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Sustainability and Safety Assessment of DME Production from Biomass Gasification with Flexible Sorption Enhanced processes

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Introduction

- Work carried out in the context of the H2020 EU Project FLEDGED.
- Focus of this presentation will be on the evaluation of Sustainability and Safety impacts.
  - How 'sustainability and Safety' aspects could be integrated in the early stages of development.
  - How the results can participate in the decision making like the selection of the process configurations.

FLEDGED H2020 project

The ***FLEDGED*** project will deliver a process for ***Bio-based dimethyl Ether (DME)*** production from ***biomass*** gasification, validated in ***industrially relevant*** environment (TRL5).

NOVEL FLEDGED PROCESS

Flexible sorption enhanced gasification (SEG) process

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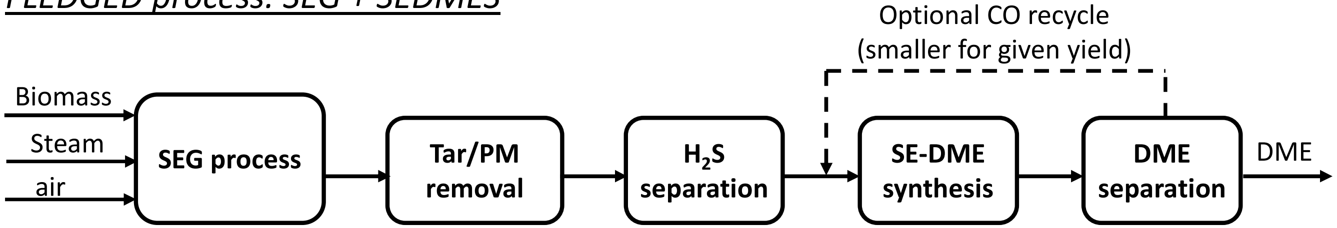
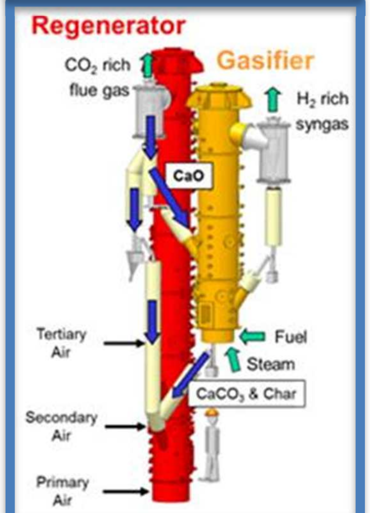
Sorption enhanced DME synthesis (SEDMES) process

- Process intensification
- Efficiency improvements
- Cost reductions
- Process flexibility

FLEDGED process: SEG + SEDMES



Flexible SEG process will be demonstrated at TRL5 in the 200 kW dual fluidized bed facility at University of Stuttgart.

