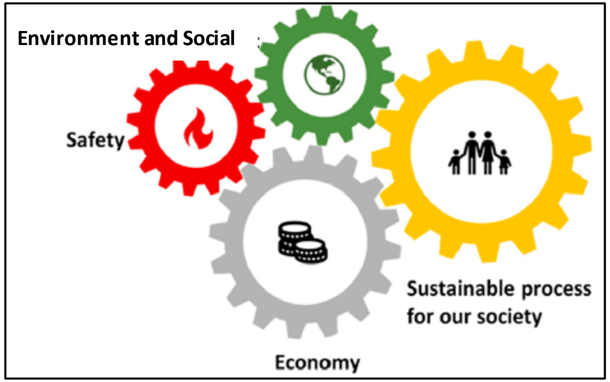
E-EUBCE 2020

28th European biomass Conference and Exhibition, 6-9th July, 2020.

Risk and Sustainability Analysis

Dedicated WP for the evaluation of the sustainability & safety impacts of the FLEDGED process.

- Multicriteria impact analysis targeting the key pillars of sustainability along with safety has been performed,
- Impacts evaluated : environment including air quality, health, safety and socio-economic.



Key pillars towards sustainability

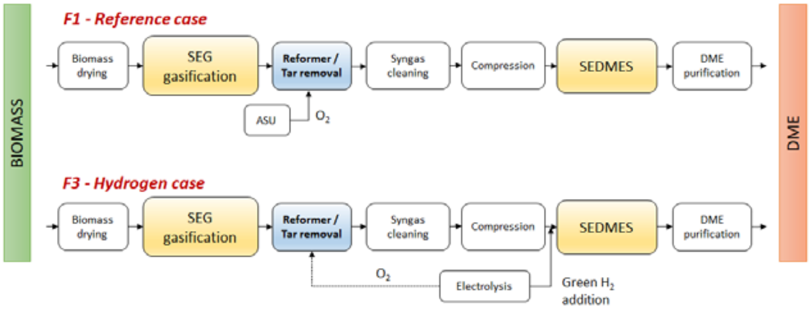
Risk & Sustainability Analysis

- Environmental LCA — Quantis
- Process Safety Analysis — INERIS
- Socio Economic Analysis — INERIS

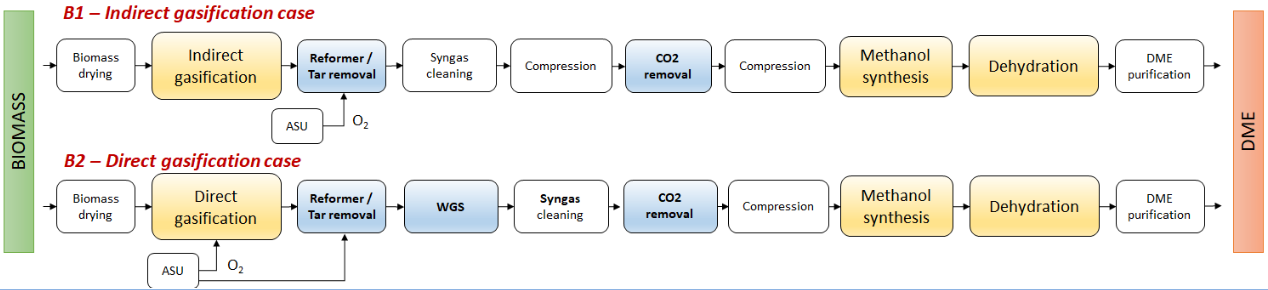
Risk & Sustainability Analysis

Focus on the comparison of safety and sustainability performance of FLEDGED vs Benchmark solutions

