

BEST

Bioenergy and
Sustainable Technologies

FFG

COMET
Competence Centers for Excellent Technologies

Bundesministerium
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Das Land Steiermark

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Green gas and green fuels from dual fluidized bed biomass gasification

Paris, 22/10/2019

Walter Haslinger

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Content

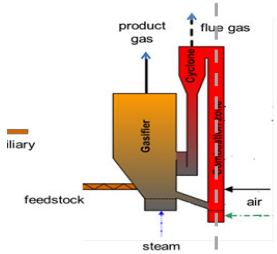
- Overview on dual fluidized bed (steam) gasification and some synthesis routes
- Selected examples of process chains towards
  - Green hydrogen
  - Green transportation fuels
- Outlook on demonstration
- Some conclusions

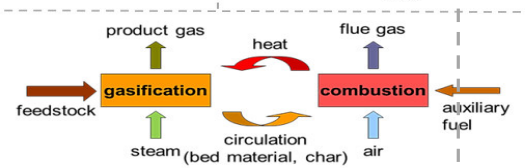
DFB-SG in a nutshell

Technology Overview

Product gas:

H_2: 40-45 %
CO: 20-25 %
CO_2: 20-25%
CH_4: 10-12%

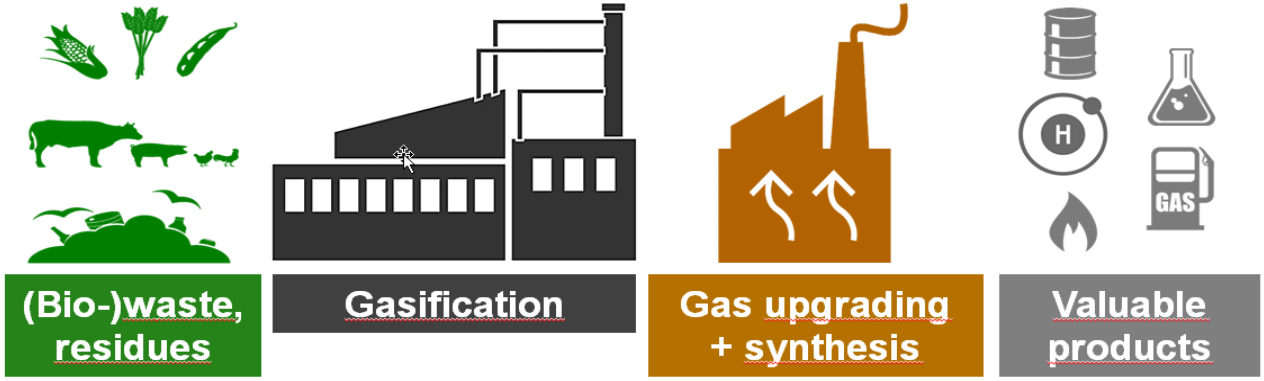




CHP Plants



Value Chain & End Use

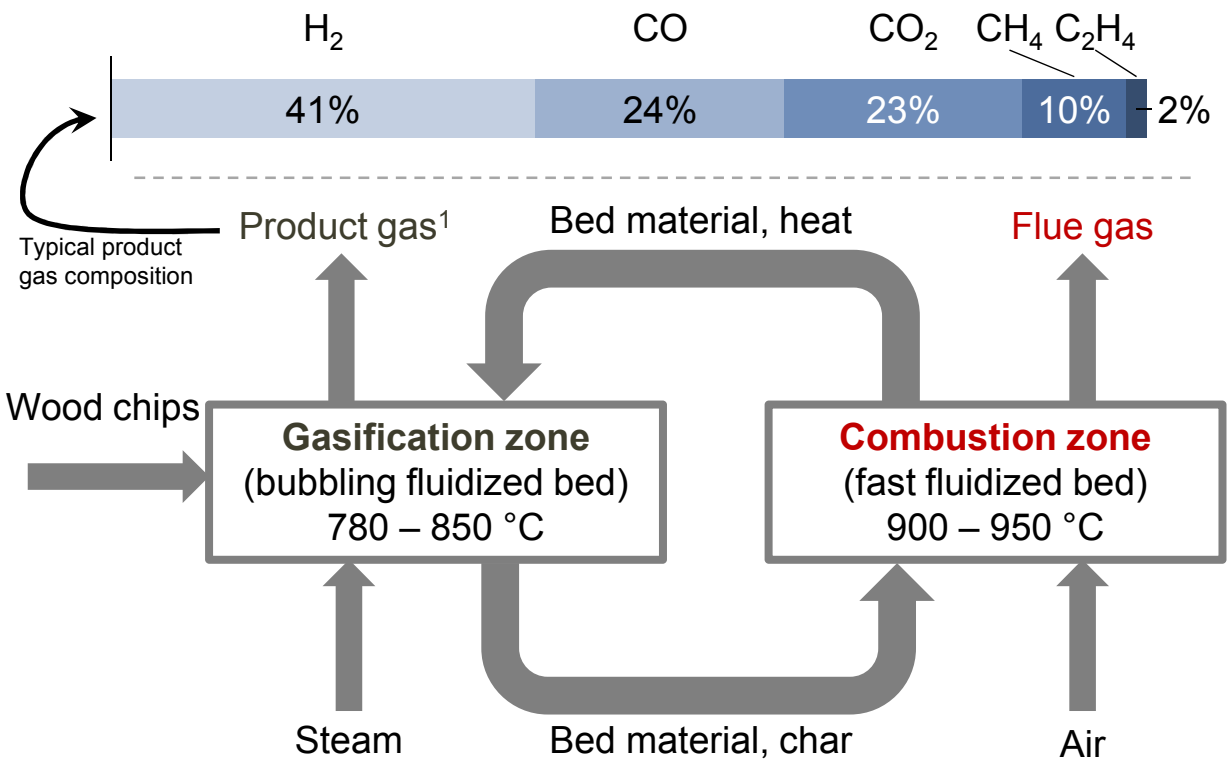


(Bio-)waste, residues | Gasification | Gas upgrading + synthesis | Valuable products