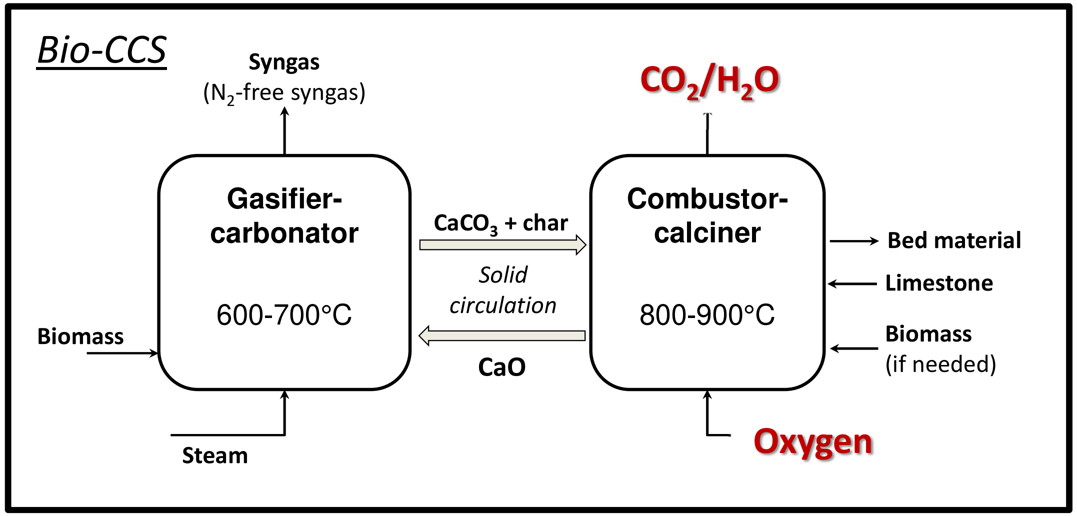


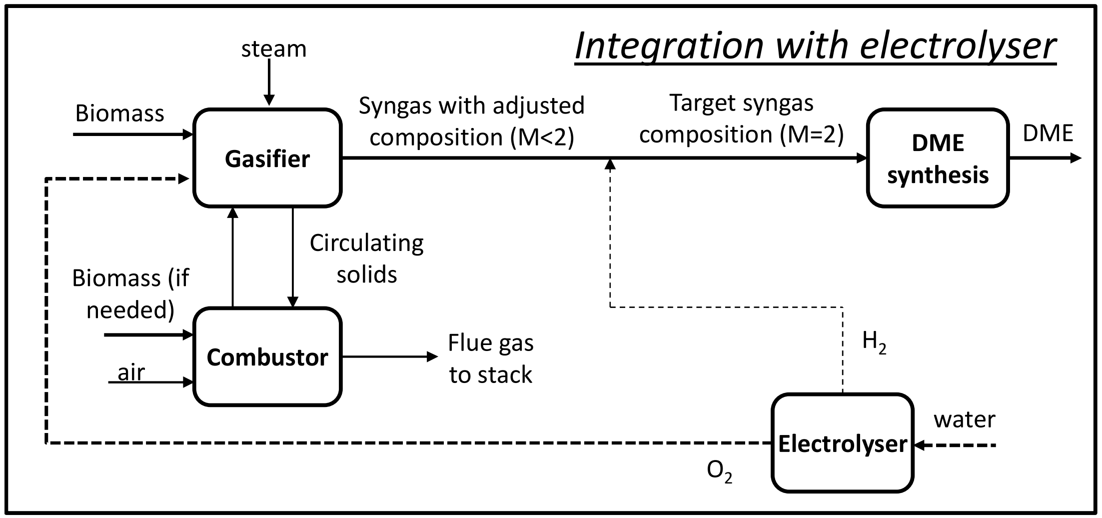
SEDMES process will be demonstrated at TRL5 in multi column PSA rig at ECN

Process flexibility (biomass portfolio, process add-in options)

- Gasification tests with different types of biomass (lignocellulosic, MSW, RDF…….),
- Gasification tests under oxyfuel combustion for bio-CCS,
- Gasification and DME synthesis tests with adjusted process parameters for integration with electrolyzer.