FLEDGED solutions



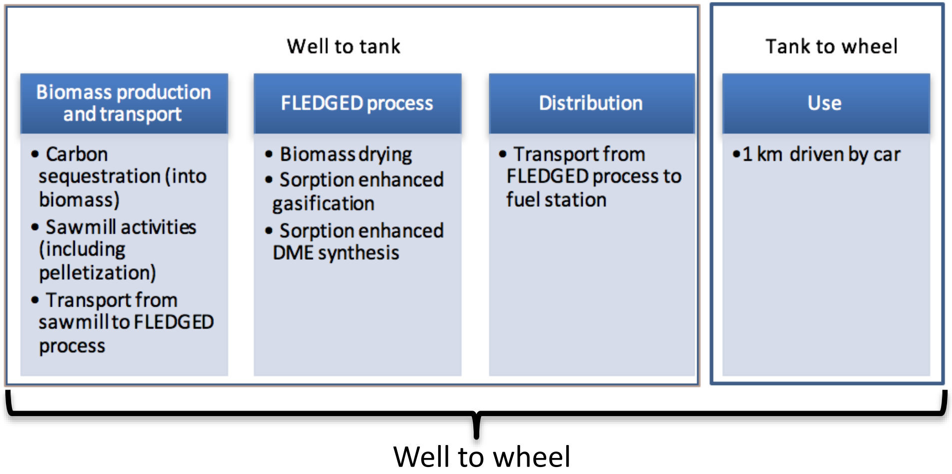
Benchmark solutions



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

1. Life Cycle Assessment

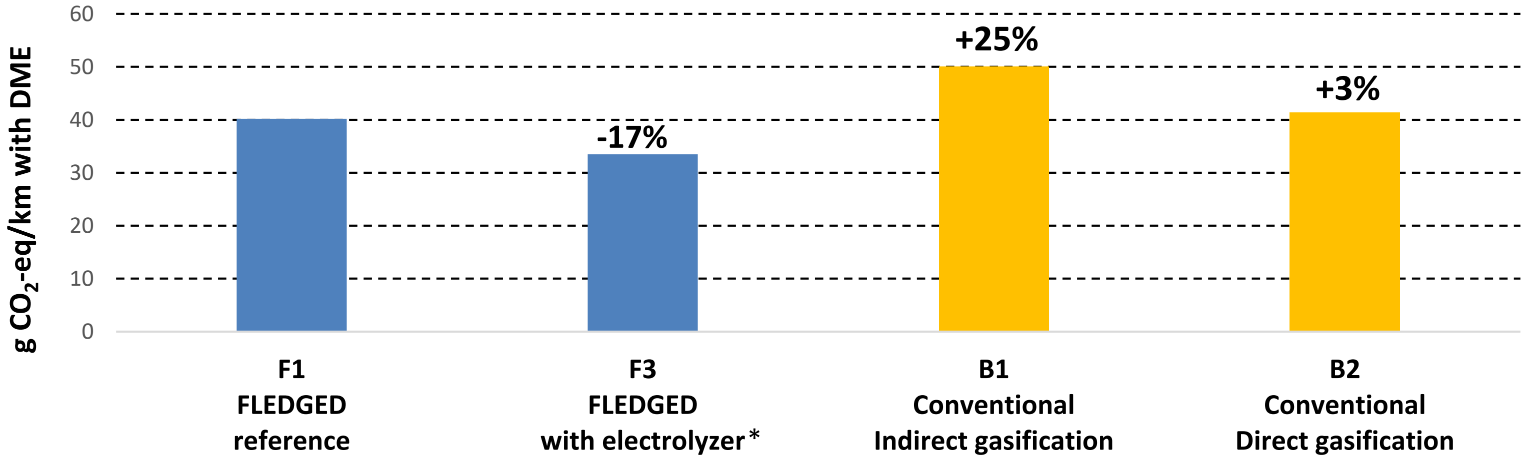
- Evaluation of environmental impacts associated with all the stages of a product's life from raw material extraction to use/end-of-life;
- The functional unit (FU) for which the LCA study is performed and the results are presented is 1 km driven.
- The system boundary of the FLEDGED LCA is shown below:



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

Life Cycle Assessment – Well to wheel (process configurations)

- 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.

