INTEGRATED PROCESS TECHNO-ECONOMIC EVALUATION AND FLEXIBLE POWER-TO-DME OPERATION MODE

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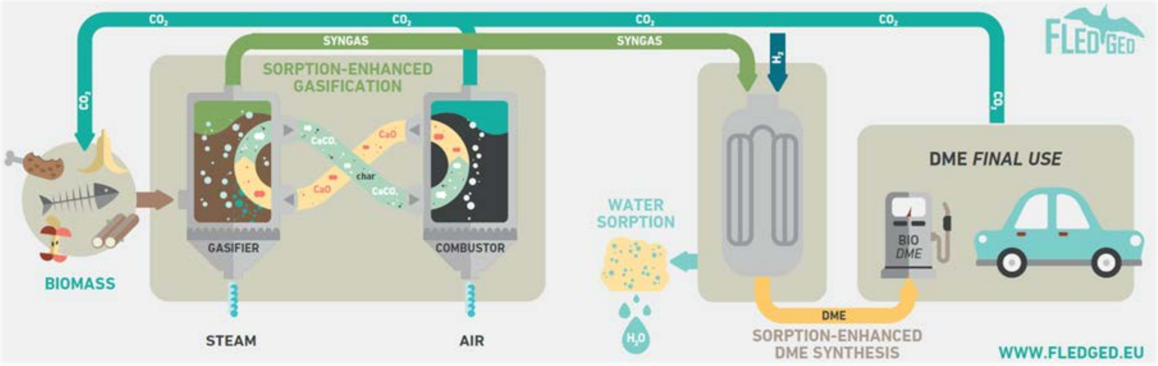
Process simulation and optimization activities

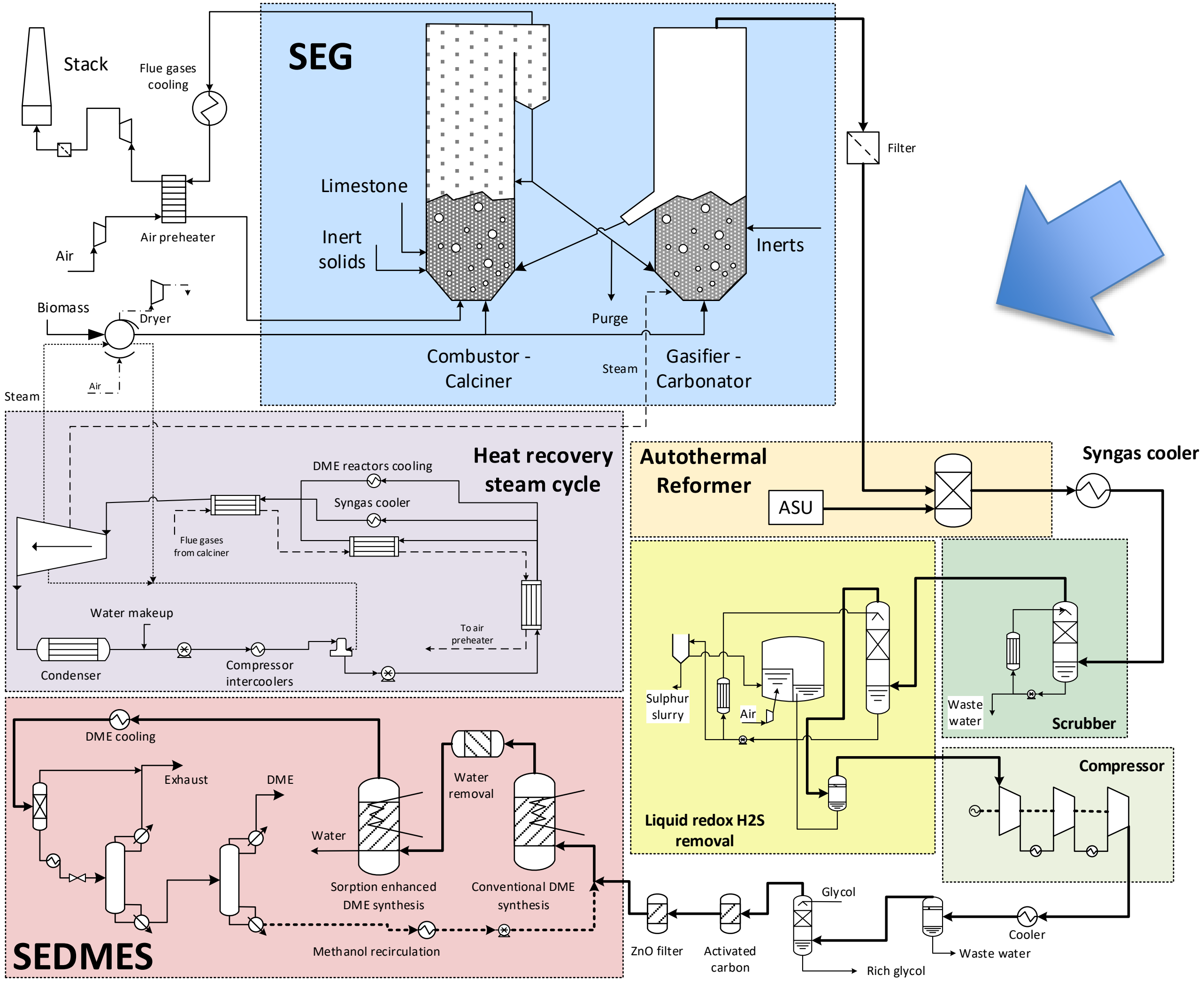
Process modelling and simulation activities *in FLEGDED project aim at establishing the performance of different alternatives for the complete integrated process in terms of:*

