Flexible DME Production from Biomass: FLEDGED Project update

Dr. Thangavelu Jayabalan
INERIS

DME Sustainable Mobility Workshop
Landesvertretung NRW
Berlin
24 May 2019

The FLEDGED 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

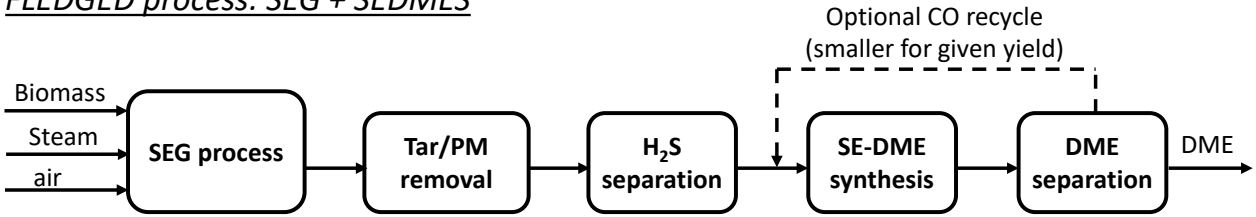
Flexible sorption enhanced gasification (SEG) process

+

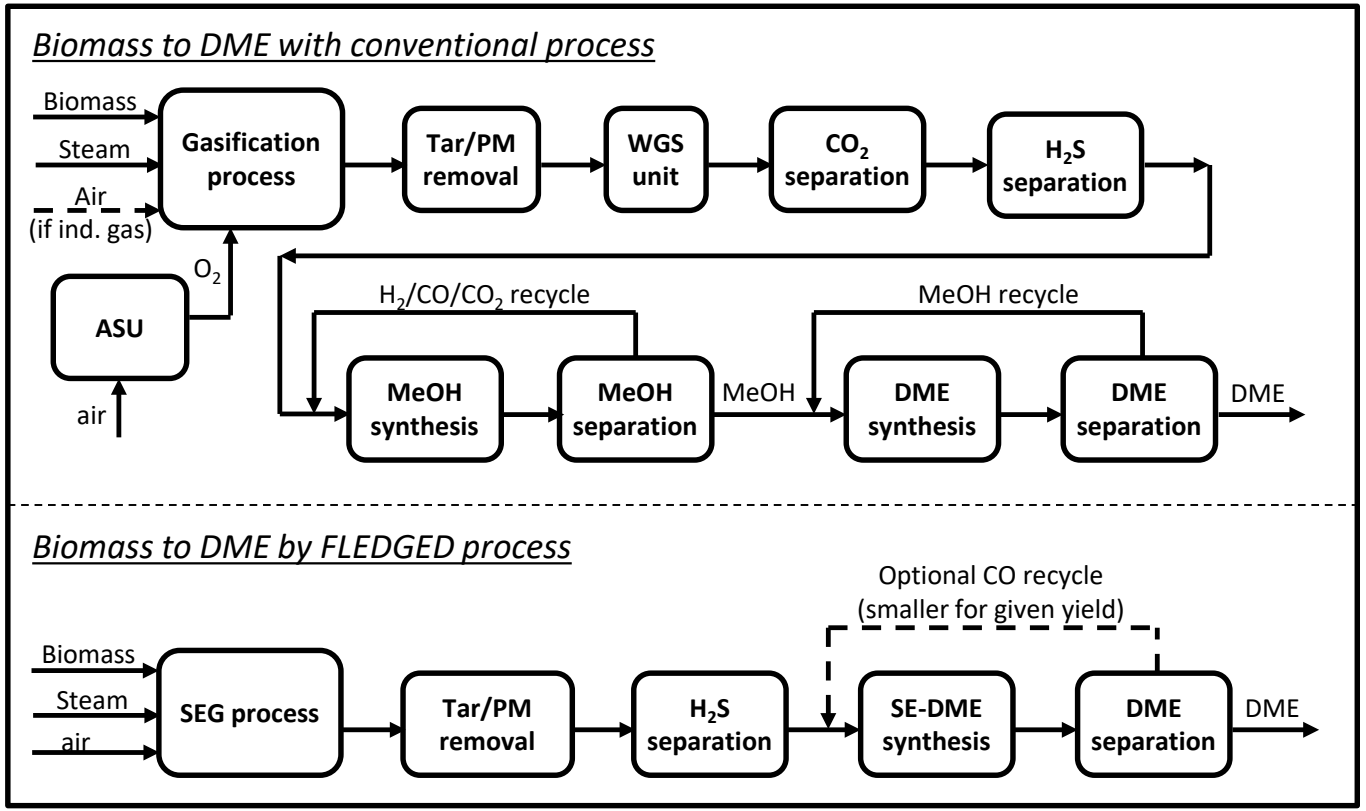
Sorption enhanced DME synthesis (SEDMES) process

- Process intensification
- Efficiency improvements
- Environmental impact reduction
- Cost reductions
- Process flexibility