Dual Fluidized Bed (DFB) Steam Gasification

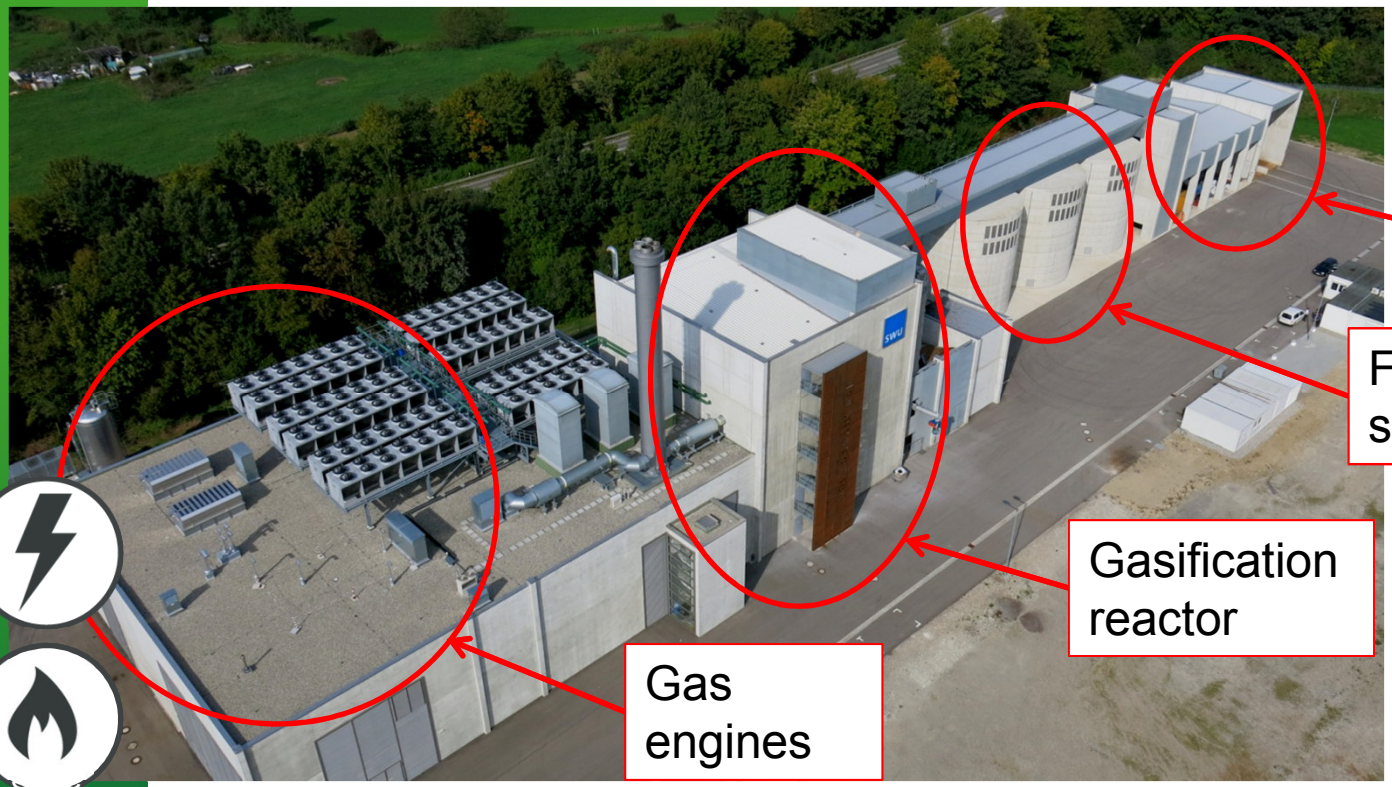
Biomass / waste is converted into mostly hydrogen and carbon monoxide – a so-called **product gas** (or synthesis gas) via **Dual Fluidized Bed Steam Gasification (DFB-SG)**.

Product gas is the starting point for a number of downstream conversion processes, like **H_2**, SNG or **Fischer-Tropsch** production.