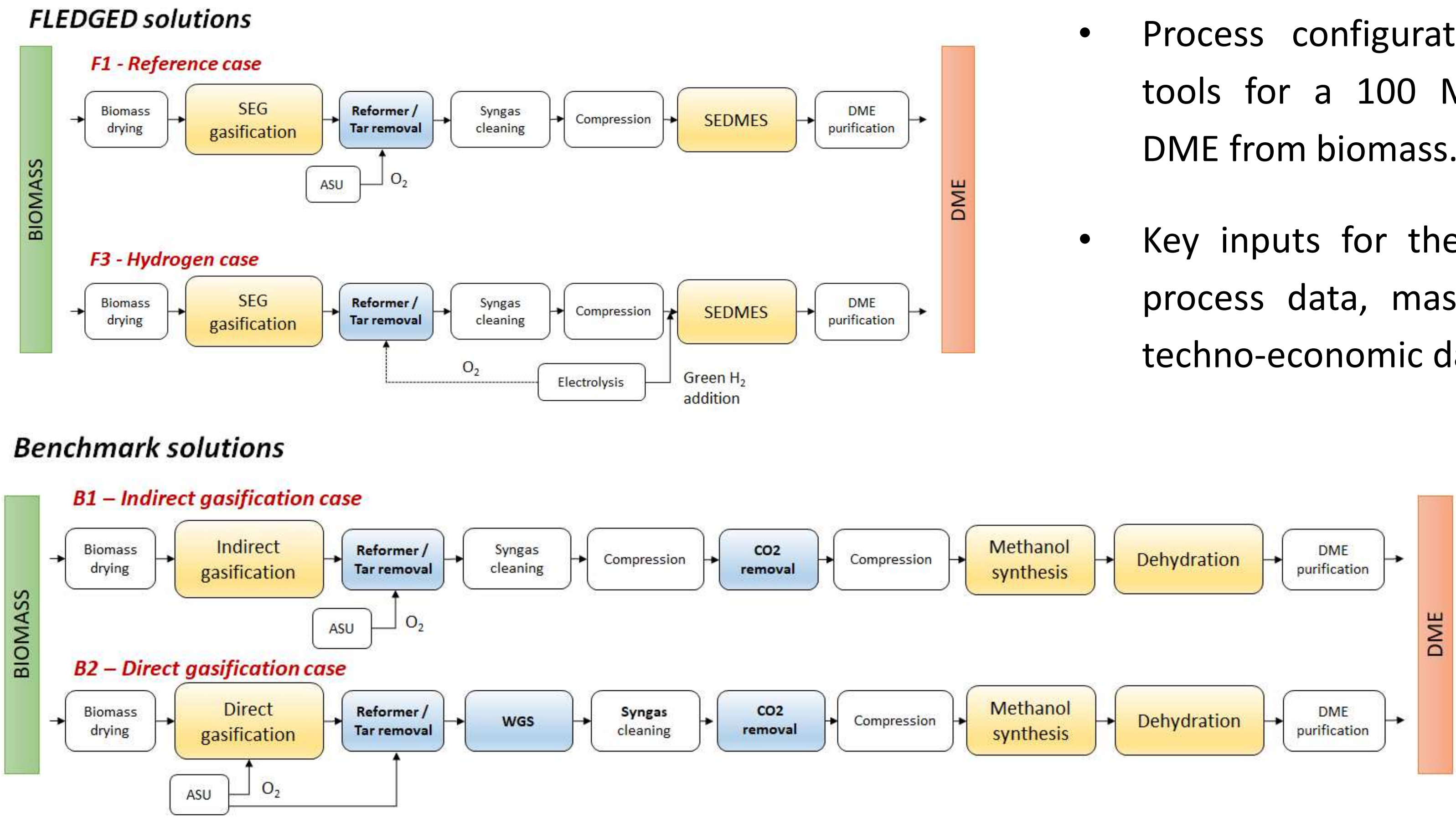
➡ ***Contribution to electric grid stability by power-to-liquid***





FLEDGED

Selected process configurations

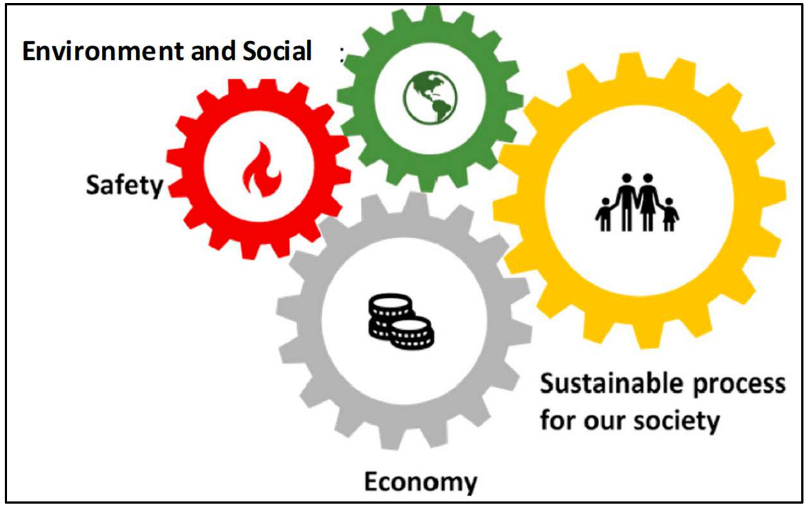


- Process configurations simulated in ASPEN+ tools for a 100 MW_{th} installation producing DME from biomass.
- Key inputs for the multicriteria assessment : process data, mass and energy balance and techno-economic data.