FLEDGED process: SEG + SEDMES



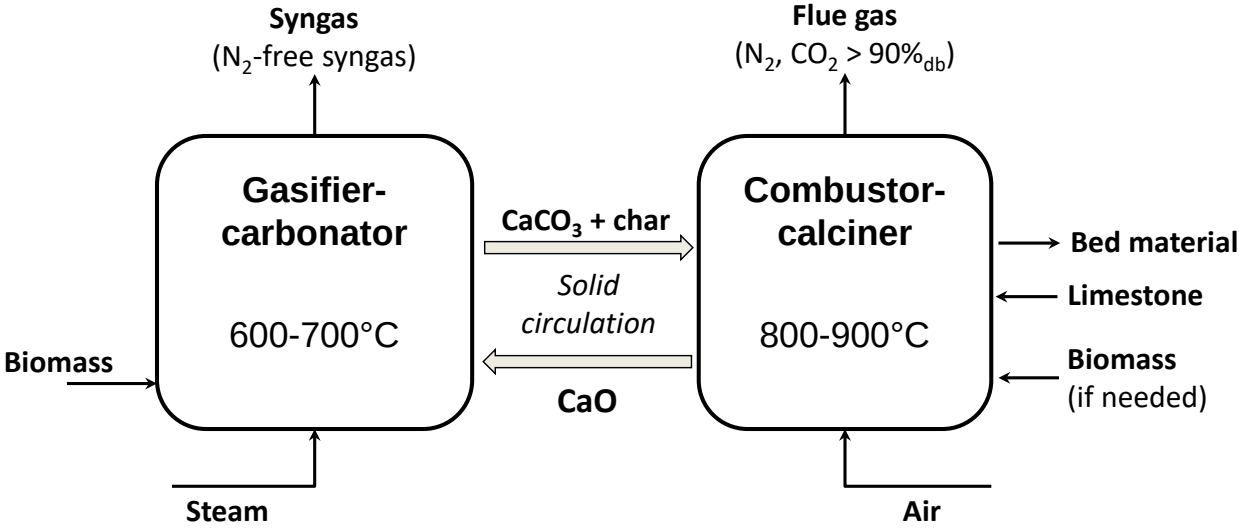
Process intensification



Sorption Enhanced Gasification

Solid material with Ca-based sorbent is circulated between the gasifier-carbonator and the combustor-calciner to:

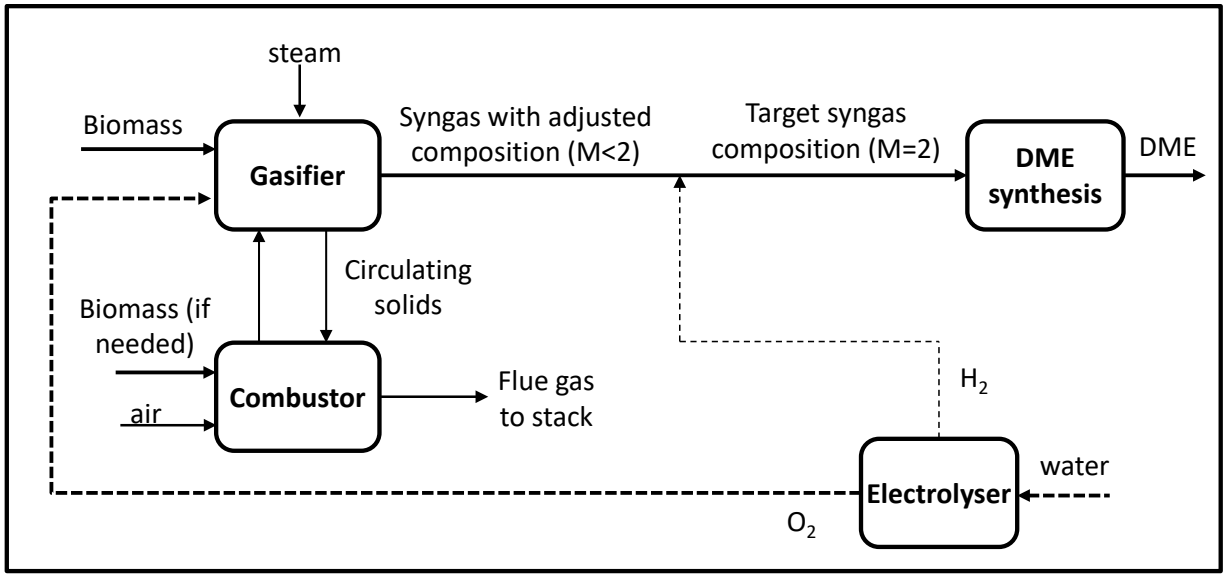
- produce a N_2-free syngas with no need of pure oxygen production and external heating of the reactor;
- absorb CO_2 in the gasifier and adjust C/H content in the syngas.



Process flexibility: integration with intermittent RES

If integrated with an electrolysis unit providing renewable hydrogen, SEG process parameters can be adjusted to produce syngas suitable for SEDMES process.

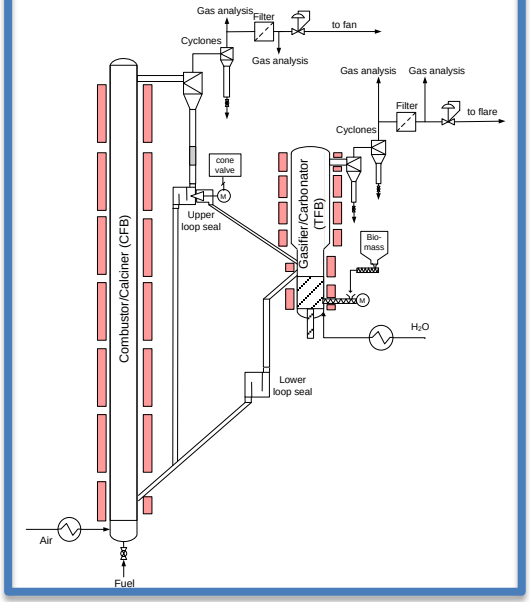
Contribution to electric grid stability by power-to-liquid conversion



