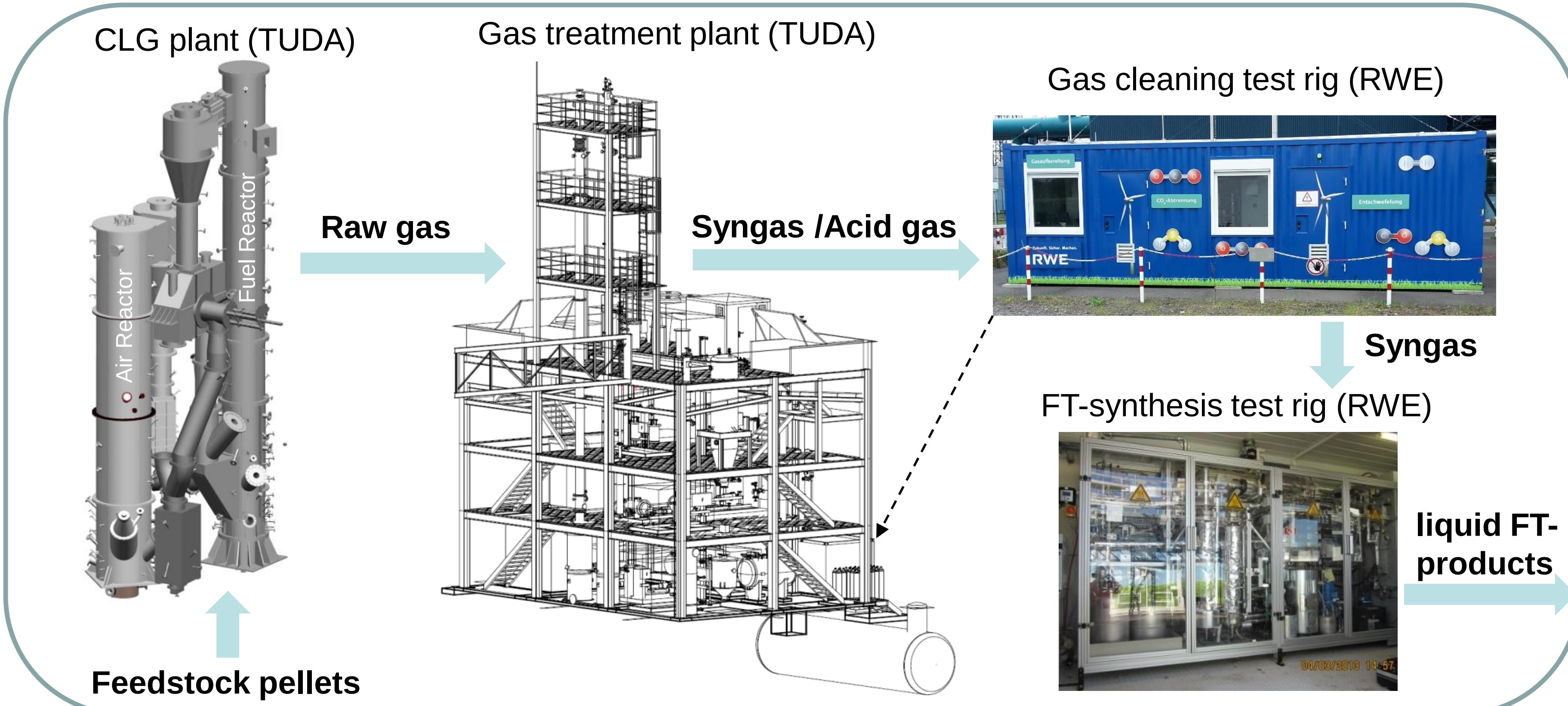
Full Process Chain



Utilization of available infrastructure → lower CAPEX

Summary & Outlook

- Novel biomass-to-biofuel process chain for second generation biofuels
- Innovative pre-treatment, gasification and syngas treatment concepts
- Investigation of full process in 1 MW_{th} pilot scale



Consortium & Funding

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Thank you for your attention!