Risk & Sustainability Analysis

Multicriteria impact analysis targeting the key pillars of sustainability for the different configurations were performed.

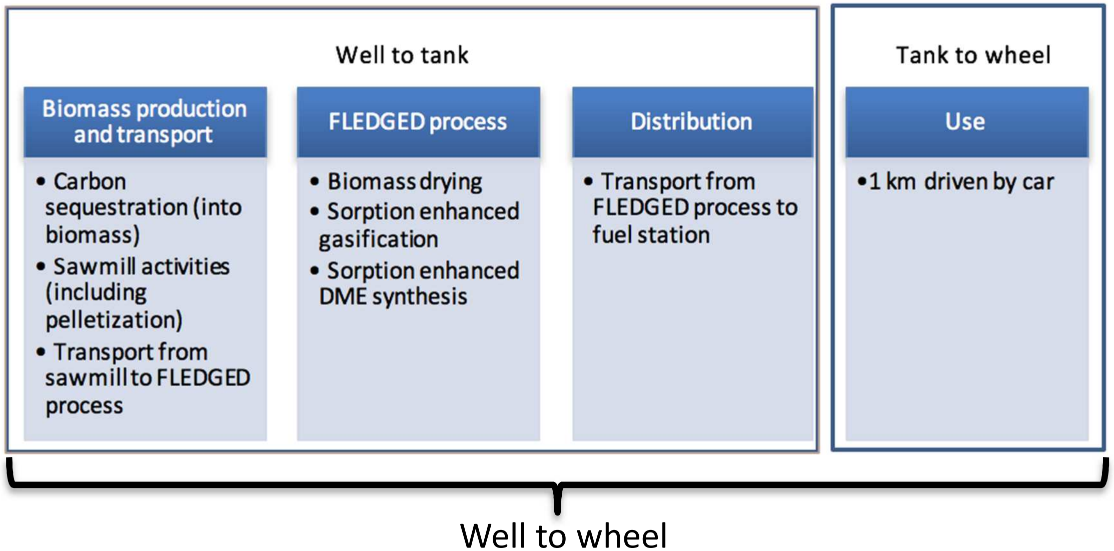
- Impacts evaluated : environment including air quality, health, safety and socio-economic.