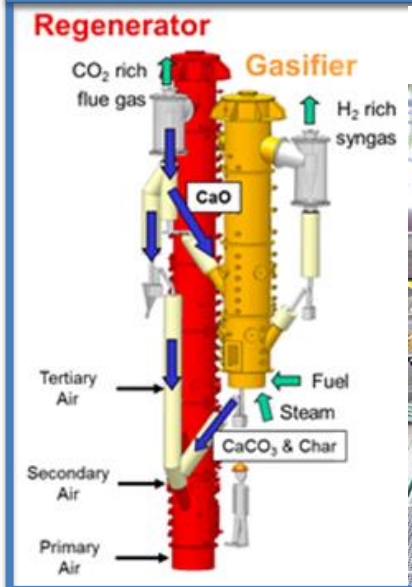
Main facilities for SEG demonstration

75 kW CSIC-ICB bubbling fluidized bed gasifier

20 kW USTUTT dual fluidized bed facility

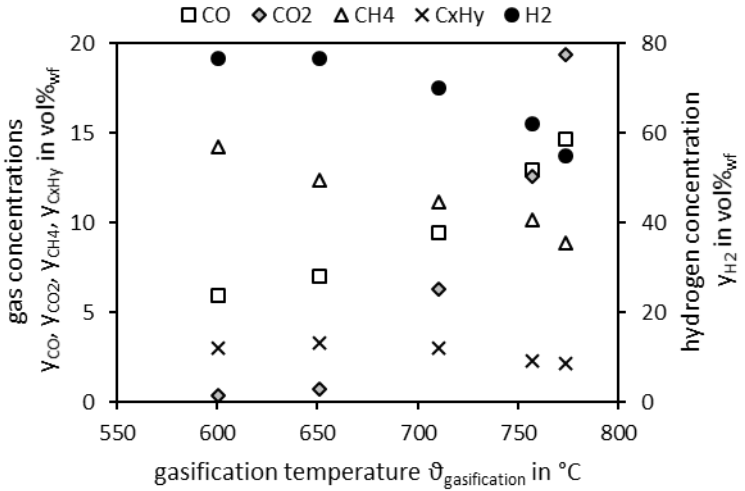


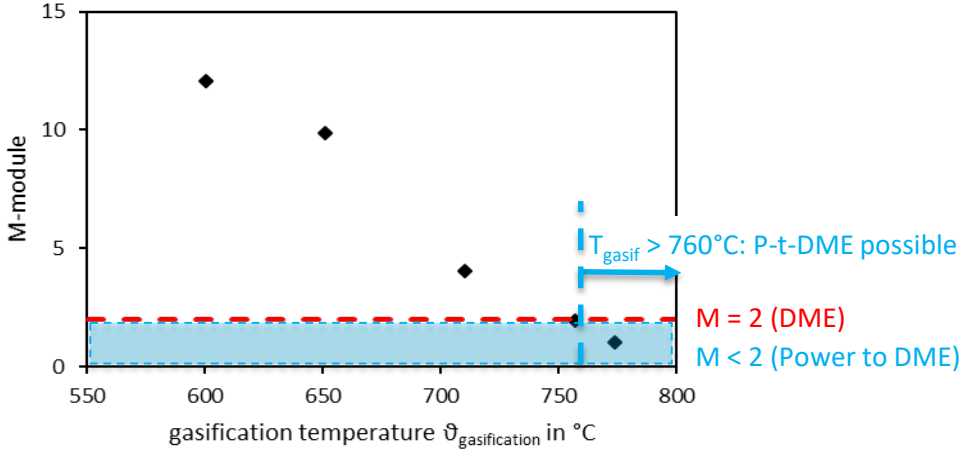
Flexible SEG process will be demonstrated in the TRL5 200 kW dual fluidized bed facility at IFK, University of Stuttgart.



SEG process flexibility: tailored syngas module

Influence of the gasification temperature on syngas module ‘M’





$$M = \frac{H_2 - CO_2}{CO + CO_2}$$

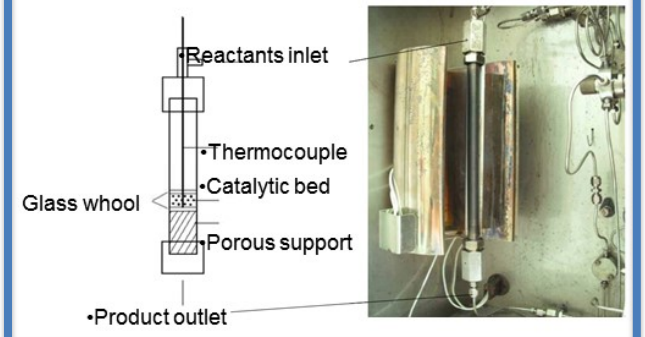
University of Stuttgart
Germany

ifk

FLEDGED

Facilities for SEDMES development

Facilities for testing and synthesis of SEDMES catalysts at CSIC-ICP



High throughput test-rig (Spider setup) and Single column PSA test-rig (SEWGS-1 setup) at ECN-TNO