1 Tar (incl. BTEX): 20-30g/m³, H2S ~100 ppm for biomass fuel before any gas cleaning for downstream processing

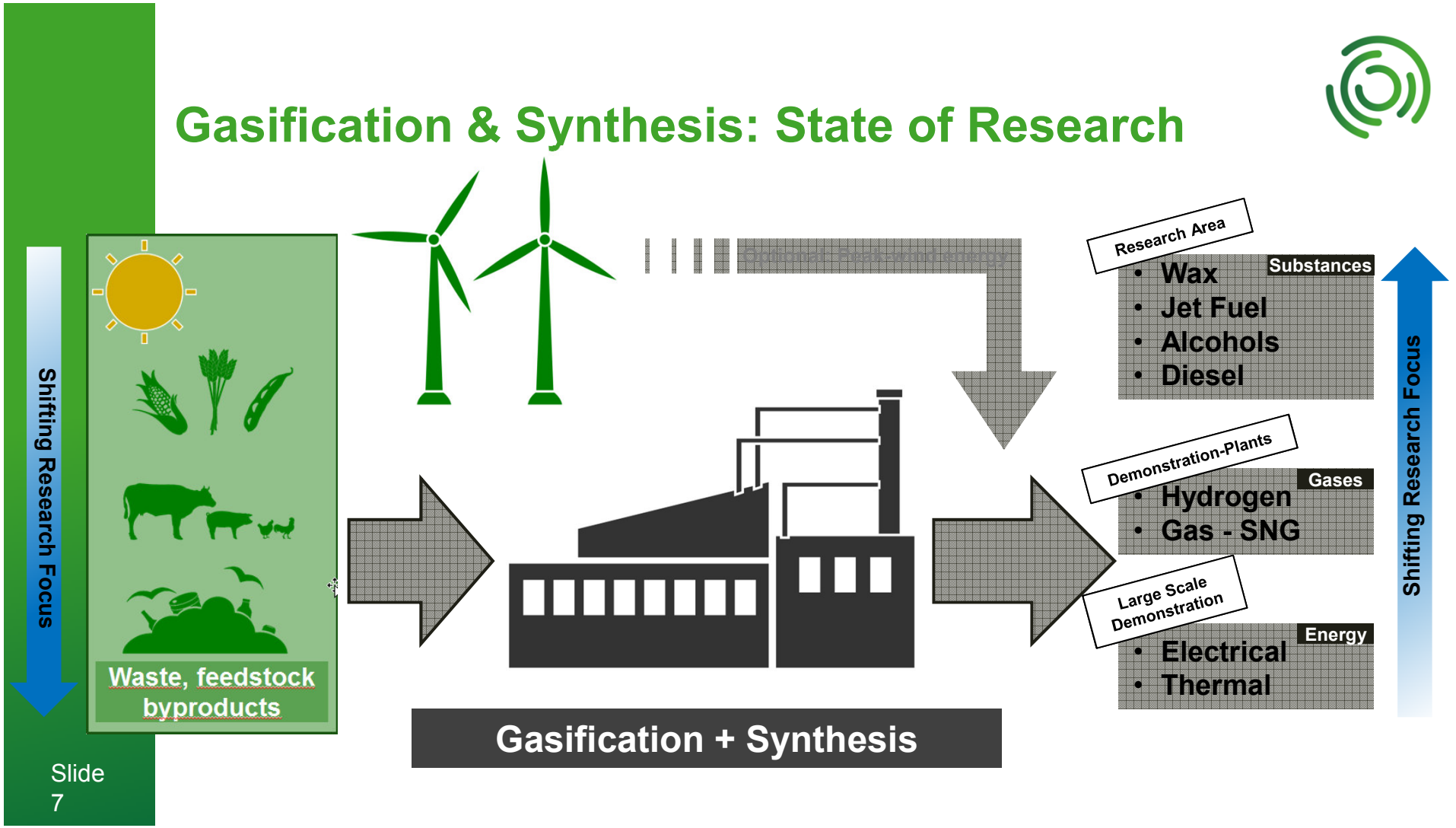
Example Senden Gasification Plant



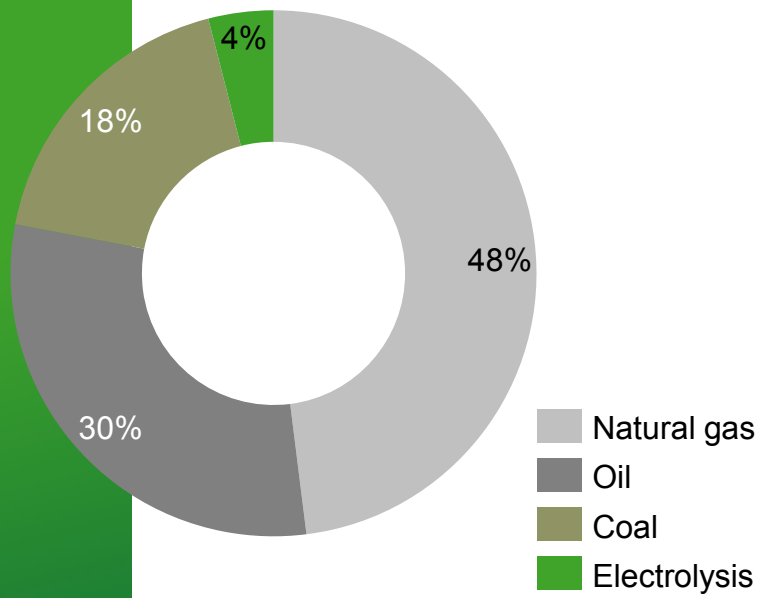


~100.000 operating hours in Güssing, up to 6500 hours per year in Senden with increasing trend.

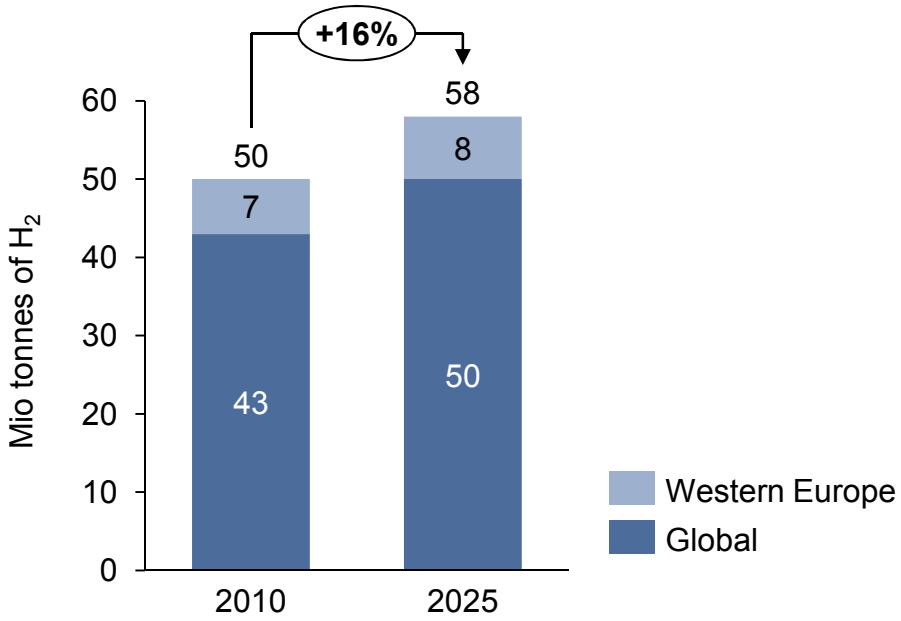
Gasification & Synthesis: State of Research



