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Preparation of a 1 MW_{th} pilot plant for full-chain 2nd generation biofuel production tests based on chemical looping gasification

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CLARA – Public Workshop
22 April 2021

Outline

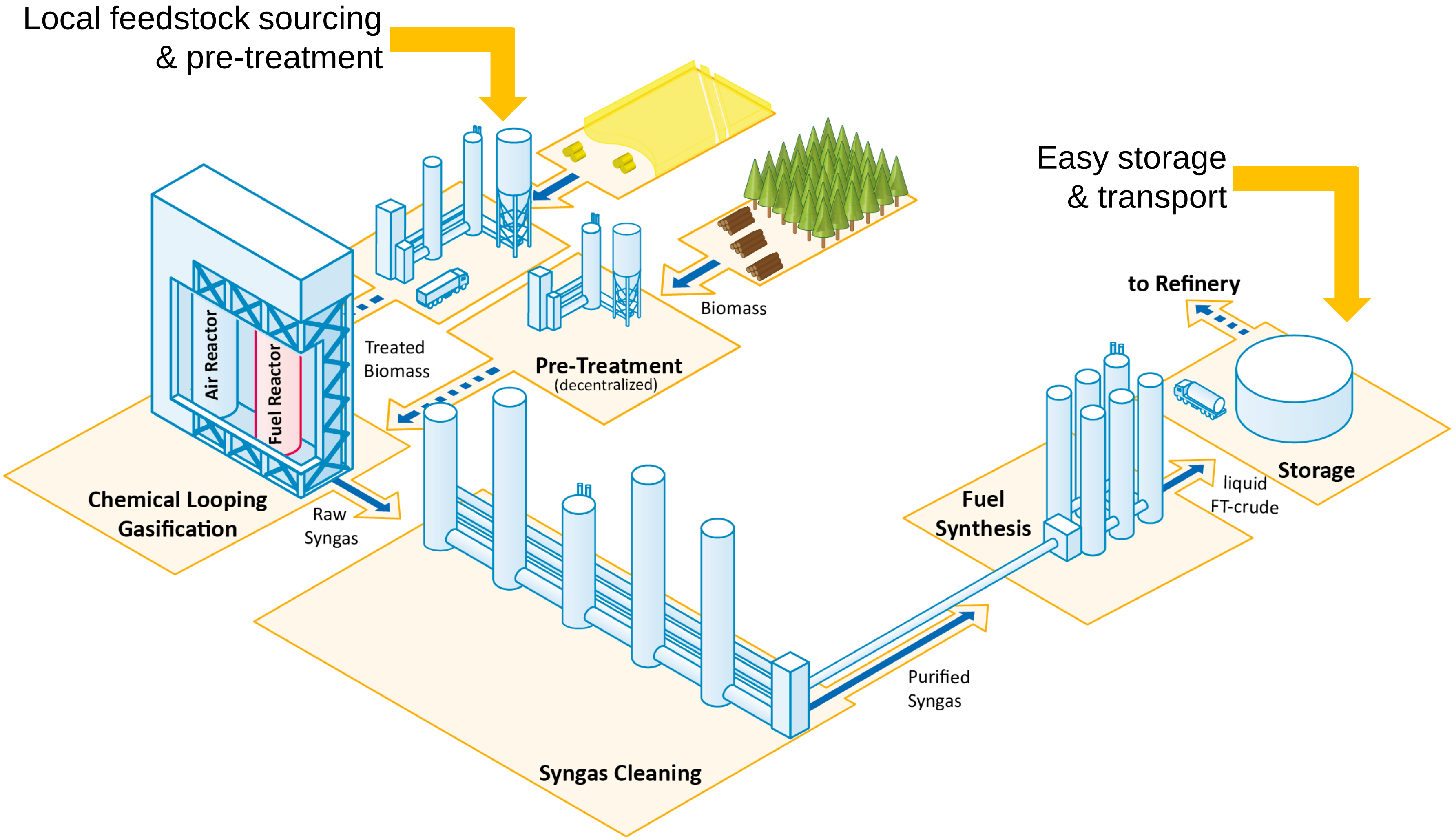
Full Process Chain

CLG Technology

Pilot Plant

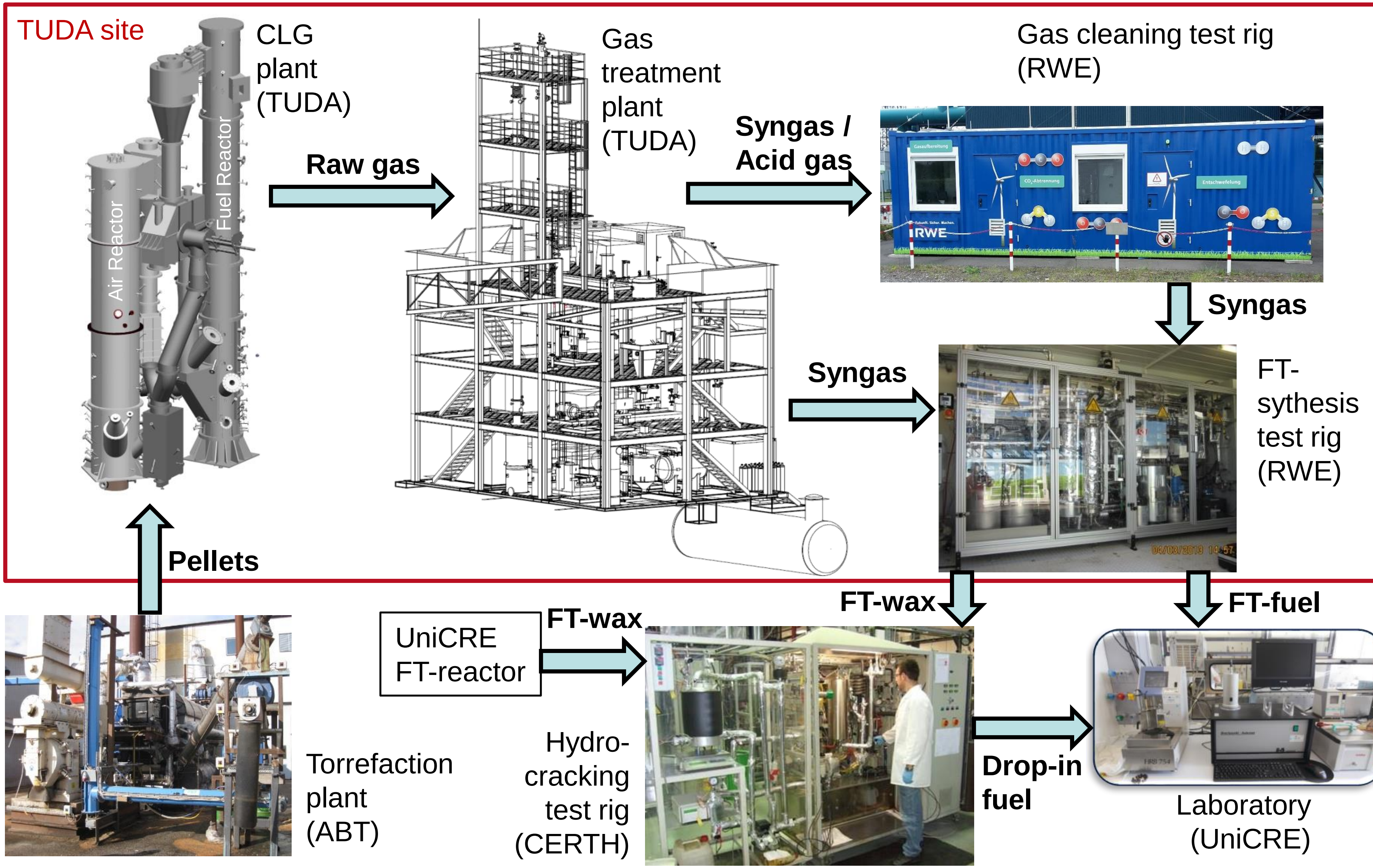
Summary & Outlook

Concept



➢Cost competitive and environmentally compatible fuels for road transport

Full-Chain Pilot Testing



Chemical Looping Gasification (CLG) - Reactions

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

    $$C + CO_2 \rightarrow 2\,CO$$

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

  - Heterogeneous Me_xO_y – gas reactions
  - Tar cracking
  - Steam methane reforming

