CONVERGE technology for efficient methanol production: Energy and Environmental analysis

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International workshop on CO2 capture and utilization/ Eindhoven/ 16-17 February 2021

Objectives

» Green methanol for biofuel production using waste feedstock as raw-material

» The waste feedstock (from 4 different regions) will be characterized and used in process modeling and simulation tasks; its supply chain will represent important data for LCA

» The optimum economic layout will be identified for CONVERGE technology

» LCA will compare the environmental impacts of CONVERGE to other green methanol production processes

» Evaluation of social impact

CONVERGE concept

» Combines five innovative processes

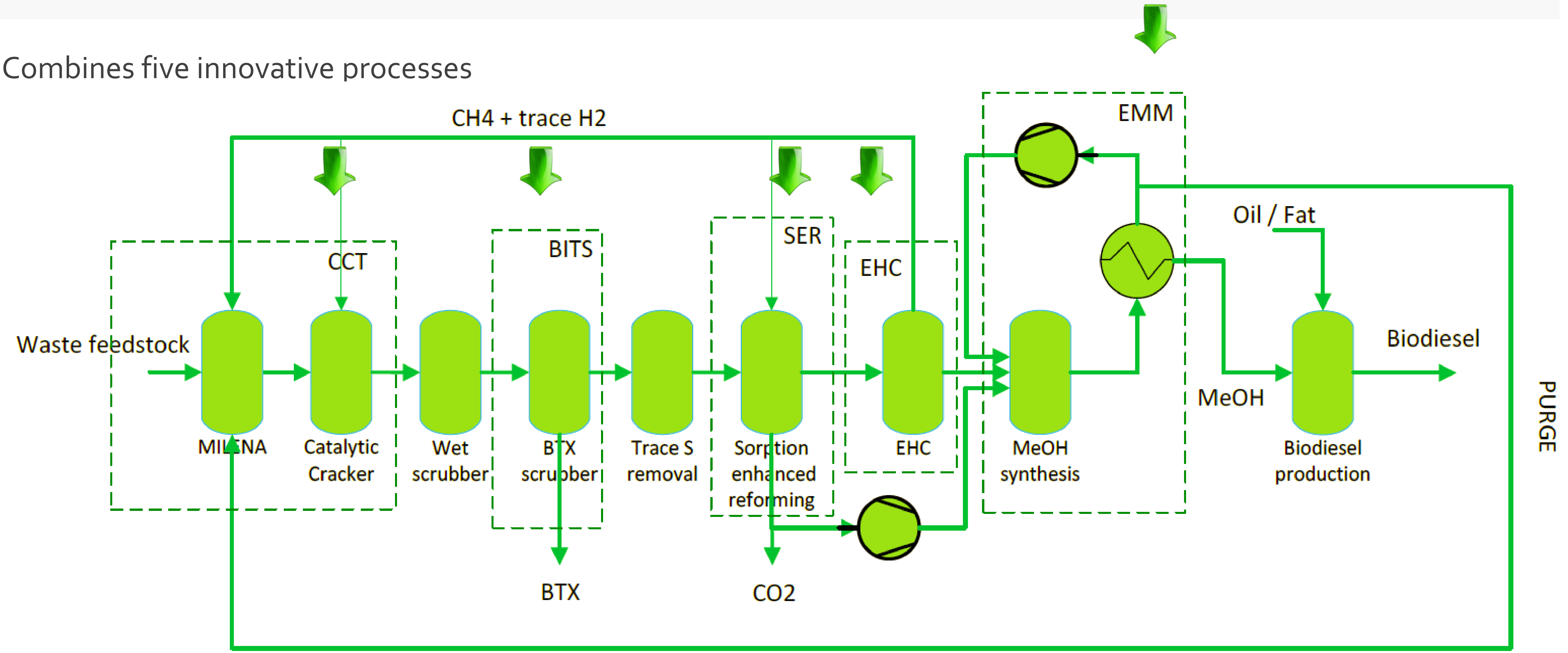


Figure 1. CONVERGE process flowsheet

CONVERGE main units

CCT	BITS	SER	EHC	EMM
» Catalytic cracking of tars from an indirectly heated gasifier to below green C8 » **Advantage:** • Removes the separation of high molecular weight tars from downstream processes, also allowing other by-product fuels, i.e. CH_4 and methanol purge to fire the gasification and SER units	» Recovery of refinery products including aromatics for green C6-C8 fraction (BTX) » **Advantage:** • Avoid the need to pressurize all the producer gas to perform hydrodesulphurization (HDS), and create an extra revenue stream that will also receive positive price pressure in a future carbon-constrained world	» Sorption-Enhanced Reforming of C1-C6 for excess-carbon removal, and H_2 production » **Advantage:** • Lowers the temperature at which reforming is performed, and produces a CO_2 stream that only partially needs to be compressed for methanol production	» Highly efficient electrochemical compression of green H_2 with by-product fuel » **Advantage:** • Elimination of mechanical compression costs for H_2 compression. In combination