Key pillars towards sustainability

1. Life Cycle Assessment

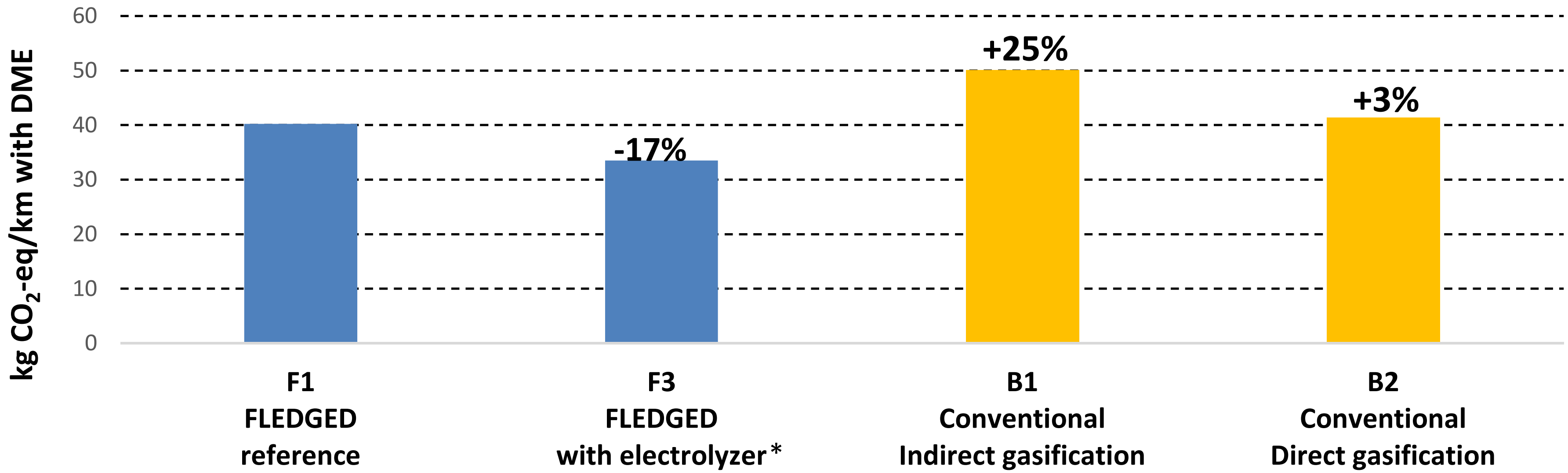
- Evaluation of environmental impacts associated with all the stages of a product's life from raw material extraction to use/end-of-life;
- The functional unit (FU) for which the LCA study is performed and the results are presented is 1 km driven.
- The system boundary of the FLEDGED LCA is shown below:



Analysis was carried out using SimaPro software and the LCI Ecoinvent database

Life Cycle Assessment – Well to wheel

- The plant size and the input of biomass remains same for all the configurations.
- DME use in a light vehicle (sedan car) was considered for the calculations.



Net electricity consumption: **0.0 MW** **62.9 MW*** **3.1 MW** **5.2 MW**

The parameters influencing the environmental impact (carbon footprint) are the process yield (kg of DME produced with a given biomass input) and the net electricity consumption.

For this configuration 100% of electricity from renewable sources is assumed since it will be run only if this type of electricity is available.

2. Process Safety Analysis

Safety comparison methods were developed by chemical companies in the early 90s for the selection of the safe process routes by ranking the hazards.

Among different comparison methods, Index methods are better adapted for safety comparisons

- easy and fast to implement,
- provide assessment results in the form of scores which are simple to interpret,
- Good knowlegde of hazards related to materials and process is required.

Examples of index methods available in literature

- Dow Fire and Explosion Hazard (F&EI).
- Environmental Risk Management Screening Tools (ERMST).
- Hazardous Waste Index (HWI) related to hazardous waste materials.
- Inherent Safety Index (ISI).

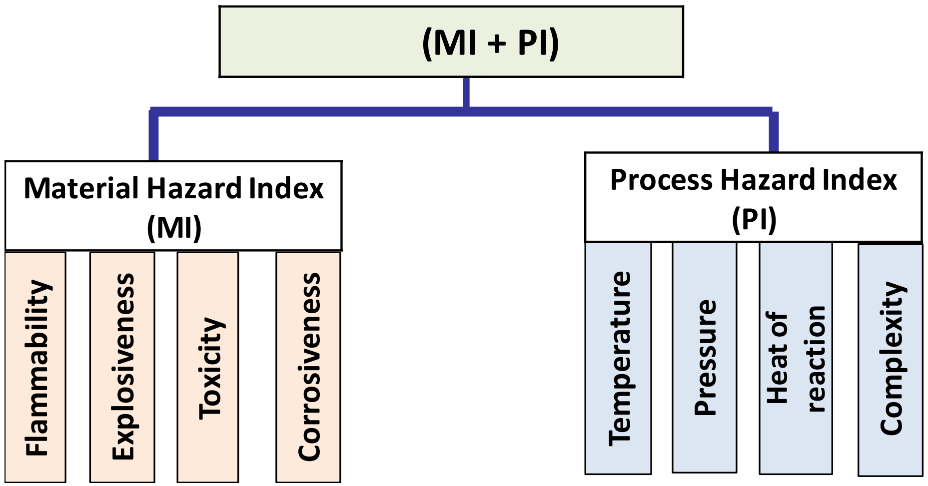
Inherent Safety Index

Scoring of ISD parameters

Inherent safety is driven by the elimination of the hazard, instead of trying to mitigate its effects through implementation of safety barriers wherever possible.