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

  - Water gas shift reaction

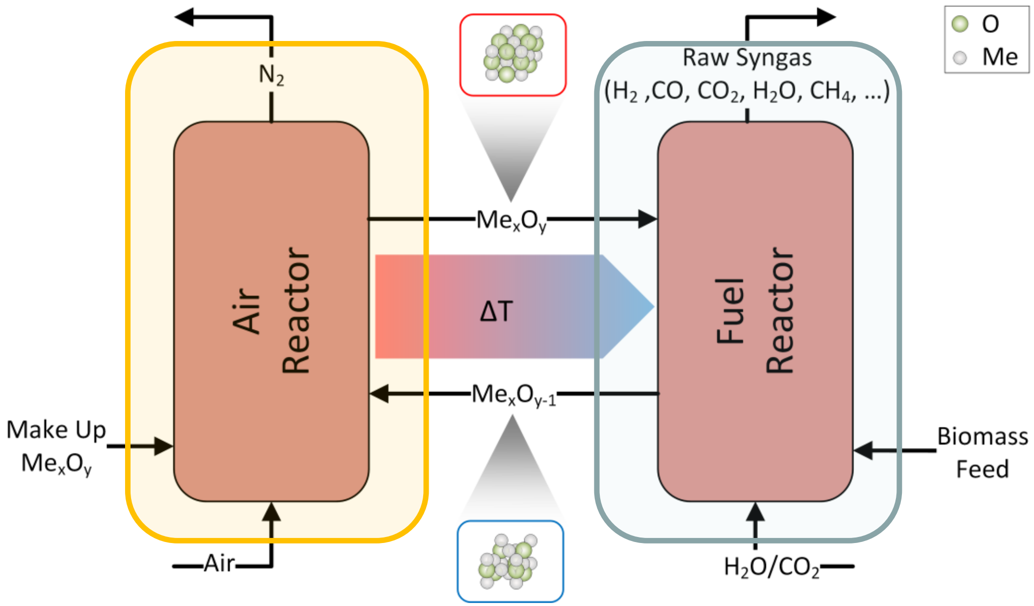
    $$CO + H_2O \leftrightarrow H_2 + CO_2$$