Primary Hydrogen Sources and Demand

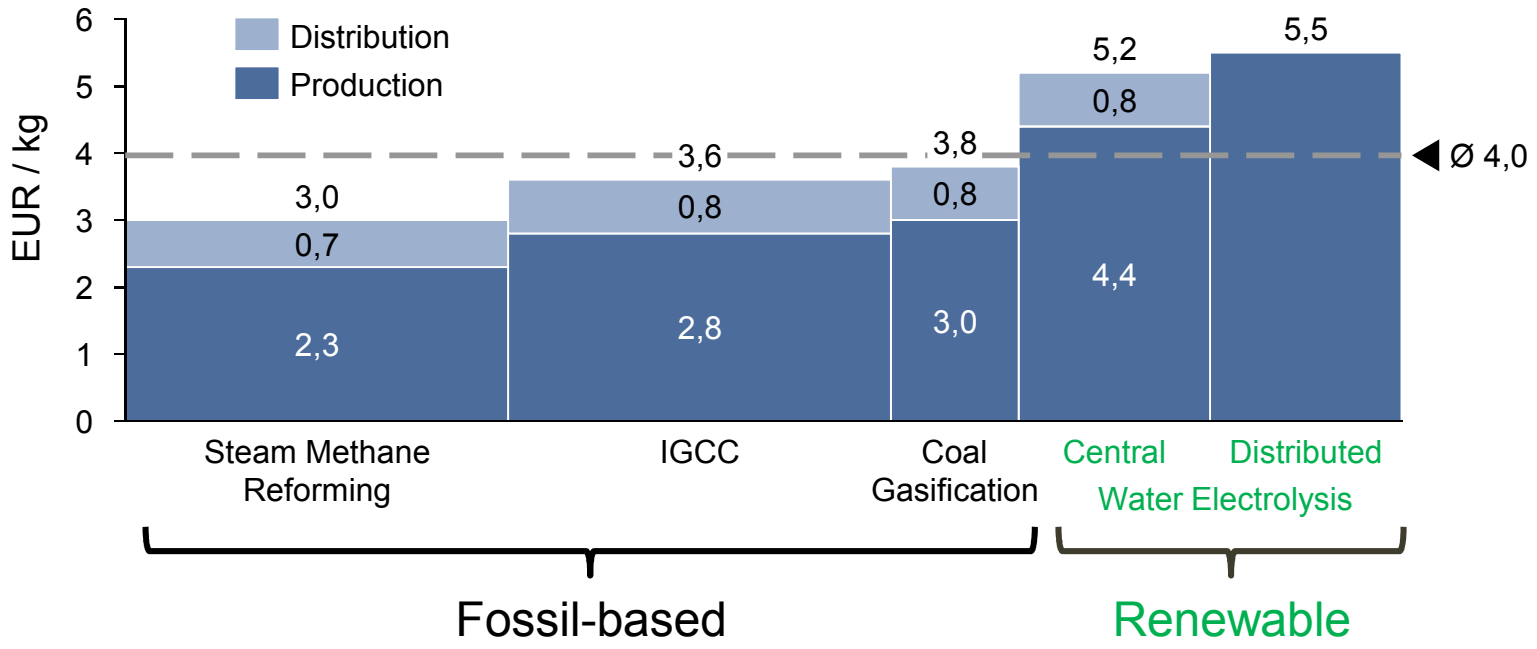


Current feedstock used for H_2 production. (Arregi et al., 2018)



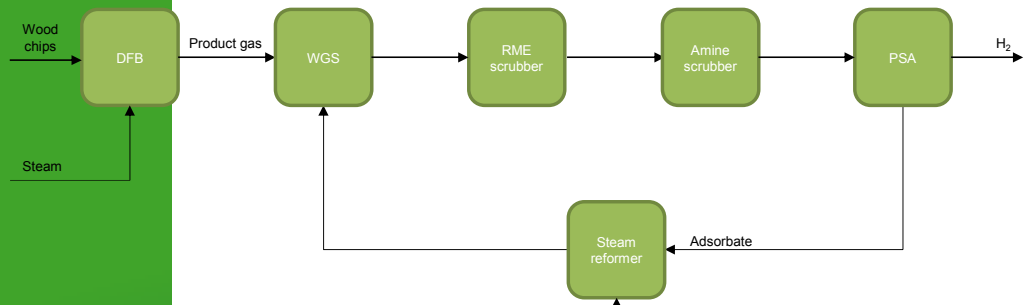
World Hydrogen Industry Study 2010 by Freedonia and Production and *Utilization of Green Hydrogen* by The Linde Group. (Fraile et al., 2015)

Expected Hydrogen Cost

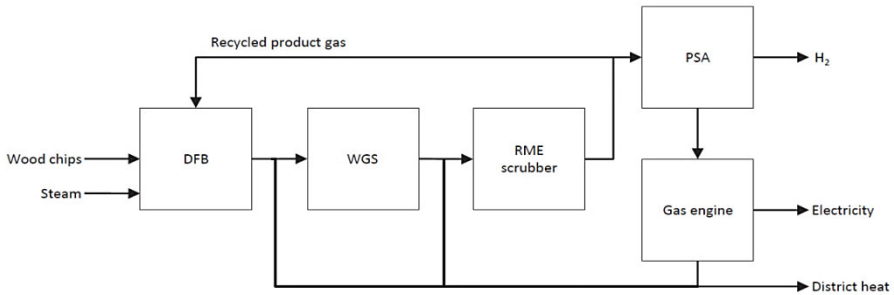


Projected 2030 H_2 cost [EUR/kg H_2] adapted from *A portfolio of power-trains for Europe: a fact-based analysis* by McKinsey in Cooperation with enterprises from sectors automobile, energy, industrial gases, fossil fuels and governmental organizations.

Process Layout for Hydrogen Production



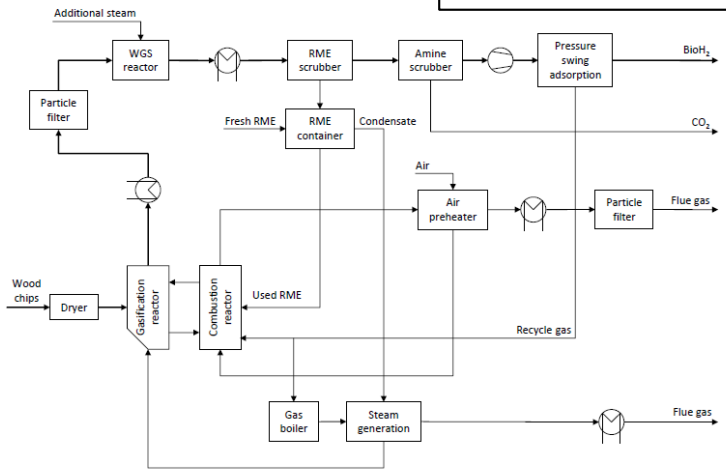
…with steam reformer



…with gas engine

Different layouts are possible due to local (market) situation and size of the plant, also influencing efficiencies.