TRL5 multi-column PSA rig at ECN-TNO

Steam separation enhanced DME synthesis

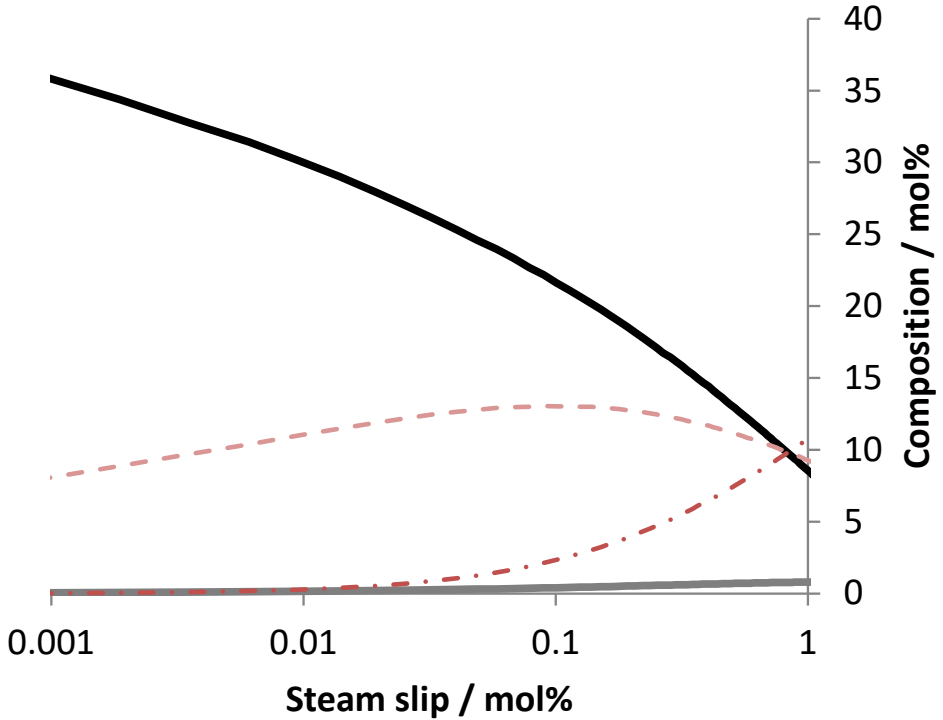
Methanol synthesis

$$CO_2 + 3H_2 \rightleftharpoons CH_3OH + \mathbf{H_2O}$$

Methanol dehydration

$$2CH_3OH \rightleftharpoons CH_3OCH_3 + \mathbf{H_2O}$$

Equilibrium with in situ water removal



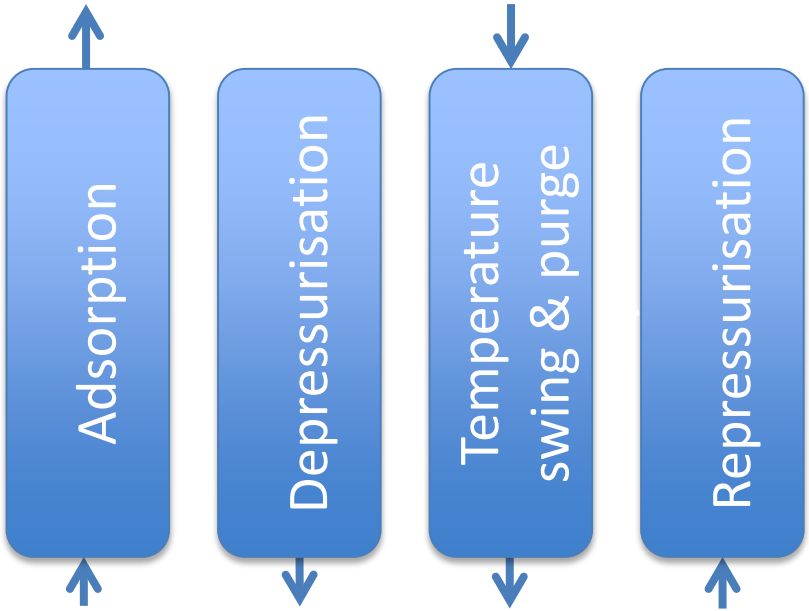
275 °C
25 bar(a)

54 mol% H_2
15 mol% CO
7.7 mol% CO_2

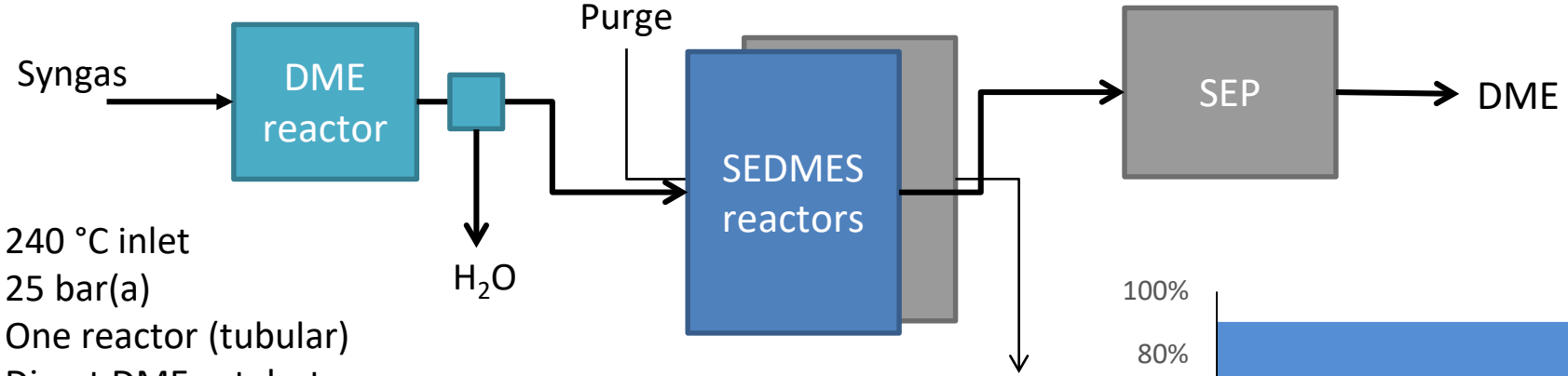
Sorption enhanced DME synthesis: the cycle in practice

Example: 4-step TPSA cycle design

1. Adsorption
2. Depressurisation (blowdown)
3. Temperature swing & purge
4. Repressurisation

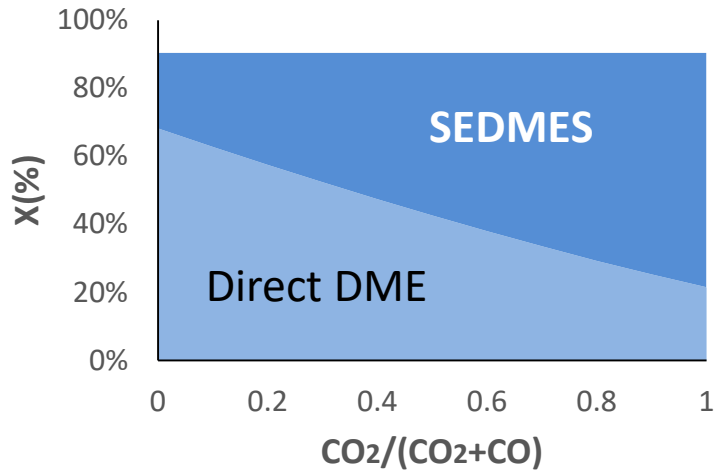


Sorption enhanced DME synthesis process



240 °C inlet
25 bar(a)
One reactor (tubular)
Direct DME catalyst
($Cu/ZnO/Al_2O_3$ + H-ZSM5)