ISI = (MI + PI) + 10 % SU

ISI – Inherent safety index; MI – Material hazard index
PI – Process hazard index; SU – Secondary units



Process temperature °C	Score
> 0	1
1- 70	0
70 - 150	1
150-300	2
300-600	3
> 600	4

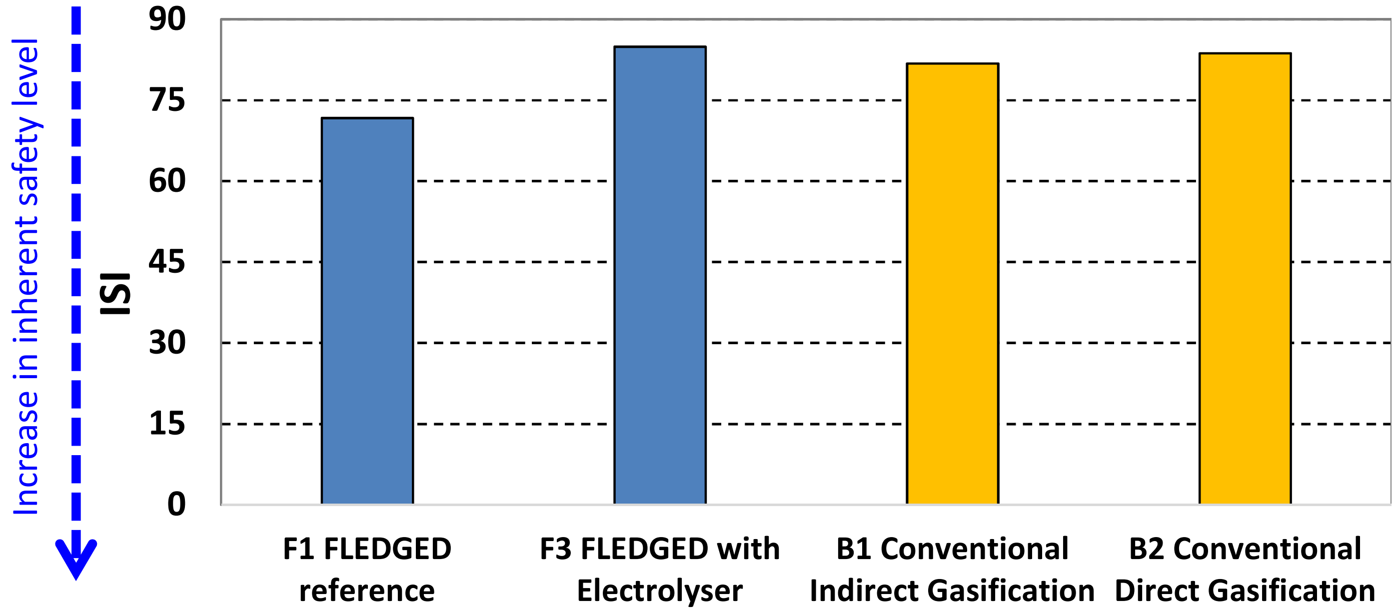
Process Pressure (bar)	Score
0 – 1	1
1 - 5	1
5 - 20	2
20 – 100	3
100 – 200	4

Secondary unit	Score
Heat exchanger, distillation column, flash	1
Pump, blower, cyclone, cryogenic heat exchanger	2
Compressor, ASU, ATR	3

- *Heikkila A.M, 'Inherent safety in process plant design. An index-based approach, VTT publications, VTT Technical Research Centre of Finland, Espoo.*
- *S. Park et al., Incorporating inherent safety during the conceptual process design stage: A literature review, 2020. Journal of Loss Prevention in Process Industries.*
- *Trevor Kletz, Inherently Safer Design, The growth of an idea. Process Safety Progress, 1996*

Inherent Safety Index Results

Lower index score for a configuration implies a higher inherent safety level.