- 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

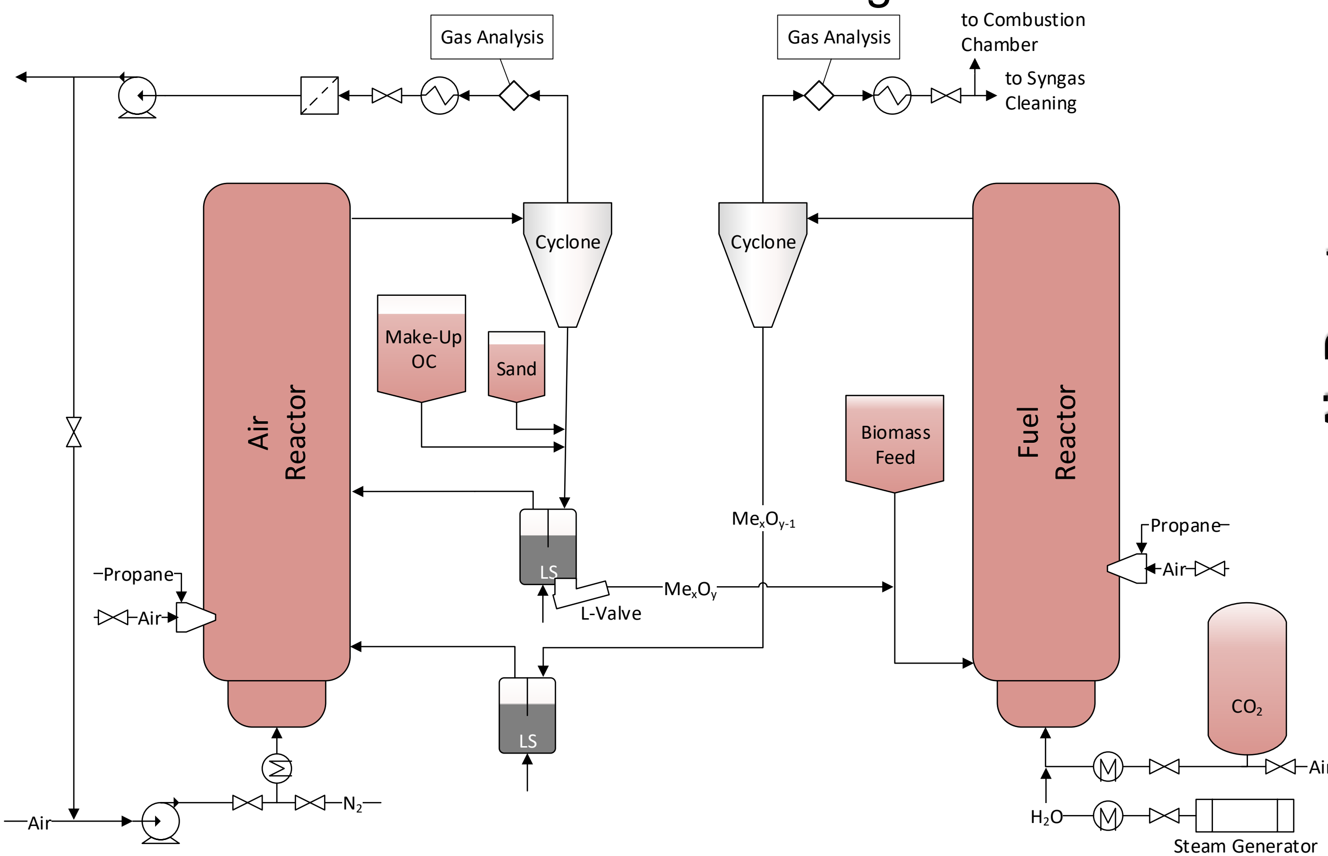
    $$C + O_2 \rightarrow CO_2$$

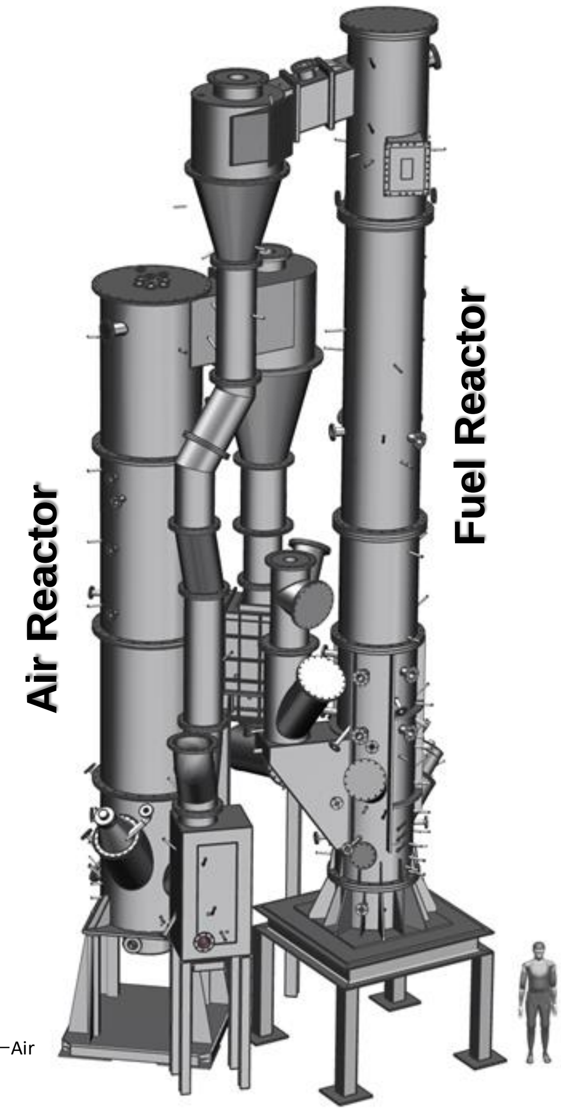


➢ Required energy must be provided by re-oxidation of oxygen carrier

Chemical Looping Gasification (CLG) – Experimental Setup – 1 MW_{th}

- Two coupled circulating fluidized bed reactors (FR, AR)
  - Good heat & mass transfer characteristics
- Operation experience in chemical looping combustion
- L-valve for control of global solid circulation
- No external electrical reactor heating → Autothermal

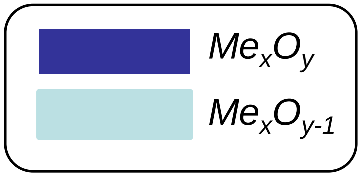




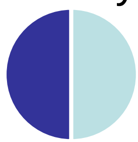
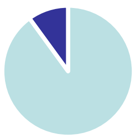
Chemical Looping Gasification (CLG) – Materials

- Oxygen carrier
  - Oxygen transport capacity
  - Thermodynamic suitability
  - High reactivity
  - Stability
  - Carbon deposition
  - Fluidization properties
  - Cost