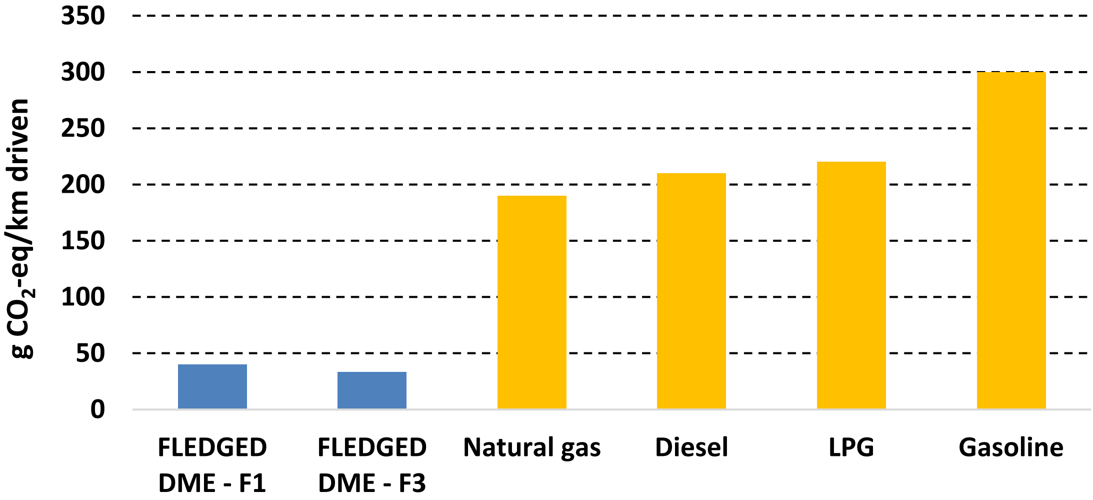


Net electricity consumption: 0.0 MW | 62.9 MW* | 3.1 MW | 5.2 MW

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.

Life Cycle Assessment – Well to wheel (fuels)



The impact of DME produced with the FLEDGED reference (F1) configuration is

- 79% lower than that of natural gas,
- 81% lower than that of diesel,
- 82% lower than that of GPL
- 87% lower than that of gasoline.

- FLEDGED DME impact is much lower than that of fossil fuels.
- CO_2 emissions of FLEDGED DME in the use stage (vehicle) are compensated by the CO_2 intake of the lignocellulosic biomass which is a key advantage.

2. Process Safety Analysis

- Assessment of technological risks related to the FLEDGED value chains.
- Safety promotion at the early stages of development through consideration of Inherently Safer Design principles (T. Kletz et al).

Focus on safety issues related to :

- Intensification & flexibility of process,
- Storage & logistics (characterization of different feedstocks),
- **Comparison and selection of process configurations,**
- Scale-up risks and regulatory review.

- *Trevor Kletz, Inherently Safer Design, The growth of an idea. Process Safety Progress, 1996*

Inherent Safety Index

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

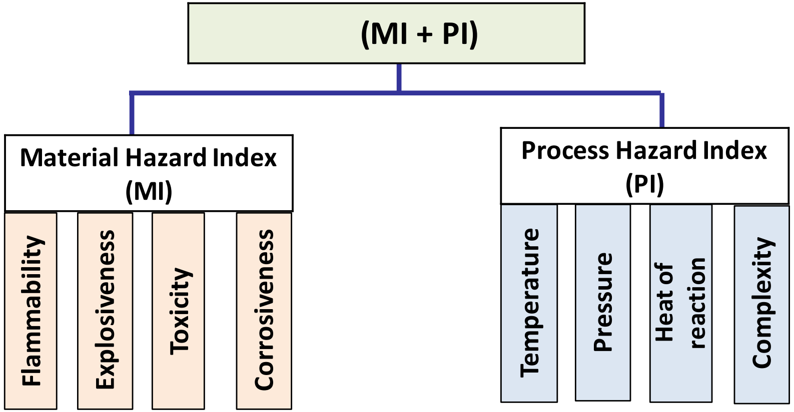
Four primary principles of the inherently safer design concept proposed by Kletz :