- ***Productivity and efficiency*** → *High DME yield*
- ***Cost*** → *Process intensification for cost reduction*
- ***Flexibility*** → *Different types of feedstock, CCS and RES-supported improved production*
- ***Social and environmental impact*** → *Input for LCA, social impact and risk assessment*

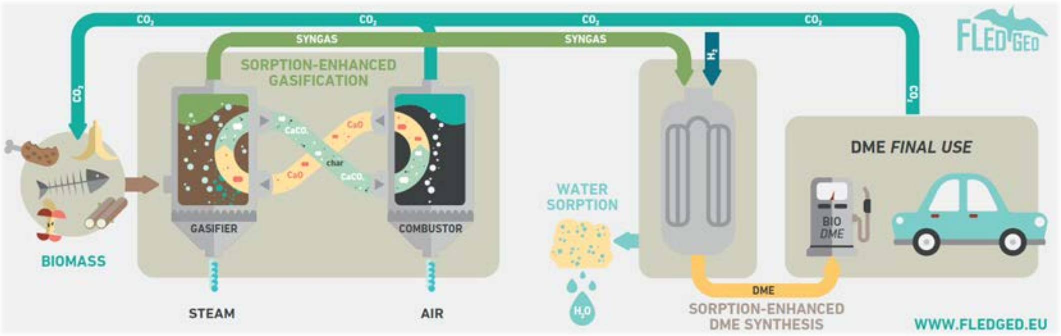


Most of the activities are ongoing with final results foreseen in the next months and a ***public deliverable*** *will be released with detailed methodology and results.*

FLEDGED – Process integration



From the concept…

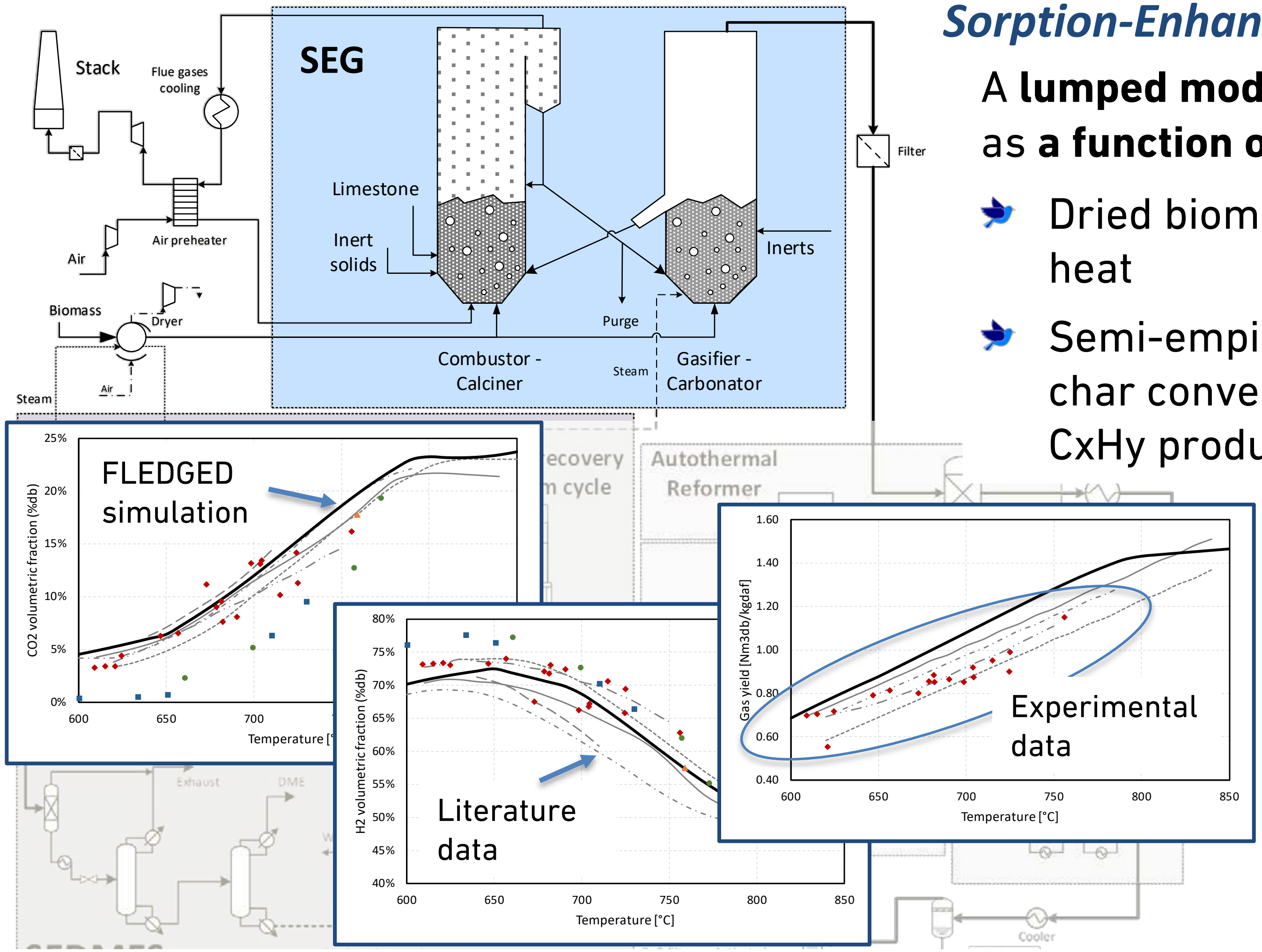


… to the integrated plant

The plant is designed and optimized:

- for a **100 MW$_{LHV}$ wooden biomass input** (large scale applications)
- for a **10 MW$_{LHV}$ treated municipal solid waste biomass input** (specific business case that will be presented in detail in the next presentation)

FLEDGED – Process integration



Sorption-Enhanced Gasification (SEG)

A **lumped model of the SEG** calculates energy and mass balances as **a function of the gasifier temperature**:

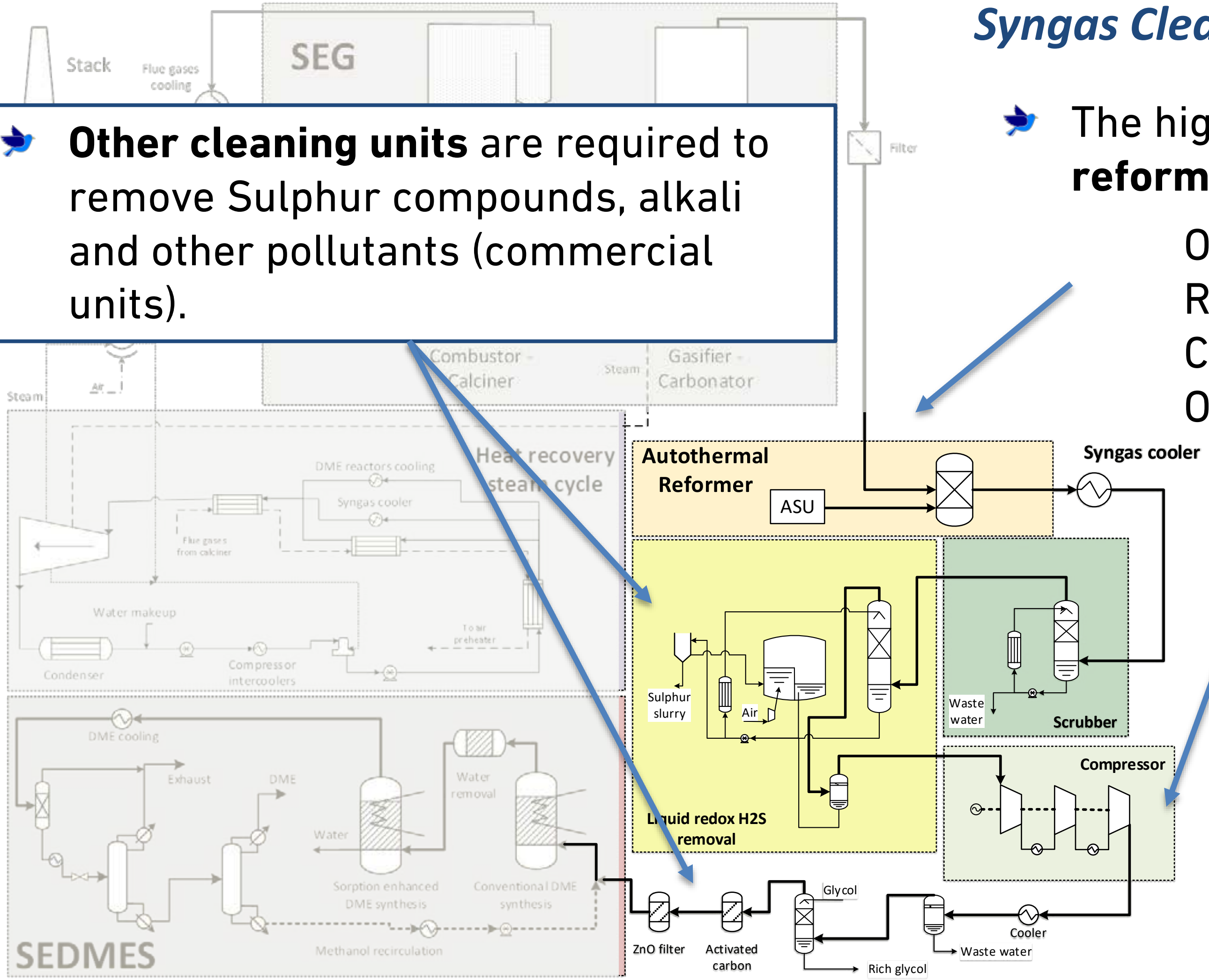
- Dried biomass from a tube bundle drier exploiting recovered heat
- Semi-empirical correlations are used to estimate the CaO and char conversion in carbonator, WGS reactions equilibrium and CxHy production
- Calibration and validation on data from literature and experimental activities

In reference conditions, the gasifier operates at 716°C, resulting in char conversion above 68% and 25% of separated CO_2.

Fuchs et al.[a], *Biomass Conv. Bioref.*, 2019; Koppatz et al.[b], *Fuel Processing Technology*, 2009; Alamia et al. [c], *Energy Tech.*, 2017

FLEDGED – Process integration

- **Other cleaning units** are required to remove Sulphur compounds, alkali and other pollutants (commercial units).



Syngas Cleaning and Conditioning

- The high methane content at the gasifier outlet requires a **reforming unit**:

  Oxygen blown autothermal reformer.
  Reformer temperature: 800 °C
  CH_4 conversion: 90%
  Oxygen demand: 0.04 kg/Nm^3_{syngas}

- A multi-stage intercooled compression unit rises the pressure to 25 bar.

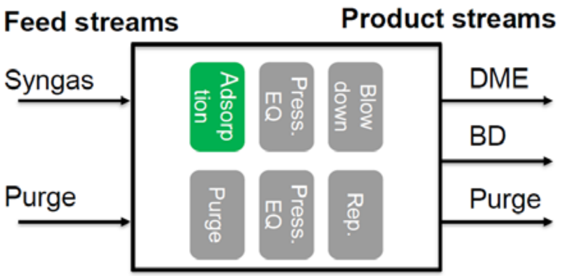
The **global conversion efficiency (CGE)** from dry biomass to conditioned syngas varies between 71% and 75% depending on the cases.