…with gas boiler



From Biomass (or Waste) to Hydrogen



77% CGE

Outlet 50 °C, saturated
= CHP configuration

CO_2 removal efficiency 99%
2.4 $MJ_{(th)}$ + 0.4 $MJ_{(el)}$ / kg CO_2

H_2 recovery 85%

Wood chips

DFB

Product gas

WGS

RME scrubber

Amine scrubber

PSA

H_2

@10 bar, >99,97 %

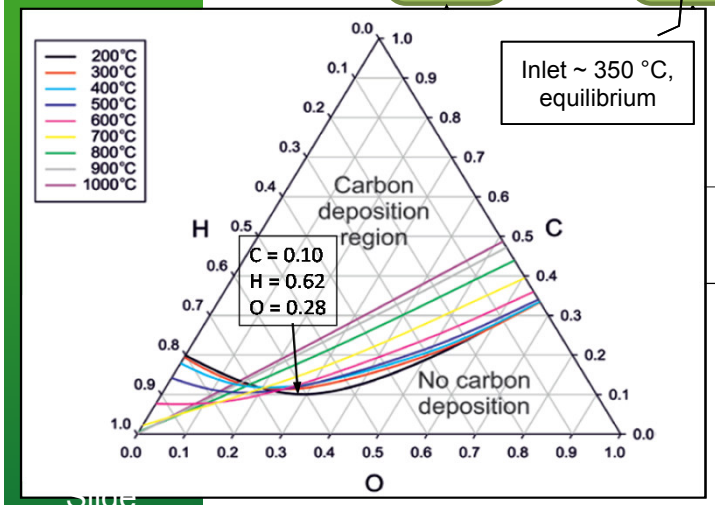
compression

Inlet ~ 350 °C, equilibrium

Steam reformer

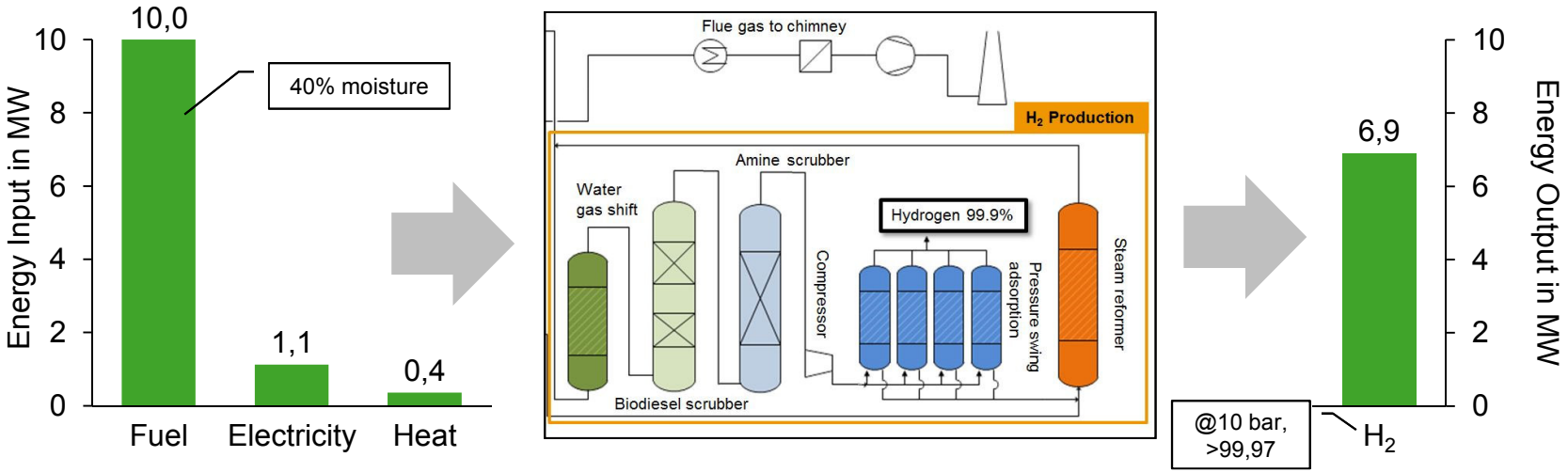
Adsorbate

S/C = 2.5



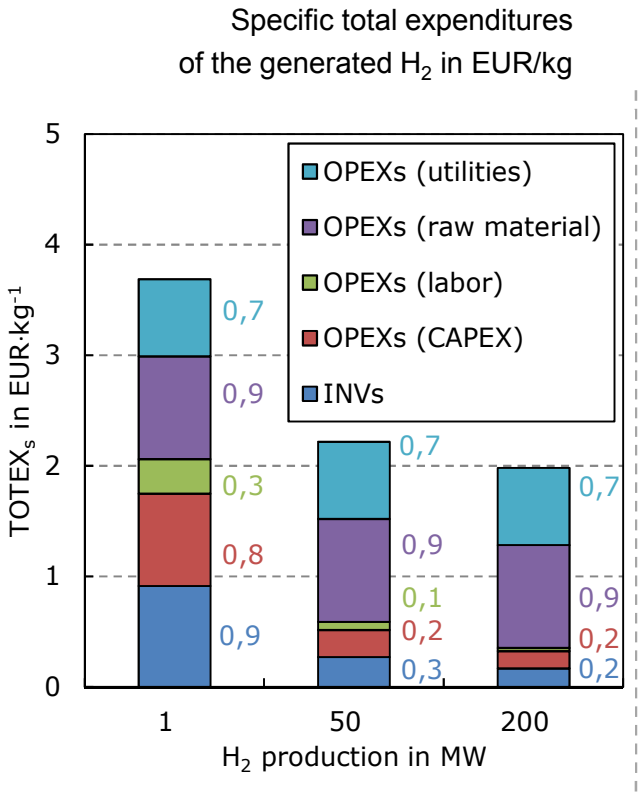
Tar, BTEX, and sulfur components were not taken into account.