with SER and EMM compression costs are driven to an absolute minimum	» Enhanced Methanol Membrane to ensure efficient green biodiesel production » **Advantage:** • Due to in situ separation of inhibition products the catalyst for methanol production operates more efficiently as the composition remains further away from equilibrium

CONVERGE - Advantages

Technical

- ↘30% of energy losses related to biodiesel production → ↗12% in production;
- **Syngas treatment:** ↗5% in C/H_2 purity → ↗17% overall carbon usage;
- **SER:** reduce the H_2 production and CO_2 separation from 2 MJ/kgCO_2 down to 1.2 MJ/kgCO_2;
- **EHC:** reduce the purification and compression work from 16 MJ/kgH_2 down to 12 MJ/kgH_2;
- **Enhanced Membrane Methanol synthesis:** single pass conversion >33% → size reduction of the methanol reactor;

Economic

- 15% ↘ of CAPEX for the overall process;
- 10% ↘ of OPEX;

Environmental

- Reduction of CO_2 emissions by 0.2 kgCO_2/kgMeOH as consequence of higher production efficiency;
- Reduce the biomass transportation costs as consequence of the process flexibility and supply chain evaluations for 4 distinct geographical regions;

WP5 - Details

WP objectives

- Definition of the Base Case (BC) and CONVERGE Case

Steps to reach the objectives

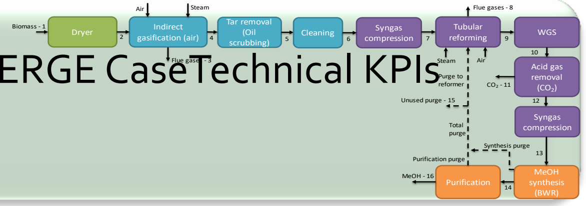
- Identification of possible raw-materials for BC and CONVERGE Case
- Identification of the main blocks for BC and CONVERGE Case
- Identification of the best operating conditions of various sub-units
- Construction of BC and CONVERGE Case process flow-diagram

Tools to reach the objective

- Process flow-modelling tools (i.e. Aspen Plus)
- Validation of the models
- Discussions, side-meetings, e-mails, skype calls

Results obtained

- Detailed mass & heat balances for BC and and CONVERGE CaseTechnical KPIs (e.g. cold gas efficiency)
- Plants economics (e.g. levelized cost of fuel)