  - Toxicity
  - Catalytic properties
  - Availability
- Biomass feed stock
  - Wood pellets
  - Pine forest residues
  - Wheat straw pellets

Chemical Looping Gasification (CLG) – Process Control



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

AR:  FR: 

- Advantages:
  - One material
  - Independent control of heat and oxygen transport
  - Catalytic activity of reduced oxygen carrier
  - Easy to implement
  - Fast to respond to changes
- Challenges
  - Air reactor fluidization and discharge
  - Attrition at low oxidization levels
  - Char combustion in oxygen deficient air reactor
    - ➢ Not a Problem: Char conversion favoured over OC oxidation

Chemical Looping Gasification (CLG) – Process Design

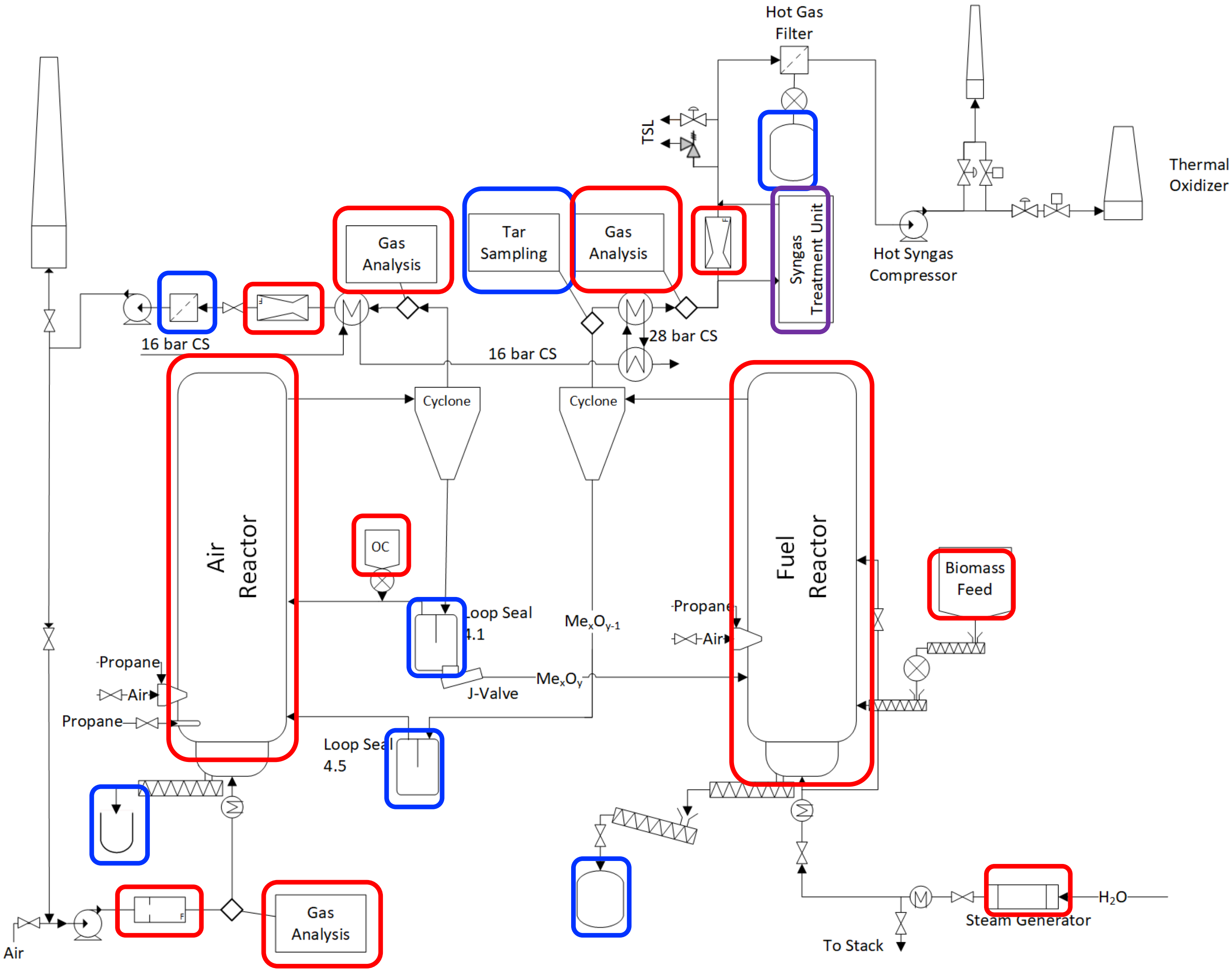
- Fuel: Wood pellets
- Oxygen carrier: Ilmenite
- Thermal design of 1 MW_{th} (Cooling system)
- Process control strategy: Limitation of oxygen inside air reactor