FLEDGED – Process integration

Sorption-Enhanced DME Synthesis

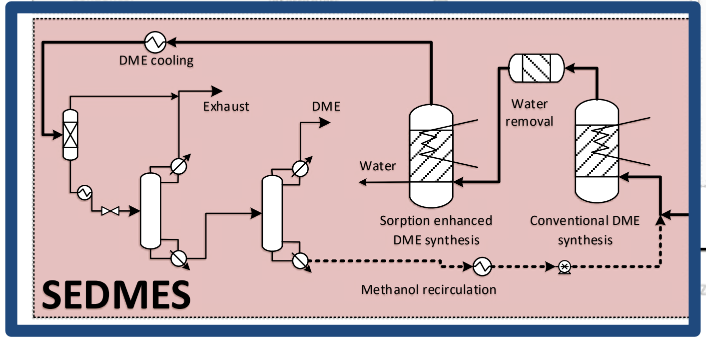
A **lumped model of the SEDMES** calculates chemical equilibrium and compositions according to the experimental results and detailed models from other WPs:

- Mass flow rate and composition are provided from TNO (intermittent cycling operation of SEDMES units)
- Regeneration phases generate a **purge stream** and a **blowdown stream (**recompressed and recirculated)
- Crude DME is sent to a **distillation section** to separate residual reactants, MeOH and water from the final product.



DME recovery: 99 $\%_w$
DME purity: 99.93 $\%_w$

Cryogenic section is required (-66°C)



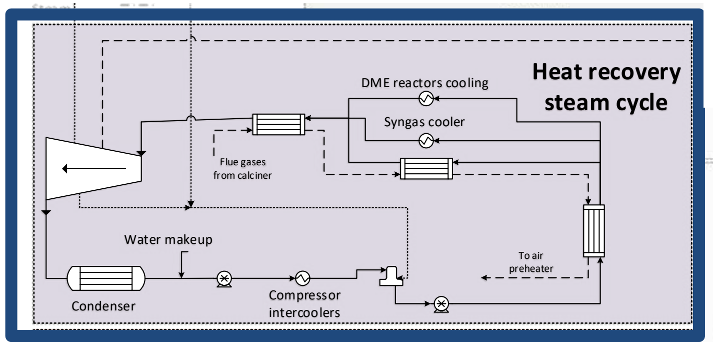
The global conversion efficiency (CGE) from syngas to DME is around 77%, but different options are still under investigation by TNO, considering variations in SEDMES operating parameters.

FLEDGED – Process integration

Heat recovery optimization

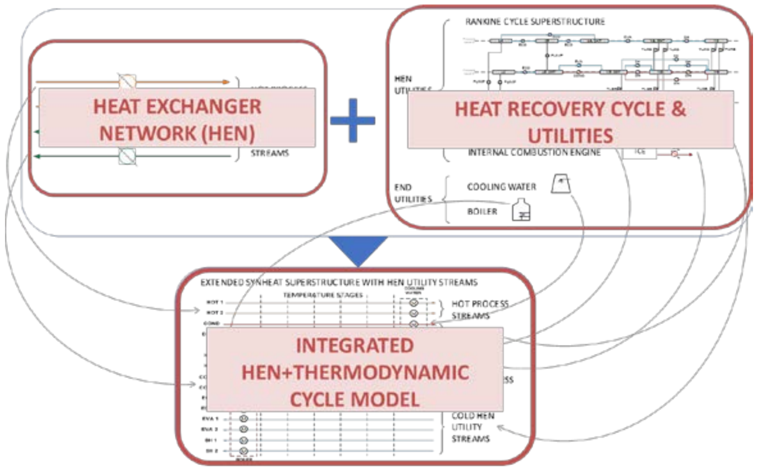
Simultaneous optimization of the layout of the **heat recovery steam cycle** and of the **heat exchangers network**:

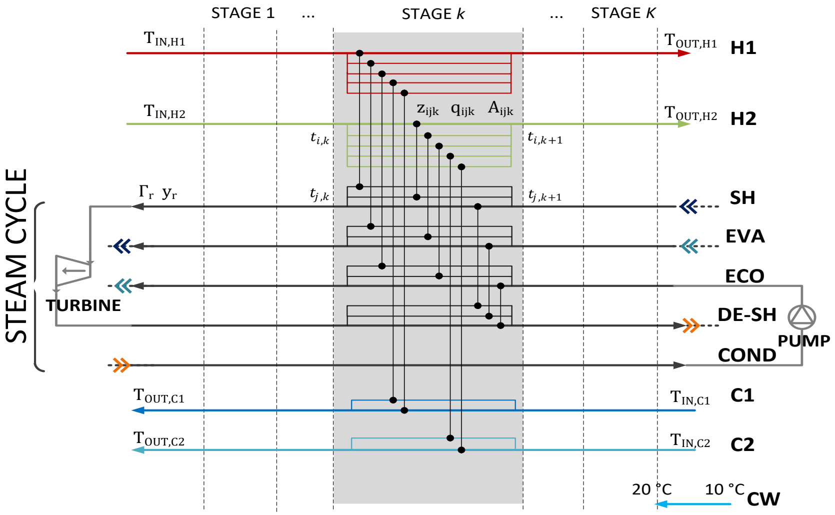
- Minimize total annual cost
- Consider steam users (e.g. gasifier and dryer) and technical limits (e.g. materials)