- Intensification of the FLEDGED process improves the inherent safety profile (less units),
  - *Amine unit, WGS eliminated in FLEDGED process (higher flammable gas concentrations).*
  - Mild operating conditions in the FLEDGED process units (pressure, temperature).
- F3 case with higher scores : electrolyzer dealing with pure hydrogen.

3. Socio-economic analysis (SEA)

Assess advantages and drawbacks of the FLEDGED scenarios relative to benchmark scenarios

- Taking an integrated view of environmental, health & economic impacts by monetizing impact indicators
- Comparing additional costs and benefits in a cost-benefit analysis (CBA)
- Expressing results as today's value of costs and benefits incurred over the period (= Net Present Value)

For the FLEDGED process for biomass based **DME fuel production**

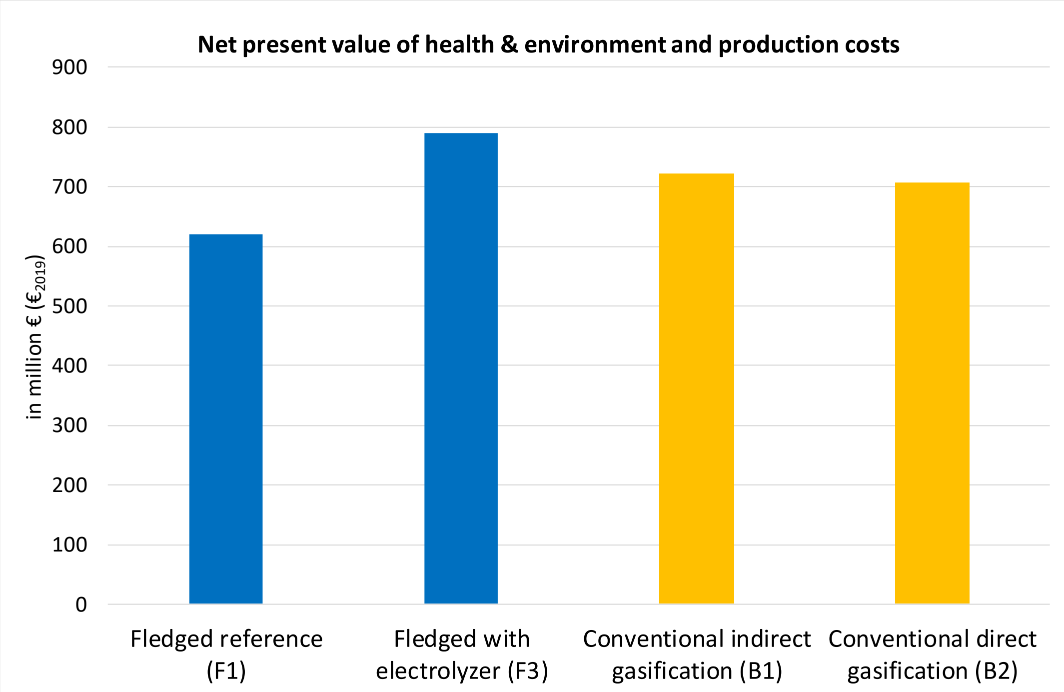
- Monetization of LCA health & environment results and extrapolation to plant level over life-time
- CAPEX & OPEX data over plant life-time

For the **use of DME fuel** in road transport replacing diesel

- Modelling of vehicle park to assess impacts on air pollutant emissions and GHGs up to 2040 (for DME use versus benchmark diesel scenarios)
- Air quality modelling and health impact assessment
- Additional costs of DME distribution network, truck retrofit….