WP 5 Objectives

Energy efficiency

Costs

Environmental impact

Social Impact

Comparison between state-of-the-art and CONVERGE technologies

Base case

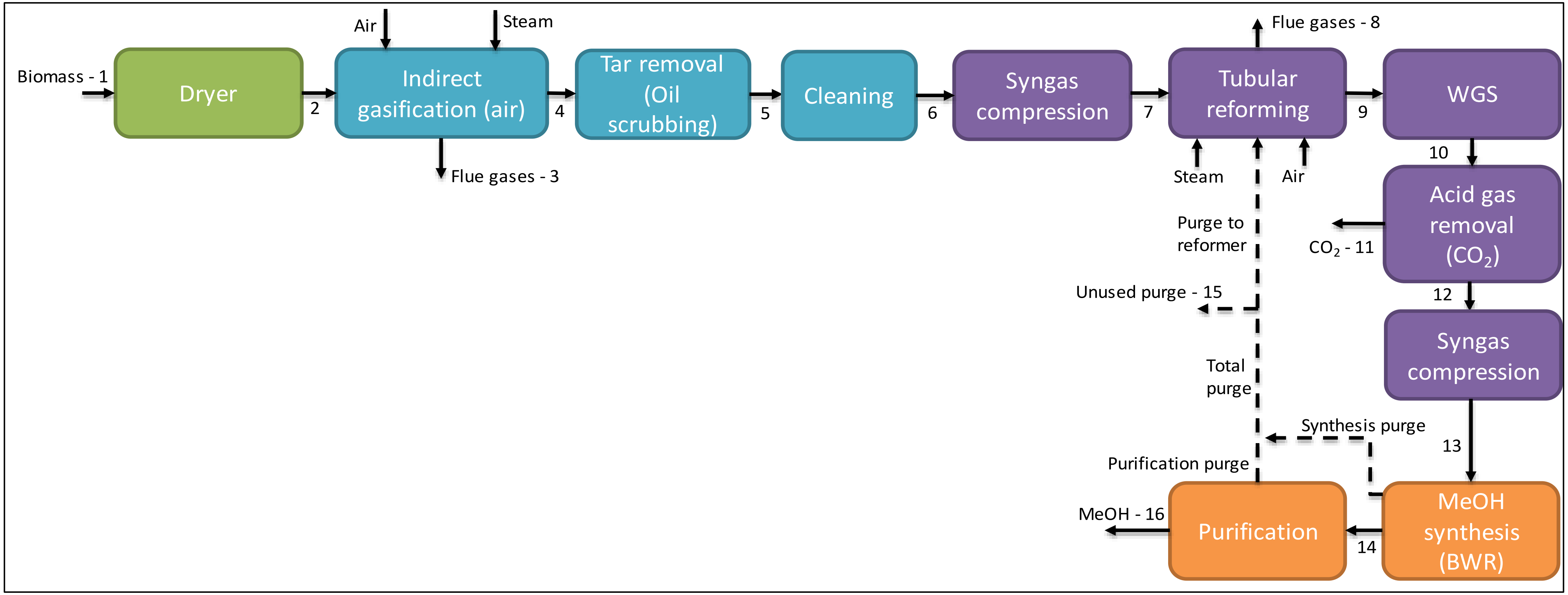


Figure 2. Simplified process flow-sheet of the Base Case

Technical analysis – Case studies

CONVERGE Case

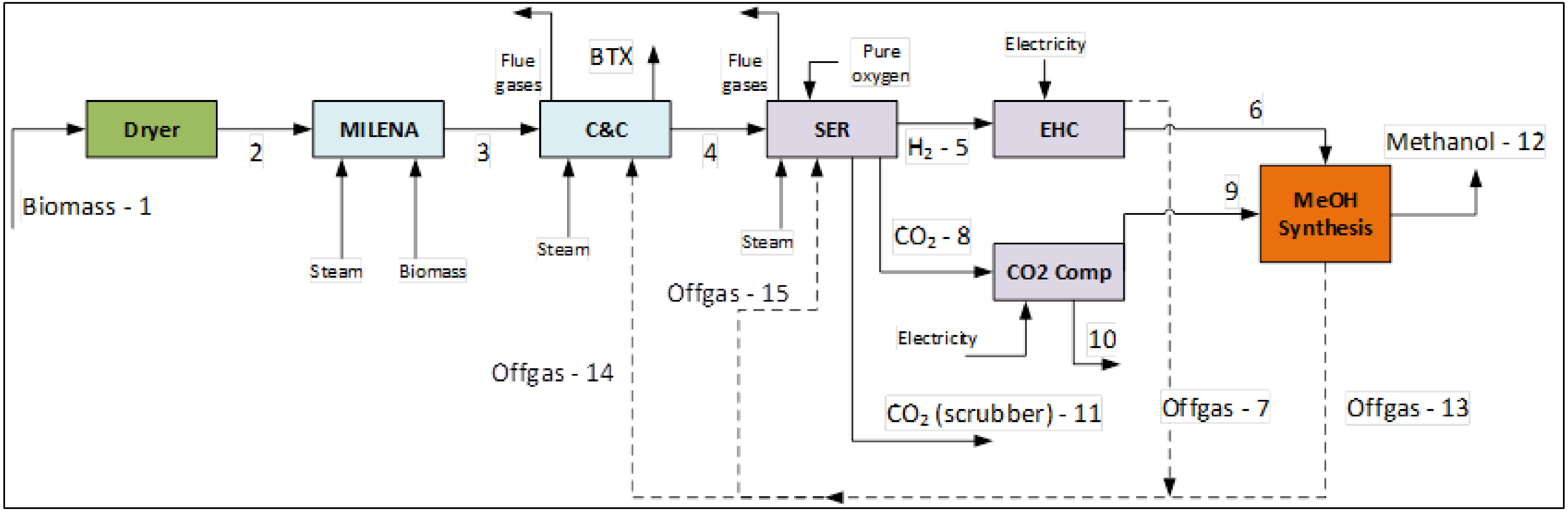


Figure 3. Simplified process flow-sheet of the CONVERGE Case

Technical analysis

Table 1. Case studies comparison

PROCESS	BASE CASE (BC)	CONVERGE CASE
Biomass drying	Tube bundle drier	Tube bundle drier
Biomass conversion (Syngas production)	Indirect gasification (MILENA) Atmospheric pressure Air and steam	Indirect gasification (MILENA) Atmospheric pressure Air and steam
Tar removal	Oil scrubbing (OLGA)	Catalytic Cracking
Syngas cleaning and conditioning	Water scrubbing Compression up to 22 bar Tubular reforming WGS bypassed Acid gas removal - MDEA Compression up to 72 bar	Water scrubbing - - - SER+CO_2 compression (up to 80 bar) ECC (compression up to 80 bar)
Methanol synthesis	Boiling water reactor	Membrane reactor
Methanol purification	Stripping of light gasses and water separation	Stripping of light gasses and water separation

Technical analysis

Table 2. Examples of possible biomass

	Forest residues	Cereal straw	Residual lignin