275 °C inlet
25 bar(a)
4 columns
Catalyst + sorbent
($Cu/ZnO/Al_2O_3$ + LTA)



Sorption enhanced DME synthesis

Conventional production of DME

- Low DME yield
- CO_2 production
- Complex separation

Sorption enhanced DME synthesis

- Increased CO/CO_2 flexibility
- Increased DME yield
- Decreased CO_2 content

Outlook

- Regeneration strategy:
  From TPSA to PSA

- System design
  Tradeoff DME selectivity versus productivity

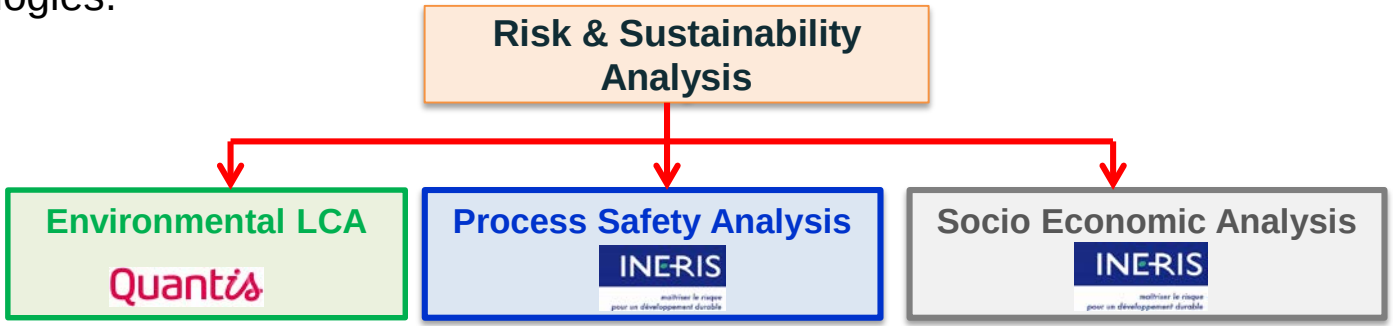
Other activities for FLEDGED process development

<u>Modelling and process integration</u> • Process simulation and optimization of full-scale FLEDGED plants • Modelling of SEG dual fluidized bed reactors • Modelling of DME reactor and synthesis process	LUT Lappeenranta University of Technology; POLITECNICO MILANO 1863; ECN TNO innovation for life; CSIC
<u>Technology scale-up and economic analysis</u> • Economic analysis of full scale SEG+SEDMES plants • Scale up study of SEG process • Scale up study of SEDMES process	FRAMES; Sumitomo SHI FW; ECONWARD TECH; ECN TNO innovation for life
<u>Risk and Sustainability Analysis</u> • Environmental Life Cycle Assessment • Process safety Analysis • Socio-Economic Analysis	INERIS maîtriser le risque pour un développement durable; Quantis
<u>Exploitation</u> • Short-term technical exploitation: design of a TRL 6-7 demo plant at ECOH • Short-medium term commercial exploitation at small scale • Medium-long term commercial exploitation at large scale • Commercial exploitation of the SEG and SEDMES sub-processes	ECONWARD TECH; Sumitomo SHI FW; FRAMES

Risk & Sustainability Analysis

Cross cutting activity aims at promoting a sustainable & safe development of the FLEDGED technology

Inputs for stakeholders to support key decisions to develop FLEDGED technologies.

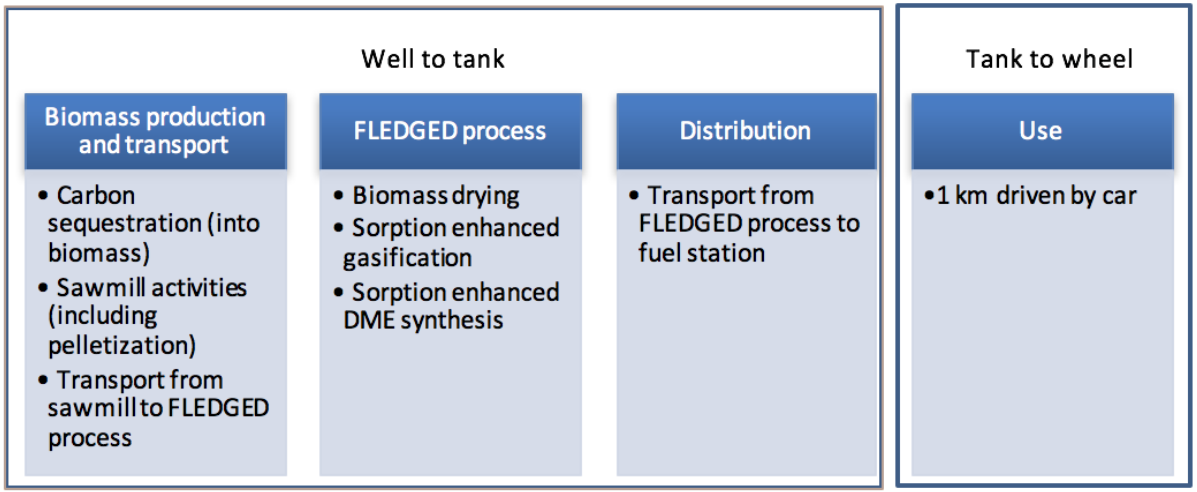


2 partners & 4 different teams with multidisciplinary competences addressing the sustainability and safety aspects.