- Substitution, Moderation, Minimization & Simplification

ISI = (MI + PI) + 10 % SU

ISI – Inherent safety index; MI – Material hazard index

PI – Process hazard index; SU – Secondary units



<u>*Examples of scoring*</u>

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

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

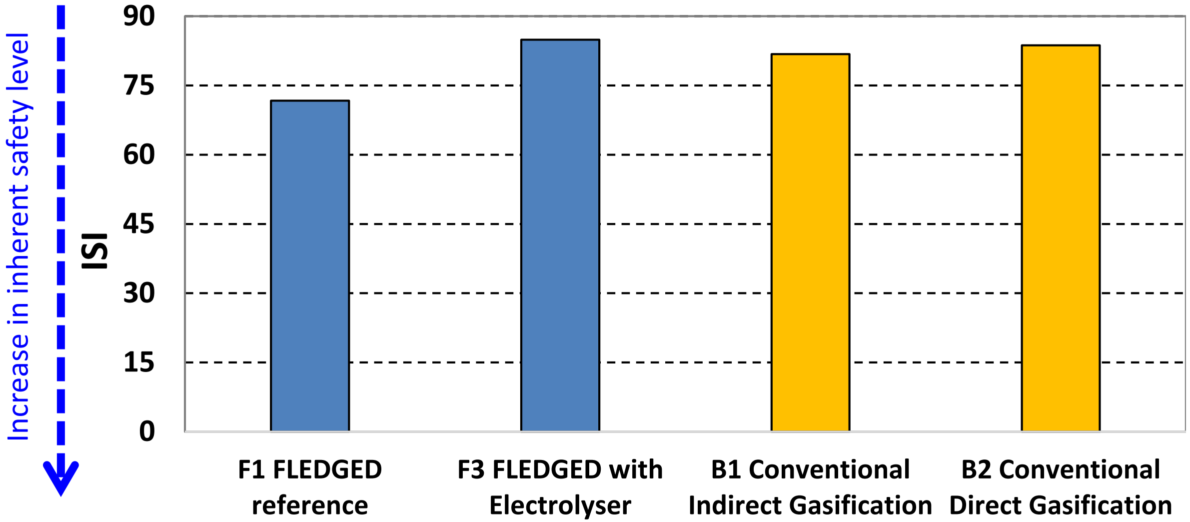
- easy and fast to implement,
- assessment results in the form of scores which are simple to interpret,

- Hazard levels associated to process and materials is depicted in the scores.

- *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.*

Inherent Safety Index (process configurations)

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



- Intensification of the FLEDGED process improves the 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**

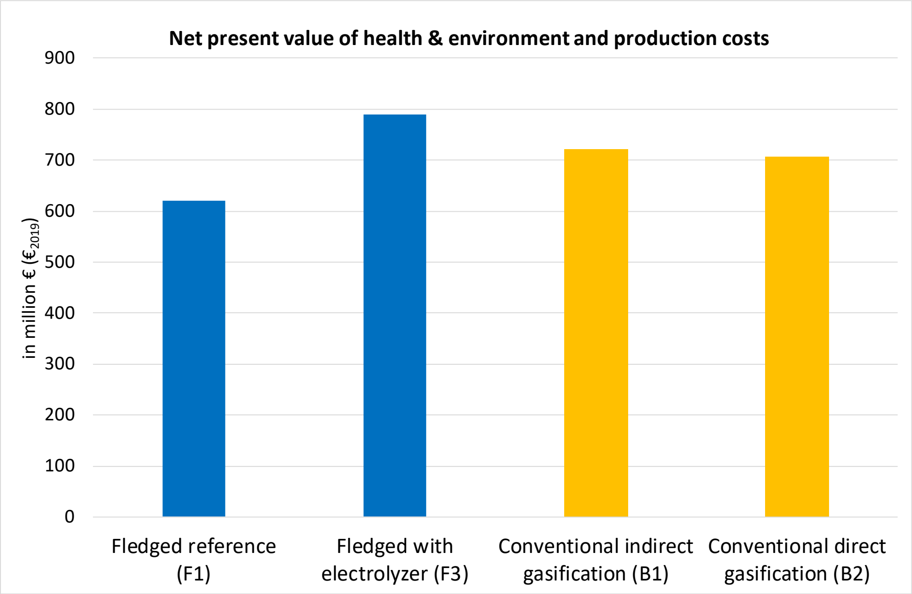
- Monetization of LCA health & environment results and extrapolation to plant level over life-time
- CAPEX & OPEX data over plant life-time

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

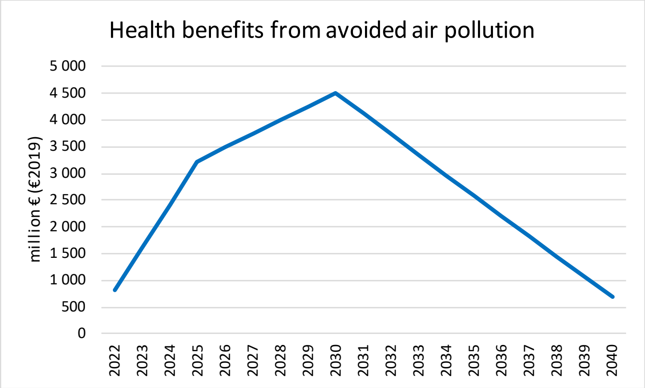
=> Environment & health costs are lower due to lower DME production of F1