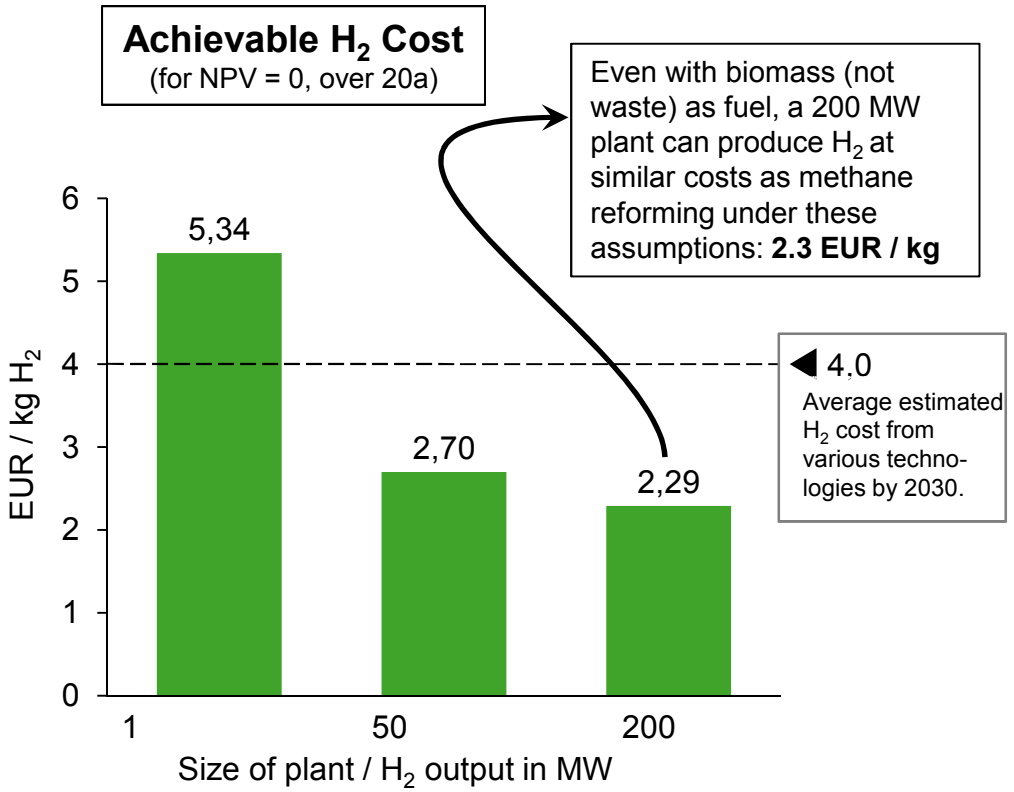
Overall Efficiency for Hydrogen via DFB



- Chemical efficiency: ~69%
- Electric consumption: ~10% fuel power for misc. consumption + compressor + amine scrubbing
- Overall efficiency: ~60%
- Cold gas efficiency of gasifier: ~77 %

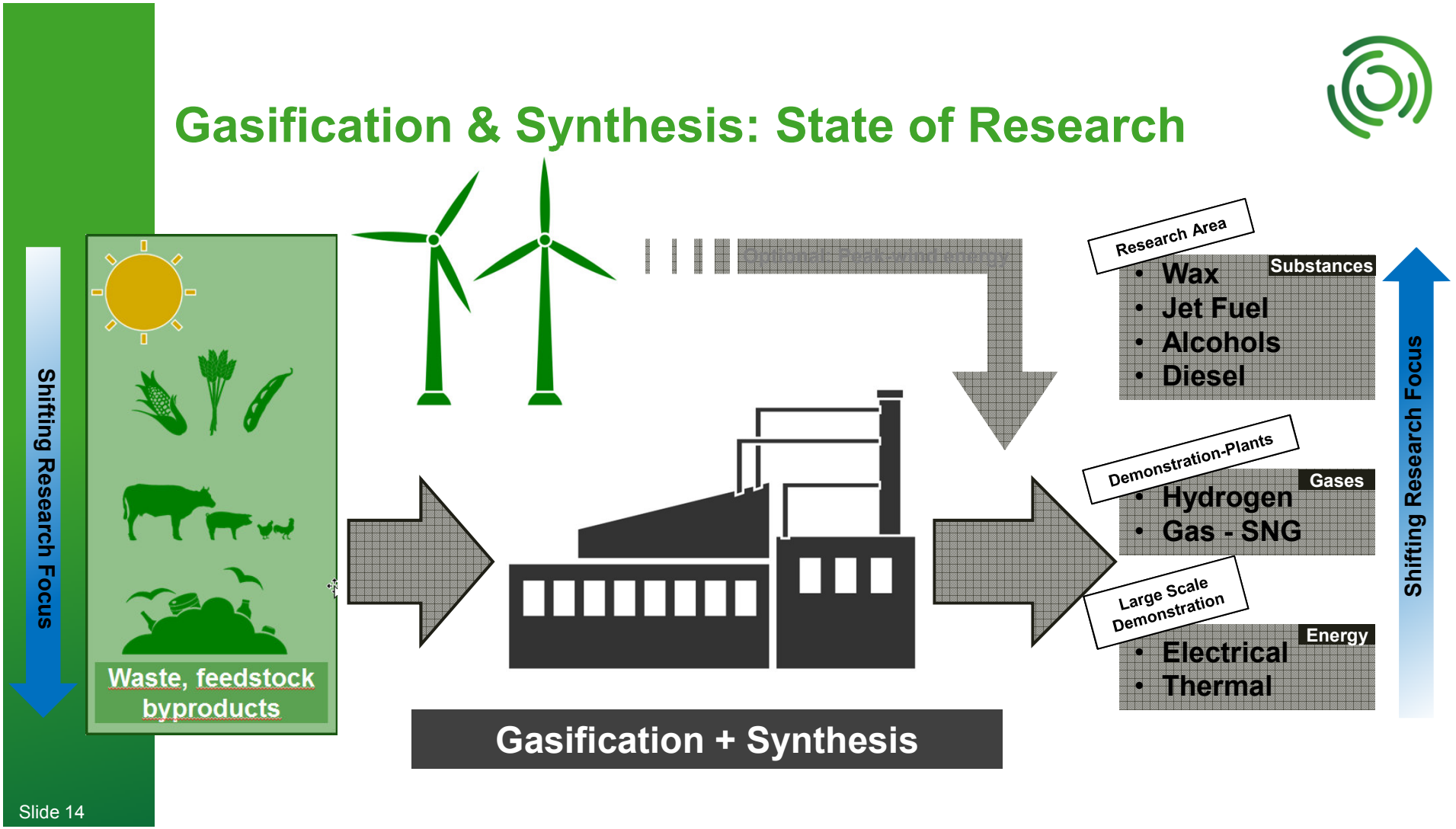
Plant Size and H_2 Production Cost



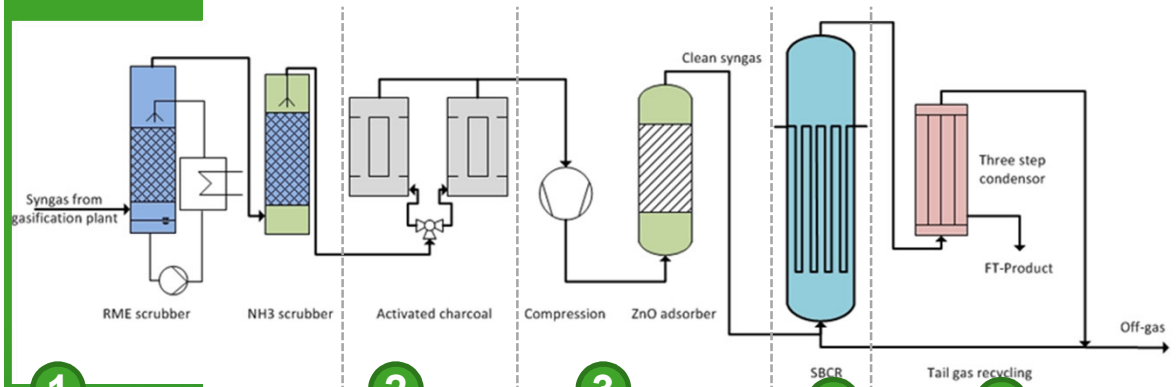


wood chips

Gasification & Synthesis: State of Research



Fischer-Tropsch Synthesis – Technology



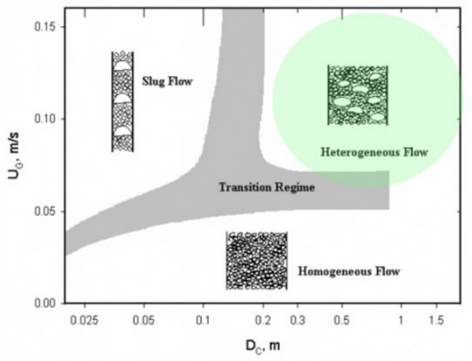
The smaller one of two Fischer-Tropsch test rigs of BEST