Final results are expected from this task by June 2020

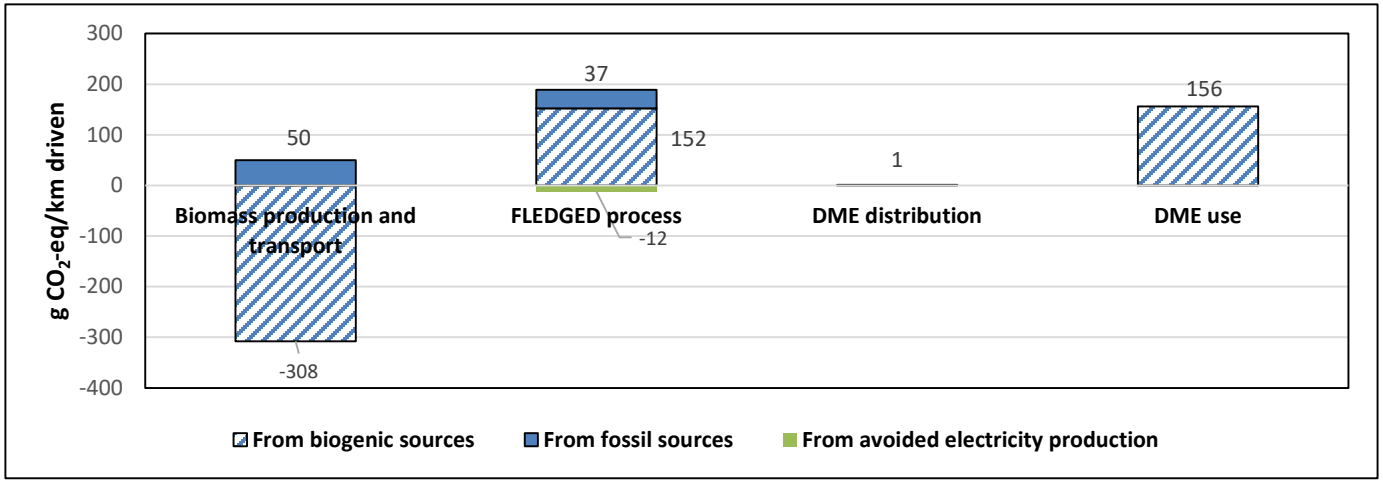
Life Cycle Assessment

- Assessment 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.
- In this preliminary life cycle assessment only the baseline FLEDGED scenario is assessed. The system boundary of the FLEDGED LCA is shown below:



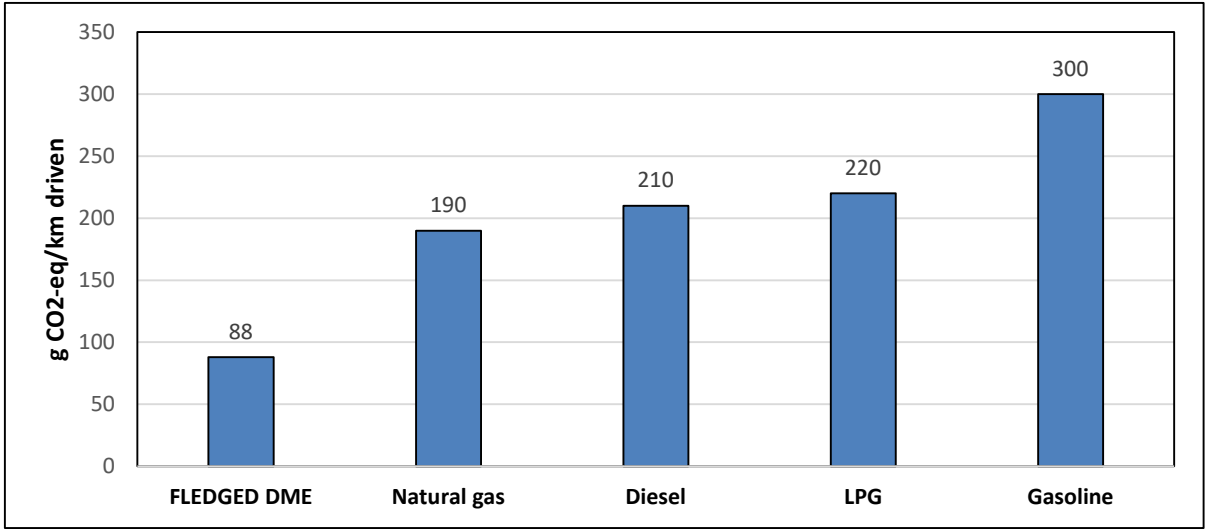
Sorption enhanced gasification followed by a sorption enhanced DME synthesis. The raw material used is wood pellets.

Life Cycle Assessment



- The climate change impact from biogenic sources is negligible because nearly all the biogenic carbon is emitted in the same form as it captured into biomass through photosynthesis.
- Biomass production and transport and production of auxiliary materials for FLEDGED process (inert gases and calcium carbonate) are the main sources of climate change impact from fossil fuels.

Life Cycle Assessment



- FLEDGED DME is in terms of climate change impact more advantageous than the conventional fossil fuels (58% less impact than diesel, 71% less than gasoline).
- Comparisons will be further made with other biofuels and configurations of DME process (configurations and feedstocks).

Process Safety Analysis

- Assessment of technological risks related to the FLEDGED value chains.
- Promoting safety at the early stages of development through Inherently Safer Design.

Special focus on

- Intensification & flexibility of process,
- Storage & logistics,
- Comparison and selection of process configurations,
- Scale-up.

Process Safety Analysis – Preliminary Results

Assessment of risks related to biomass pre-treatment, transfer and storage

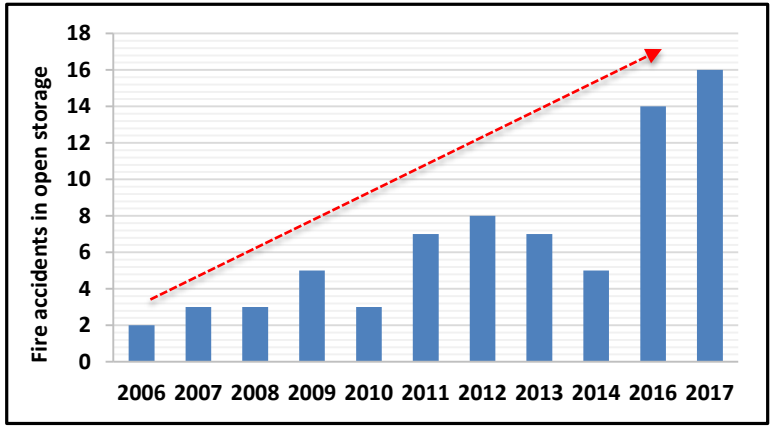
Dust explosion and self heating characteristics of feedstocks