C	50.71	48.12	57.80
H	6.08	6.57	6.20
O	42.84	48.18	33.83
N	0.38	0.45	0.80
S	0.06	0.07	0.13
Cl	0.09	0.30	0.00
Fixed C	17.93	21.02	27.80
Volatile matter	82.07	78.98	72.20
Ash	1.00	6.70	0.10
Moisture	35.00	7.80	52.00
LHV [MJ/kg]	11.55	15.37	11.01

Table 3. Global plant performance

CGE section	Base Case	CONVERGE	CONVERGE Optimized
Global (methanol)	58.59%	42.55%	49.43%
Global (methanol +BTX)	-	51.45%	58.75%
MILENA Gasifier	82.73%	84.41%	84.43%
Cleaning	99.79%	97.89%	94.96%
Reformer SER	104.79%	88.34%	94.27%
WGS+CO_2 separation	99.98%	-	-
Methanol synthesis	68.36%	82.64%	81.72%
Methanol purification	97.84%		

CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

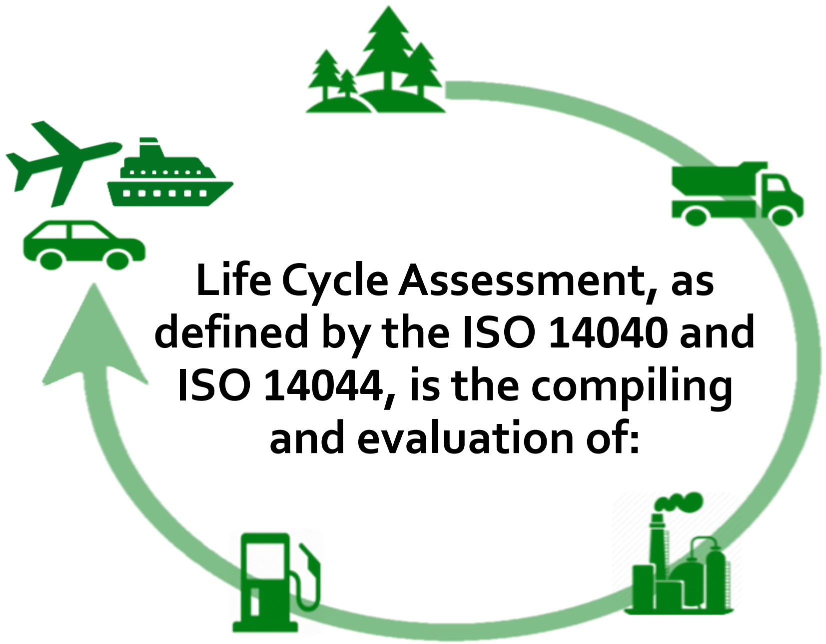
Technical and economic analysis for BC

Table 4. Case studies comparison

Technical KPI		BASE CASE (BC)		
Plant capacity		10 MW_{LHV}	100 MW_{LHV}	300 MW_{LHV}
MeOH production	ton/d	25.1	251	753
CO_2 separated	ton/d	27.7	277	831
CGE global	%		58.6	
Costs		**BASE CASE (BC)**		
Total Capital Investment	M€	39.1	206	424
Total yearly cost	M€/y	7.09	43.8	101.6
	€/ton	1010	525	406
LCOF	€/MWh	183	95	73

CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

Environmental analysis



- the inputs
- the outputs and
- potential environmental impacts of a product/system during its lifetime.