1. removal of tars, BTX and NH_3
2. removal of BTX and sulfur
3. 3 stage compression sulfur removal
4. FT slurry bubble column reactor (SBCR)
5. 3 stage product condensation (FT liquids & waxes)



Lab scale FT plant

- 15 kW-lab scale plant in operation since 2005, more than **10,000 hours of operation,** fully automated plant for unmanned operation over longer time
- **Design data lab scale plant:**
  - Temperature: 200-250 °C
  - Pressure: 15-25 bar_a
  - Space velocity: 1000-3000 h^{-1}
  - 5-10 liters day^{-1} of FT raw product



- Variation of process parameters temperature, pressure, space velocity and gas composition were carried out
- **Slurry reactor,** because of excellent heat transfer and easy scaling up, several catalysts based on iron and cobalt tested successfully
- **High efficient gas cleaning section** → sulfur content before FT reactor below 10 ppbv

Pilot FT Plant (one barrel per day)



In **autumn 2016 a FT pilot plant in the scale of 1 barrel per day of production capacity was commissioned.** With this **pilot plant** valuable knowledge **on the way from the laboratory to the industrial plant** can be gained.

- Temperature range: 200-250 °C
- Pressure: 18-24 bar_a
- Production capacity: ~ 0.5-1 BPD

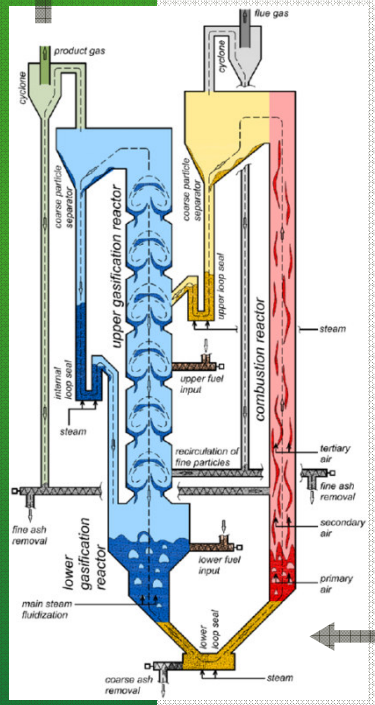
The pilot scale represents an important milestone on the way to a commercial-sized demonstration facility. A possible size for a **demo unit** would be a production capacity of **60-120** barrel per day.







Biomass + Energy → Liquid Energy + Chemicals



CO_2 removal

FT-Synthesis

H_2/CO ratio = 2:1

CO_2 recycling for fluidization

H_2 from electrolysis (wind / PV)



Gasification and FT-synthesis can also be used as storage system of (cheap/surplus) electrical energy.

In the common DFB process, the gasification reactor is fluidized with steam. In this concept, a part of the steam is replaced with CO_2 that is removed form the product gas stream. This results in a higher CO content in the product gas and a H_2/CO ratio of 2:1+. The missing H_2 to reach the ideal ratio for FT-synthesis is supplied via electrolysis from PV and/or wind energy whenever there is a surplus (prices fall below a threshold).

The net effect is a very efficient gasification process that uses most of the biological carbon and the possibility to turn electrical energy into liquid fuel (diesel, kerosene, …) and wax/oil products.

The concept is cost-effective under current market conditions and has numerous advantages, not the least of which are a very high flexibility for buffering / storing electricity without the need to store gases like H_2.

Fischer-Tropsch Synthesis: Fuels & Chemicals

from idea to industrial implementation

2005

FT lab installation erected

Based on slurry reactor technology

First FT diesel produced

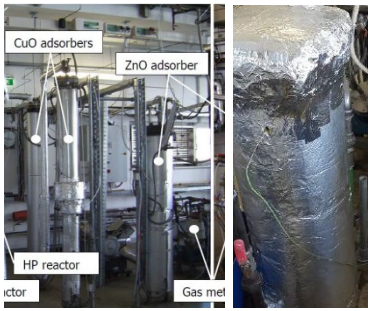


Slurry reactor

2009

Gas cleaning section & product separation improved

Upgrading of FT waxes to FT diesel & kerosene

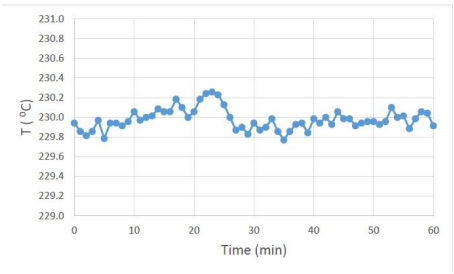


Gas cleaning improved

2014

Power-to-liquid concept “Winddiesel” demonstrated

Several thousand operating hours



T profile load change

2016/18

Planning, erection & startup of barrel per day pilot plant

Investigation started “FT to Chemicals”



Upscaling via CFM

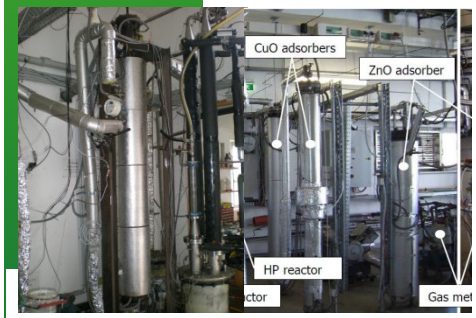
Roadmap for Further Technology Development

Stages towards industrial implementation

2005-2015

Development and improvement of FT technology in lab scale

Test of PtL application (“Wind diesel”)