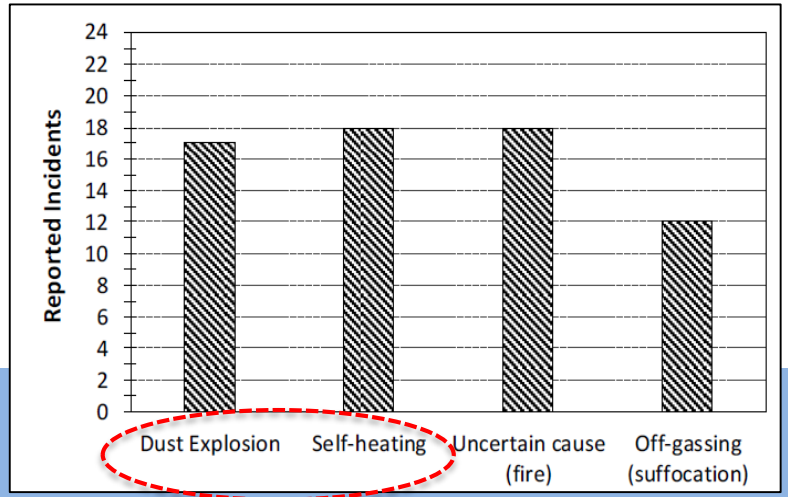
- Municipal solid wastes
- Lignocellulosic feedstocks (straw and wood)
- Refuse derived fuel

DTA/TGA pre-screening of self heating of solids

Isothermal Oven Tests

20-liters sphere apparatus for explosibility characterization





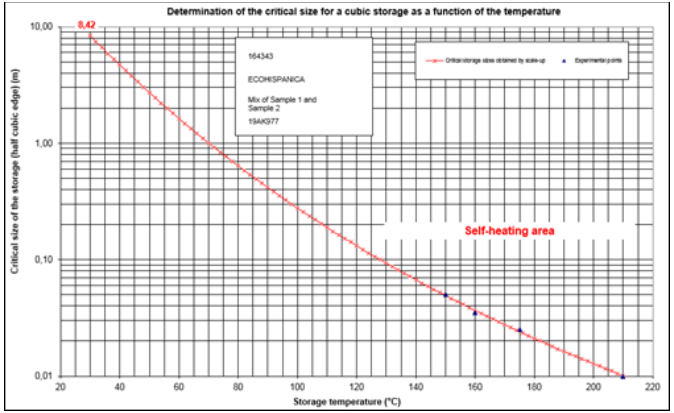
http://www.aria.developpement-durable.gouv.fr/

Krisgstin et al, Recent Health and Safety Incident Trends Related to the Storage of Woody Biomass: A Need for Improved Monitoring Strategies, Forests 2018, 9, 538

Process Safety Analysis – Preliminary Results

Feedstocks – sensitive to self heating & dust explosions

- Strong correlation on the physical and chemical properties of the biomass : particle size distribution, humidity, compaction, etc.
- Storage height dimensions vary from 5m to 15m depending on the biomass.
  - Characterisation of feedstocks, effective management of stockpiles, technical and organisational practices are required.
- The biomass feedstocks mainly belong to explosion class St1. Experimental results have shown strong explosion characteristics St-2 for fines.



Dust Explosion Classification	Dust explosion index Kst (bar.m/sec)	Qualification
St-0	0	No explosion
St-1	0-200	Weak to moderate explosion
St-2	201-300	Strong explosion
St-3	>300	Very strong explosion

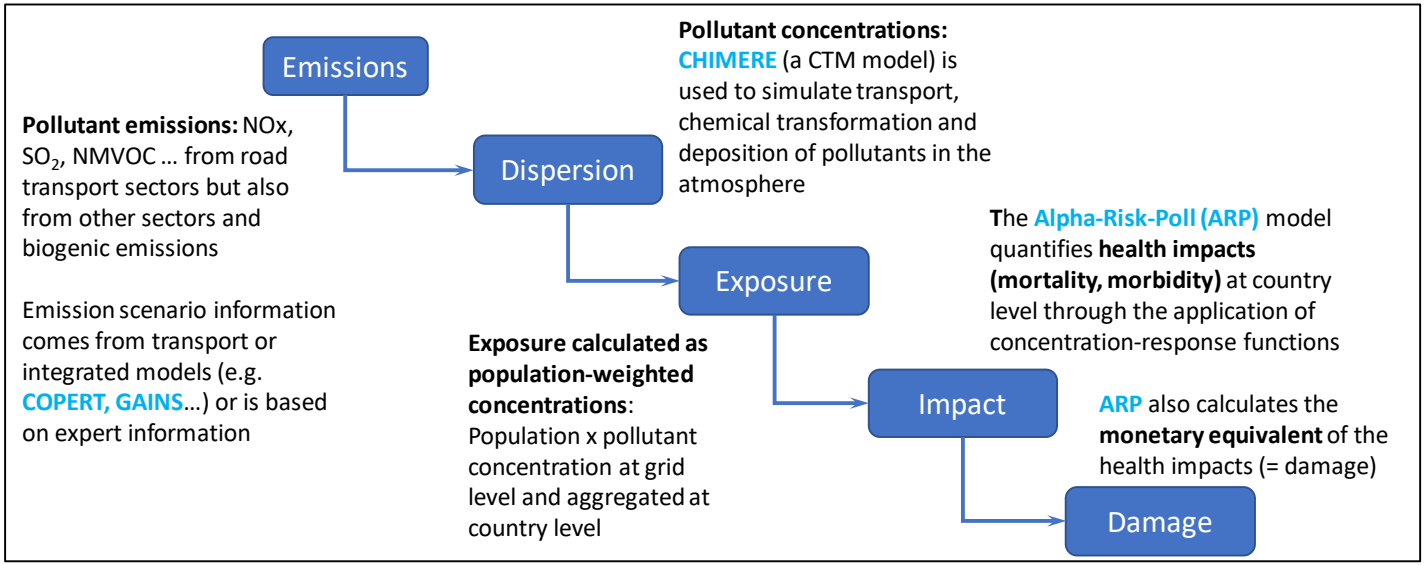
Socio-Economic Analysis (SEA) in FLEDGED