- Heat and mass balances

✓ CLG feasible in the existing pilot plant
➢ Major increase in syngas handling equipment needed
➢ Minor changes for air reactor

➢ Side stream for cleaning (250 m^3/h) and fuel synthesis (5 m^3/h)

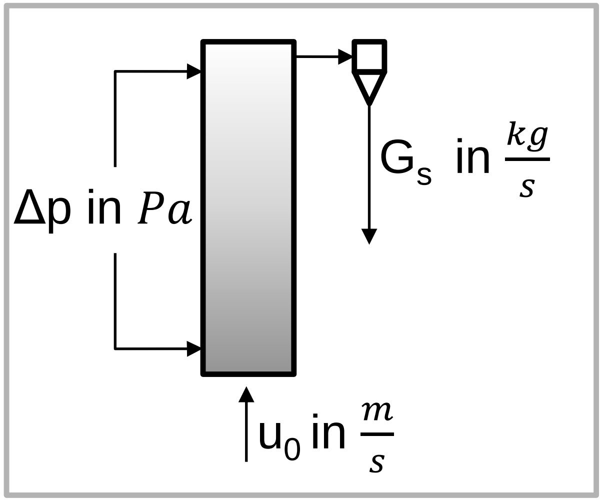
Chemical Looping Gasification (CLG) – Plant Design



Chemical Looping Gasification (CLG) – Autothermal Pilot Plant Operation

- Hydrodynamics:
  - G_s, Δp and u_0 not independent

u_0 ↓	G_s ↓	if Δp →
Δp ↑	G_s ↑	if u_0 →



- Thermodynamics:

G_s ↓	ΔT ↑	η_{cg} ↑	G_s not measurable!
ϕ ↑	T ↑	η_{cg} ↓	
P_{th} ↑	η_{cg} ↑	if autothermal	needs adjustments in G_s and ϕ