2015-2019

Development of FT technology in pilot scale

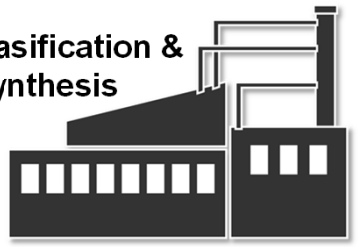


2019-2023

Improvement of economics:

- **Utilization of residues and waste streams as feed for gasification**
- **Valorization of complete FT product spectrum for industrial application**

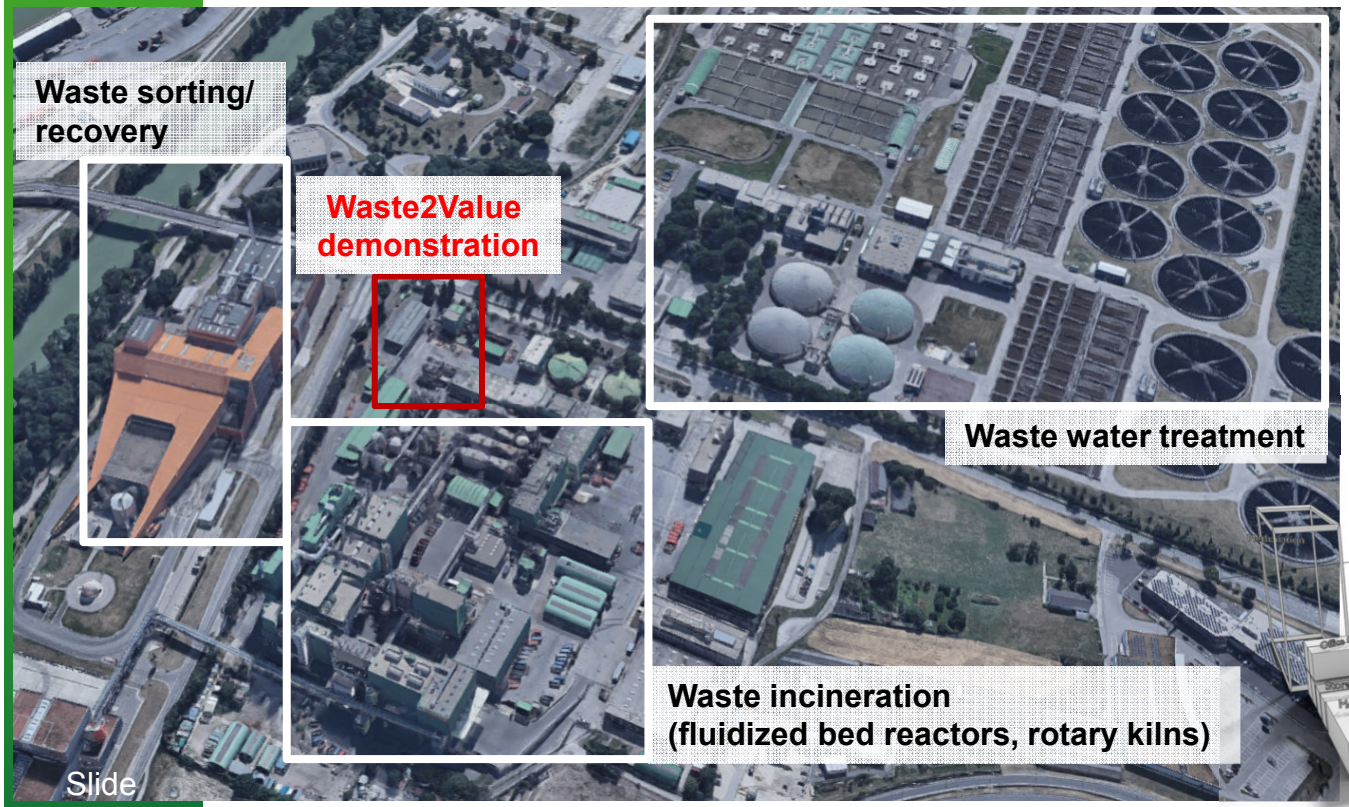
Gasification & Synthesis



>2024

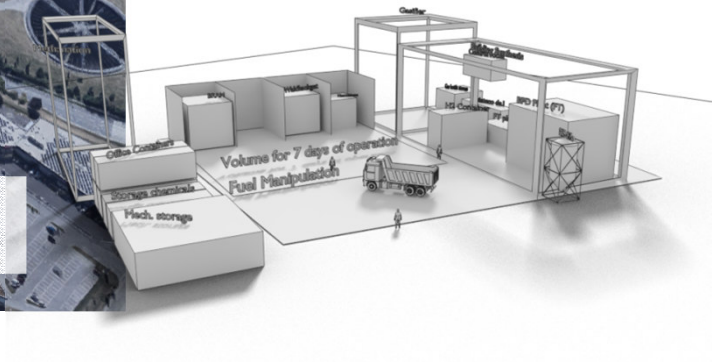
Demo scale plant (60-120 bpd)?

Demo at Waste Incineration Plant in Vienna



Waste2Value demonstration:

- DFB gasification of waste and residues
- Production of: Fischer-Tropsch fuels & chemicals, H_2, SNG, Mixed Alcohols, …
- System integration, CCU, …



Summary and conclusions



- DFB woody biomass gasification
  - Technically proven for CHP production
  - Demonstrated for SNG and H_2 production
  - At the research stage for FT (and mixed alcohols) production
- Process chains using residues and waste at the pilot demo stage
  - Full integration into industrial site under commissioning
- DFB plus subsequent synthesis processes additionally allow for
  - Sector-coupling (use of surplus electricity for adjusting optimum reaction conditions
  - Technologies are agnostic: Waste and CO_2 utilization as C source

Summary of further R&D needs



- Optimization and demonstration for scale-up purposes of
  - DFB gasification of low quality biomass and selected waste streams
  - the full process chains for the different synthesis pathways
  - the integration of surplus electricity
  - CCU options / the utilization of CO_2 as gasification agent and / or for synthesis
- Identification of process conditions to optimize element recovery from certain feedstock, eg
  - Phosphorous recovery (in plant available form) from sewage sludge

Successful R&D needs strong partners

- Thank you to the funding bodies and our industrial and scientific partners!
  - … Austrian Research Promotion Agency – FFG
  - … Institute for Chemical Engineering, Vienna University of Technology
  - … many industry partners, eg. ABB, Bilfinger Bohr- und Rohrtechnik, Güssing Renewable Energy, Hansen & Rosenthal, Mondi, Repotec – Aichernig Engineering, SMS, Wien Energie and many more

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