- Weighted operation cost based on the actual share of **operation modes**

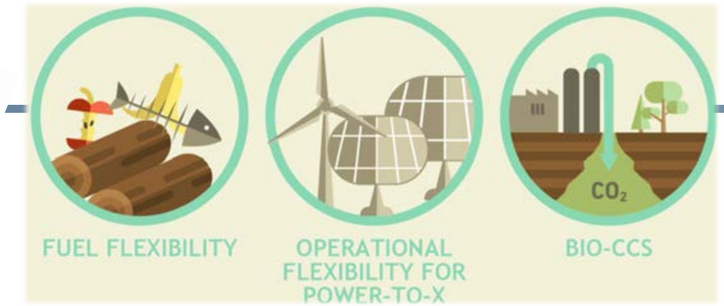
Optimization based on Mixed Integer Linear Programming (MILP) algorithms and superstructures.

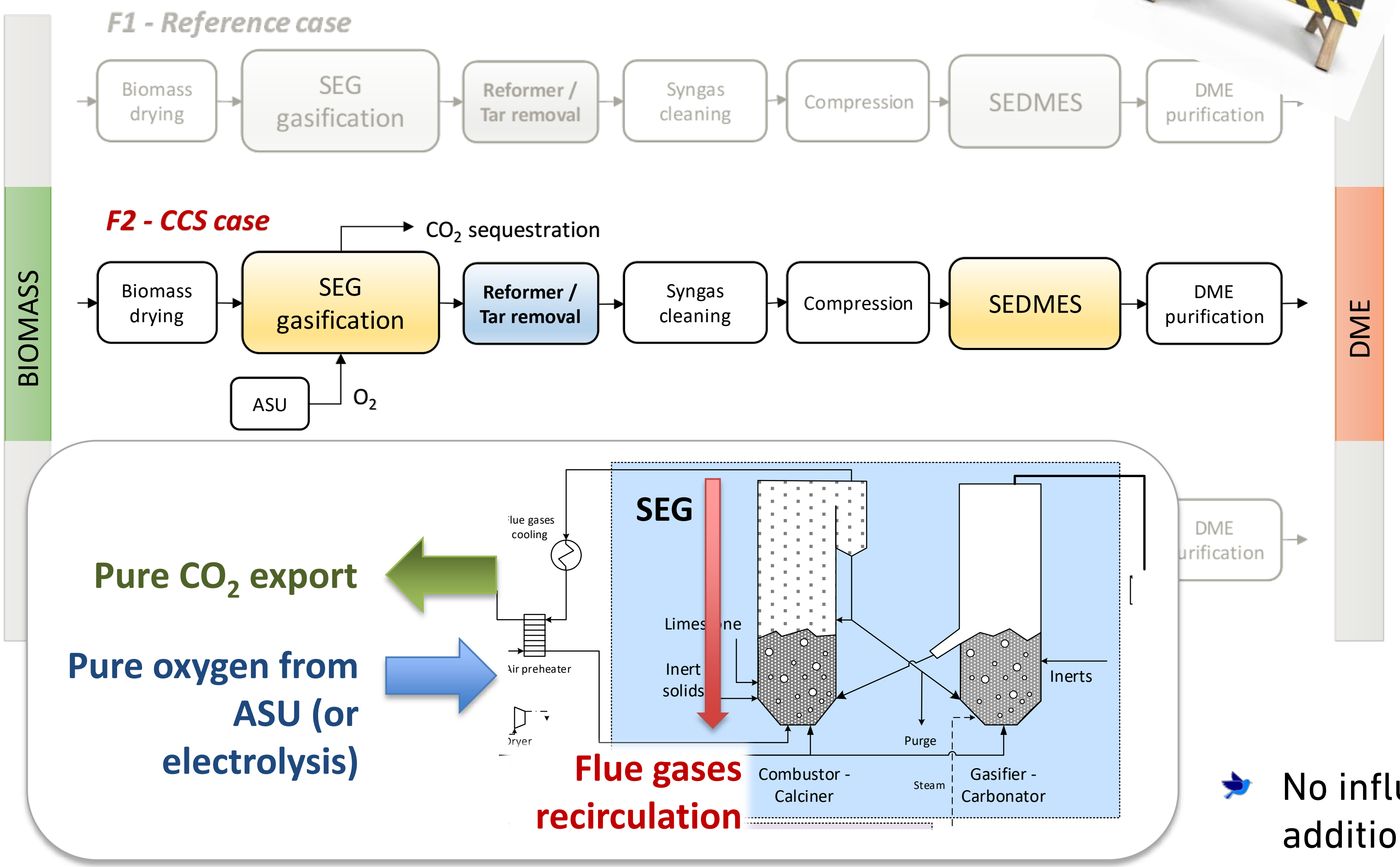




- Optimal solution: steam cycle with HP+MP level and back-pressure turbine operation (6 bar).
- Sensitivity analysis on economic parameters ongoing

Flexible operation of FLEDGED system plant





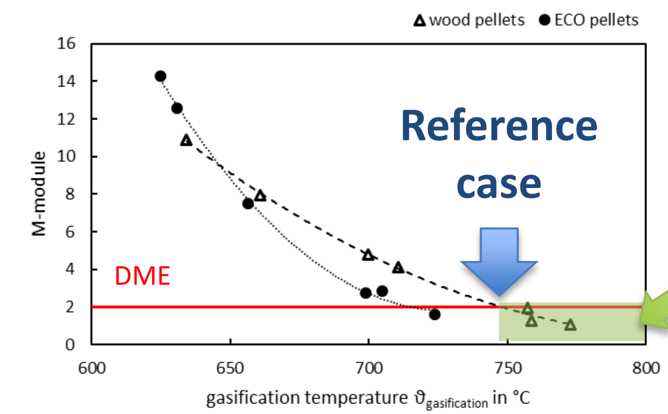
A **retrofit option** with oxygen-fed combustor:

- **almost pure CO_2 and water at stack** allowing for **CCS and negative emissions**
- **flue gases recirculation loop** required for correct fluidization conditions in the combustor.
- No influence on syngas and productivity, but additional electricity consumption

Flexible operation of FLEDGED system plant

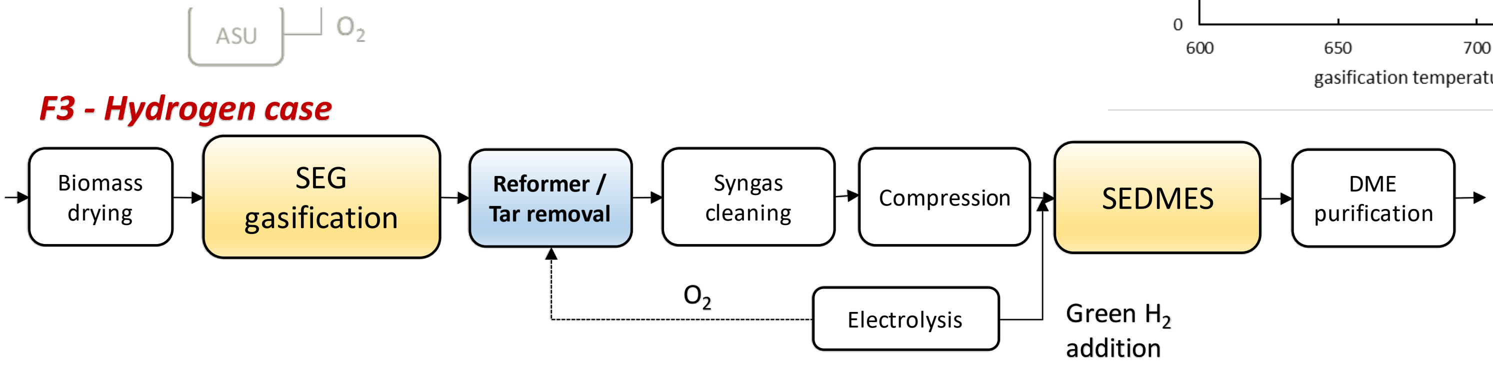
Quantity of separated CO_2 changes by adjusting the **SEG** gasification temperature:

- If hydrogen is available, **the module can be adjusted to the value 2 before synthesis**
- Higher gasification temperature reduces the module at the gasifier outlet up to the desired value