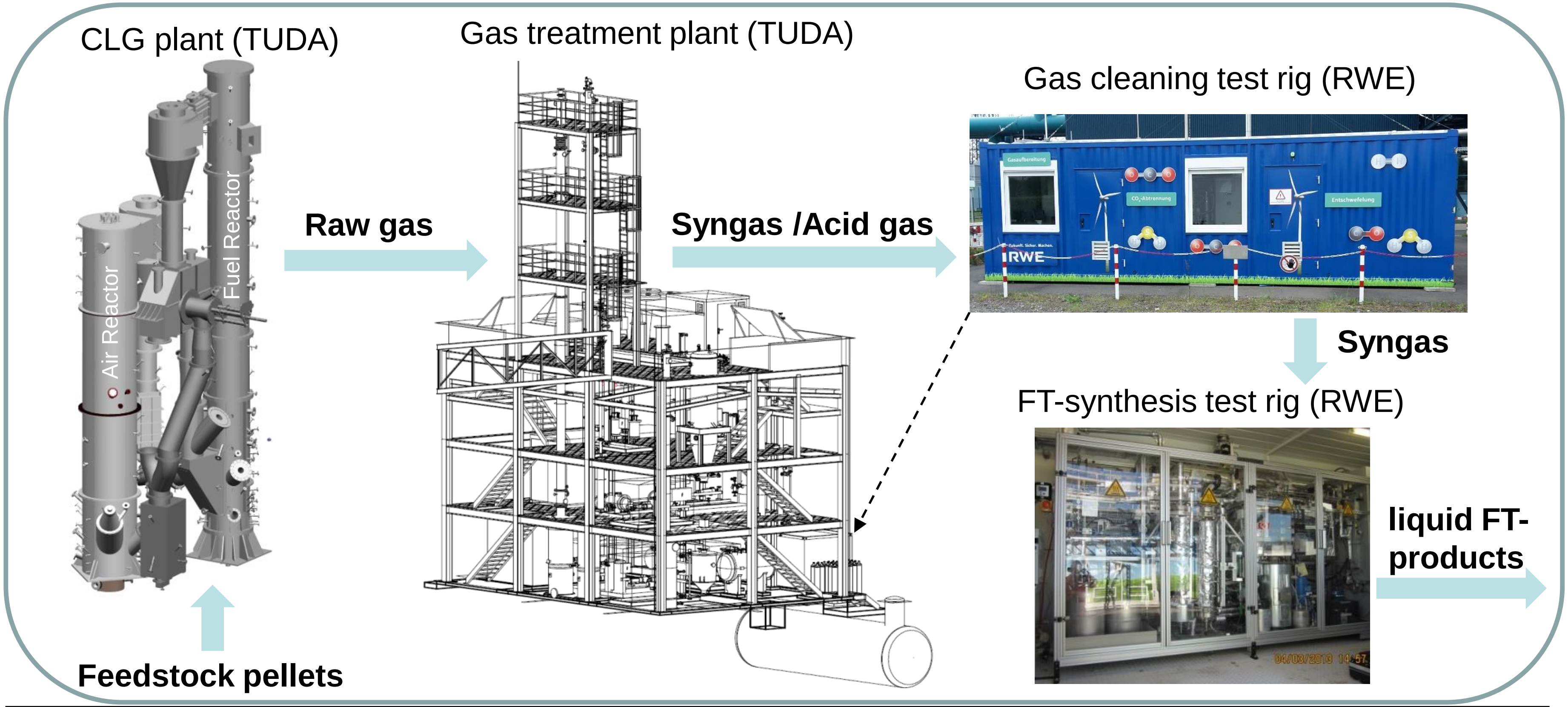
➢ P_{th} as high as safely possible

➢ Δp (reactor inventory) as high as limited by reactor hydrodynamic

cg: cold gas
ϕ: oxygen carrier to fuel equivalence ratio

Summary & Outlook

- Design of autothermal pilot plant for CLG
- Process control can be achieved via G_s, P_{th}, ϕ
- Key performance indicators: $\eta_{cg}, \eta_{cc}, x_{SG}$, syngas quality (tars, CH_4)
- Full process chain with real syngas can be experimentally investigated



Consortium & Funding

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No *817841*: Chemical Looping gAsification foR sustainAble production of biofuels (CLARA).

Thank you for your attention!