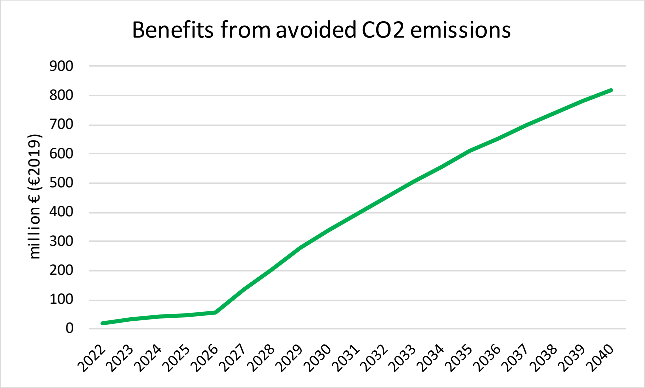
=> Both investment and operating & maintenance costs are lower for F1

Preliminary results

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

Health benefits for use scenarios decrease as Euro VI becomes dominant





Scenario 1:

- Retrofit of Euro V diesel trucks between 2022 and 2030 to use DME, phase out of old trucks over time
- From 2027 on all new trucks use DME (introduction according to vehicle park renewal rate)

NOx, PM, SO_2, NMVOC emissions from retrofitted DME trucks < Euro V diesel trucks
PM, SO_2 emissions from new DME trucks < Euro VI diesel trucks; NOX, NMVOC identical
CO_2 emissions of new DME trucks < new diesel (EURO VI) trucks
=> Health benefits decline over time, climate benefits increase

Benefits need to be compared to costs

Cost assessment ongoing

- Truck retrofit costs
- Implementation of DME distribution network
- Price differential between diesel and DME fuel

Health impacts	Pollutants
Premature mortality	O_3, $PM_{2.5}$, NO_2
Respiratory & cardiovascular hospital admissions	O_3, $PM_{2.5}$, NO_2
Chronic bronchitis	$PM_{2.5}$, NO_2
Asthma symptoms	$PM_{2.5}$
Restricted activity days	O_3, $PM_{2.5}$
Work loss days	$PM_{2.5}$

M
O

Preliminary results

Conclusions & Perspectives

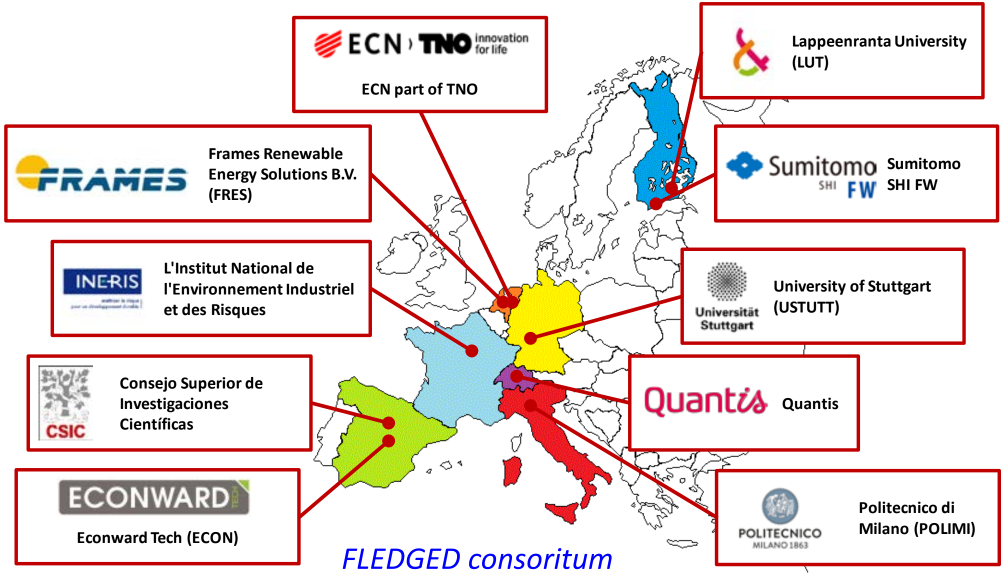
The comparison studies shows the following trends :

- 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.**
  - Lower environment & health costs at plant level and lower investment, operating and maintenance costs,
  - Higher inherent safety level due to the intensification of process.
- Electrolyser configuration (F3) is favourable for its positive environmental impact but show higher risks and costs.
  - availability and price of intermittent and renewable electricity,
  - additional costs and risks related to the electrolyser may be compensated by the productivity of the process along with public subsidies and policies.

Consolidation of the final multicriteria assesment is curretly underway for the proposition of a decision matrix.

Acknowledgements

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



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Fledged H2020 Project

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