$$M = \frac{y_{H2} - y_{CO2}}{y_{CO} + y_{CO2}} = 2$$

Flexible operation region with H2 injection

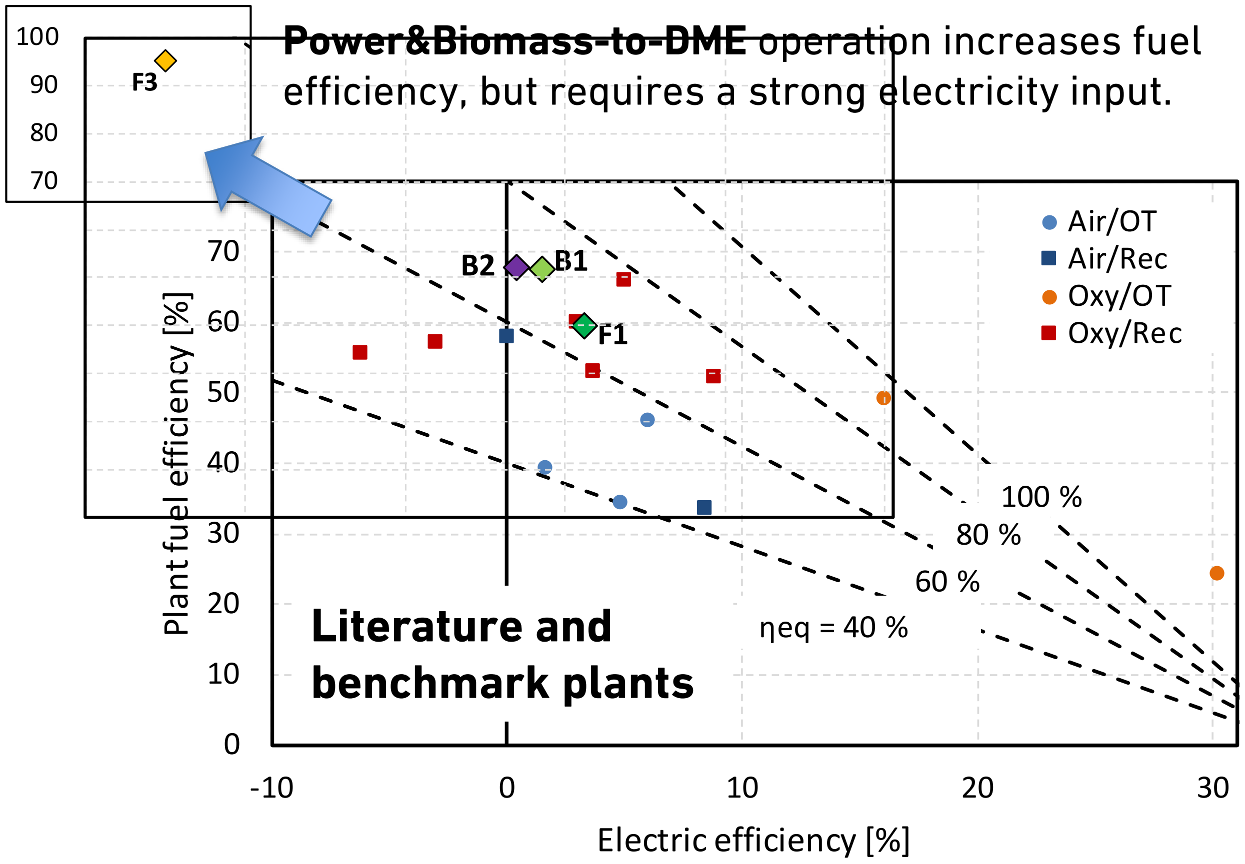


	F1 Ref.	F3 H_2
Biomass and hydrogen to DME efficiency η_F, %	59.5	67.1
Plant Carbon Efficiency, %	37.2	59.6
Eletric consumption, MW_{el}	8.12	73.55
DME production, kg/s	2.06	3.31
P2DME, MW_{DME}/MW_{el}	-	54.4

- SEMDES sized considering the higher flow rate and the different composition given by the green hydrogen addition.
- **O_2 from electrolysis** feeds the reformer (minimum operating hours)

Plant performance

Power&Biomass-to-DME operation increases fuel efficiency, but requires a strong electricity input.



Performance indexes for a multiproduct plant:

- Fuel efficiency (from biomass to DME)
- Electric efficiency (from biomass to electricity)
- Equivalent efficiency, weighting the previous ones:

$$\eta_{F,eq} = \frac{\dot{m}_{DME} \cdot LHV_{DME}}{\dot{m}_{biomass} \cdot LHV_{biomass} - \frac{P_{el}}{\eta_{el,ref}}}$$

$\eta_{el,ref}$ = 35%

Economic evaluations using the **levelized cost methodology**, including:

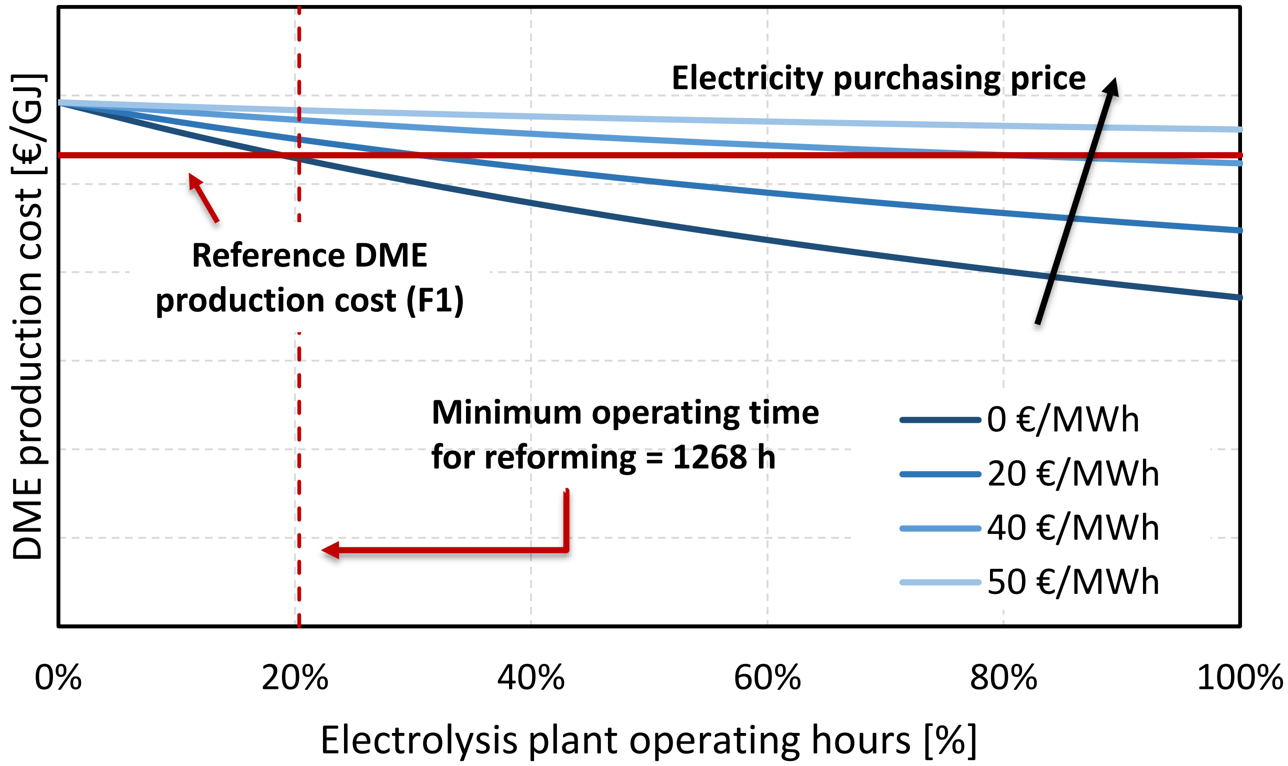
- Estimates of investment costs for innovative units
- Biomass, consumables and O&M
- Electricity sold (or bought)

Detailed final economic analysis will be available at the end of the project.