Use of GAINS integrated assessment model, Copert transport model, Chimere chemistry-transport model, ARP health impact assessment model

The Fledged reference scenario F1 appears as the most favourable scenario



F1 saves 86 million € compared to B2

F3 incurs 84 million € additional costs relative to B2

Assessment at plant production level over plant life time (20 years)

Net present value calculated with a social discount rate (4%)

In terms of production and environment and health costs F1 yields net benefits over B1 and B2

=> Environment & health costs are lower due to lower DME production of F1

=> Both investment and operating & maintenance costs are lower for F1

Preliminary results

Monetization of Impact 2002+ midpoint indicators based on CE Delft, 2018; Stiglitz & Stern, 2017

FLEDGED

Conclusions & Perspectives

Main results of the comparison studies

- Overall, the Fledged reference configuration (F1) fares well when compared to the conventional process configurations w.r.t **carbon foot print, risk and cost-benefit analysis.**

- Electrolyser configuration (F3) is favourable for its **positive environmental impact** but shows higher risks and costs and its development will depend on :
  - availability and price of intermittent and renewable electricity,
  - balance between the additional costs and risks related to the electrolyser to the productivity of the process and potential public subsidies and policies supporting the development.

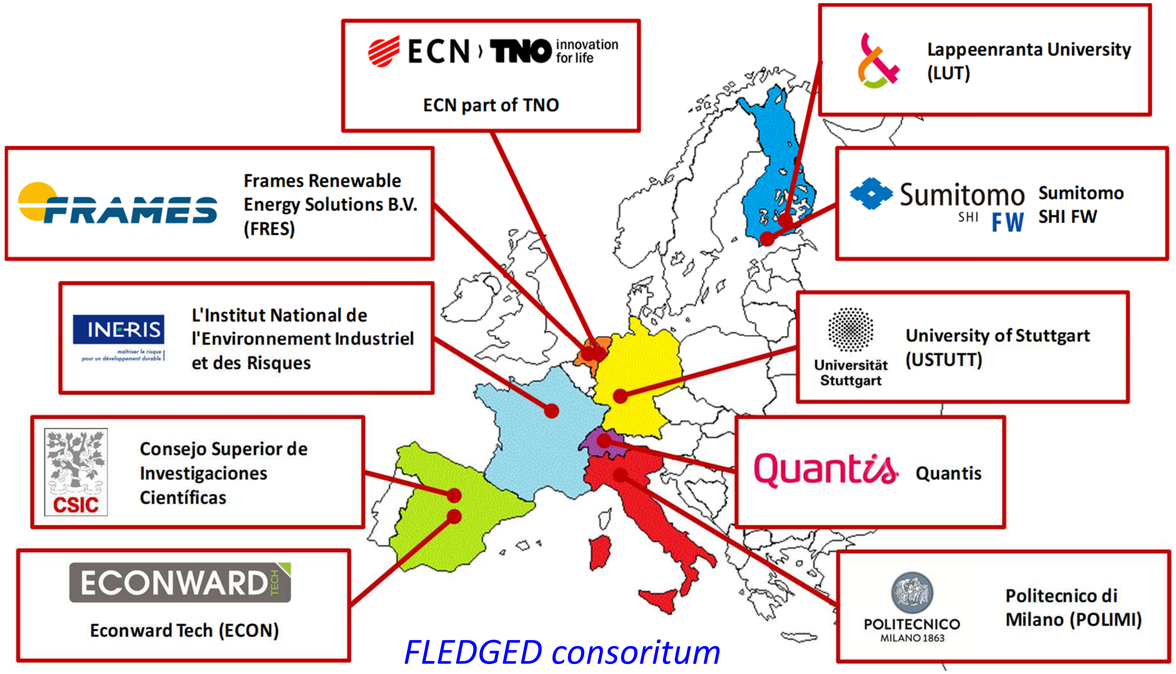
Preliminary decision matrix

	F1	**F3**
Carbon Emissions	🟢	🟢🟢
Inherent Safety Level	🟢🟢	🟡
Cost Benefit Analysis	🟢	🟡

Consolidation of the final multicriteria assessment is curretly underway with more impacts for the proposition of a decision matrix.

Acknowledgements

Alessandro POLUZZI & Barbara LUCIANO of POLIMI for the contributions to modelling and process safety analysis.



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Fledged H2020 Project

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