Aims and scope

- identify the advantages and disadvantages of the FLEDGED technology
  - focus on the FLEDGED process for DME based fuel production
  - focus on the use of DME based fuels
- provide, where possible, monetary estimates of induced environmental and health impacts (based on LCA)
- model the air quality & health impacts in Europe of DME use scenarios (replacing diesel by DME in the transport sector)
- compare benefits (= avoided impacts) to costs

SEA – Modelling air quality & health impacts of DME use scenarios

Impacts of emissions on air quality and health are estimated using the “Impact Pathway Approach”



Analysis carried out for reference and DME use scenarios

Changes in results = benefits (or disbenefits)

Benefits (avoided health damage) due to DME replacing diesel use are compared to costs for adapting vehicles

SEA - Information requirements for DME use scenarios

Emission factors

- for Heavy duty vehicles & light duty vehicles & cars
- for pure DME use and for blending (with information of percentage of DME in blend)
- exhaust and evaporative emissions
- for emissions of CO_2, CO, NO_x including the NO_2 fraction, PM_{10}, $PM_{2.5}$, VOCNM (ideally with information on VOC speciation)
- if possible according to Euro standards and depending on the speed of the vehicle
- information on whether such emission factors are measured following the NEDC (New European Driving Cycle) and the RDE (Real Driving Emissions) or are estimates only

Market expectations about the potential spread of DME as transport fuel

- shares of diesel replaced by DME per vehicle type and target year
- quantities of DME used in road transport per vehicle type and target year

Costs for the conversion from diesel vehicle to DME-fueled vehicle

- retrofitted versus new vehicle
- blending versus pure DME use

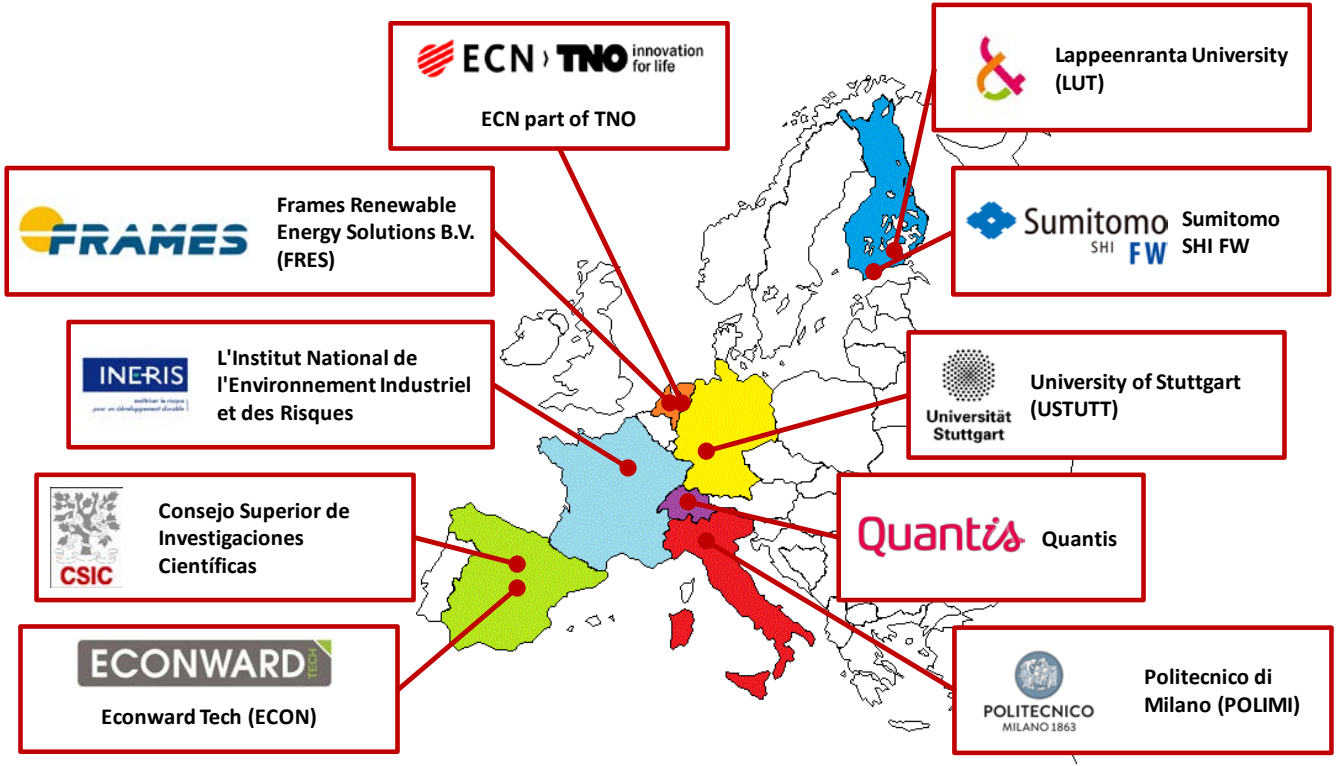
SEA - Information requirements for DME use scenarios

If you are willing to share information with us, please

- I am available for discussions during the meeting
- or send an e-mail to Simone.schucht@ineris.fr and Elsa.real@ineris.fr

Thank you

The consortium



Find out more:	www.fledged.eu
Contact us:	info@fledged.eu
Follow us:	@FledgedProject
	Fledged H2020 Project

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727600