Economic analysis

The **production cost,** in case of hydrogen from electrolysis, is strongly influenced by **electricity purchasing price**:

Example of influence of electricity price on production cost (flexible plant F3)



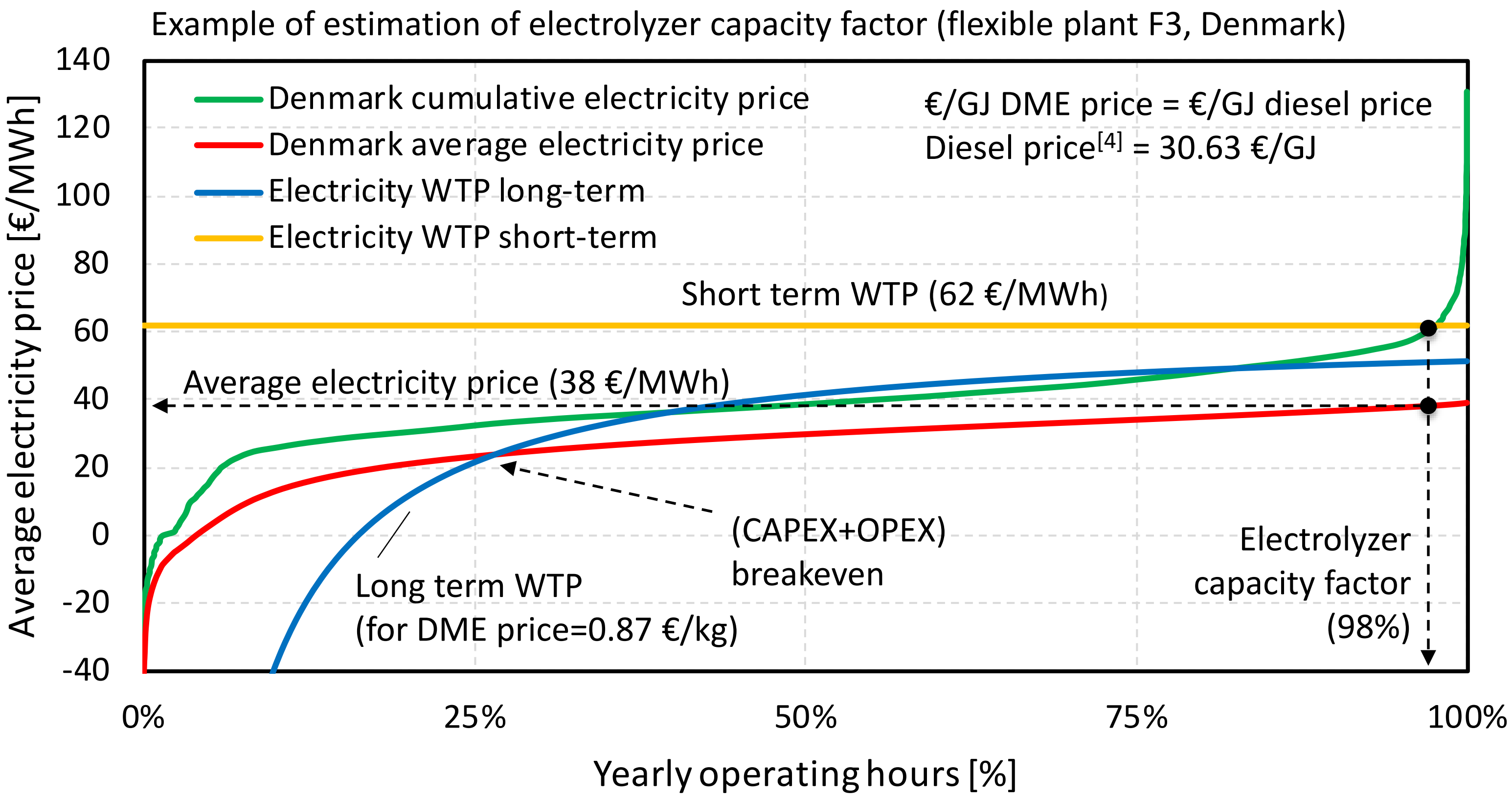
Electricity selling price during baseline operating time = 50€/MWh

- Base cost increase because of the **additional investment** for oversized units and electrolysis
- **Minimum operation of electrolysis unit** to fulfill the reformer demand
- **Breakeven** with reference FLEDGED solution

Detailed final economic analysis will be available at the end of the project.

Economic analysis – Willingness to Pay (WtP)

A criteria for switching between the two operating modes: **electricity price threshold** based on **Willingness-to-Pay**



- Fixed investment costs and DME price
- **Short term willingness to pay** (**yellowline**)
  Breakeven OPEX: revenues from DME selling = cost of electricity and water
- **Long term willingness to pay** (**blueline**)
  Maximum electricity price to breakeven the total costs: revenues from DME selling = electrolysis CAPEX + OPEX.

Poster presented by **A. Poluzzi** at **Session 5AV.3.8 "Techno-Economic Analysis of Flexible Power&biomass-to-Methanol Plants"** with detailed presentation of methodology and preliminary results.

Risk and Sustainability analysis

The objective of these tasks is promoting the sustainable and safe development of the FLEDGED technology and value chain:

- Evaluate the environmental, safety and health, socio-economic and air quality impacts.
- Providing knowledge to stakeholders to support key decisions to develop FLEDGED technologies (technical, sustainability, safety…….).

Risk & Sustainability Analysis

- Task 6.1 Environmental LCA — Quantis
- Task 6.2 Process Safety Analysis — INERIS
- Task 6.3 Socio Economic Analysis — INERIS

Presentation given by **T. Jayabalan** at **Session 4 CO.4.1** on ***"Sustainability and Safety Assessment of DME Production from Biomass Gasification with Flexible Sorption Enhanced processes"*** with detailed presentation of methodology and preliminary results.

Thanks for your attention!

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Downloadable material, presentations, public deliverables and scientific publications on www.fledged.eu

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