» Life Cycle Assessment Steps

- Goal and scope definition
- Life cycle inventory
- Life cycle impact assessment
- Interpretation

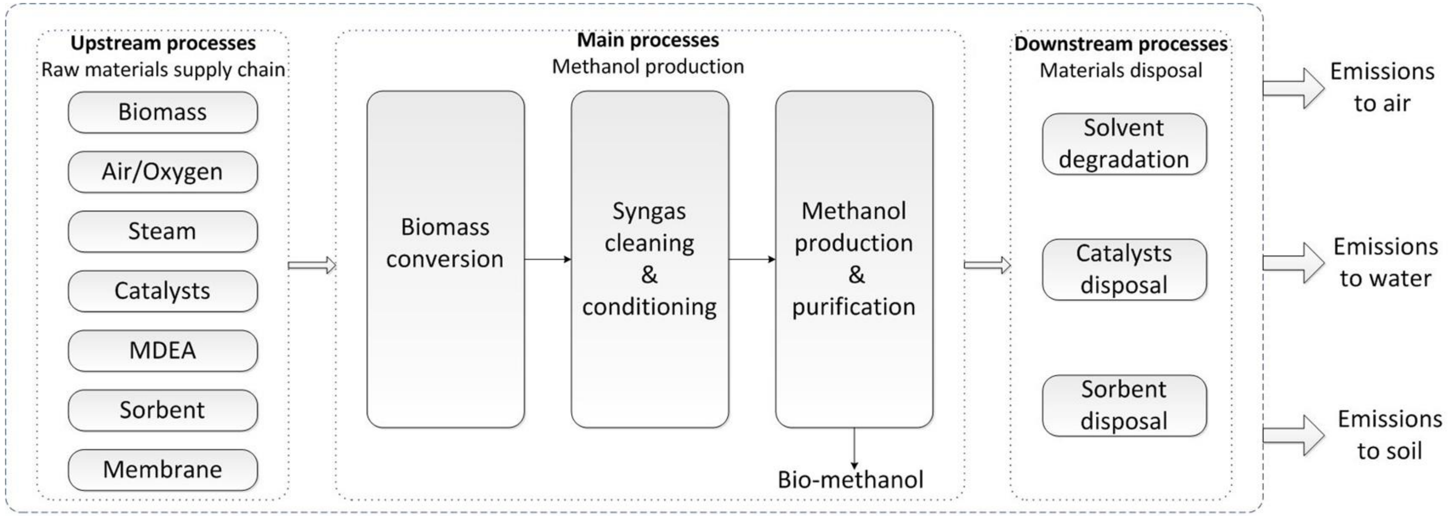
Environmental analysis

Goal and scope definition

» **Goal:** Evaluate and compare the environmental burden of bio-methanol production proposed in the CONVERGE technology with other technologies for bio-methanol production.

» **Scope:**

- boundary conditions



- functional unit - one tone of MeOH
- plant lifetime - 20 years
- plant location - Europe: Sweden

Life cycle inventory

» Quantification of inputs and outputs for a product/process throughout its life cycle

- Energy
- Raw materials
- Air emissions
- Water emissions
- Soil emissions

Life cycle impact assessment

thinkstep GaBi Product Sustainability Performance

ReCiPe Impact Assessment Method

- Global Warming Potential (**GWP**)
- Freshwater Eutrophication Potential (**FEP**)
- Ozone Depletion Potential (**ODP**)
- Fossil fuel Depletion Potential (**FDP**)
- Freshwater Ecotoxicity Potential (**FETP**)
- Human Toxicity Potential (**HTP**)
- Mineral Depletion Potential (**MDP**)
- Photochemical Oxidant Formation Potential (**POFP**)
- Terrestrial Ecotoxicity Potential (**TETP**)

Environmental analysis

Interpretation

Table 5. LCA Results

KPI	Units	Base Case	CONVERGE
GWP	kg CO_2 eq./ tMeOH	1305.4	1470.47
ODP*10⁹	kg CFC-11 eq./ tMeOH	5.85	4.89
FDP	kg oil eq./ tMeOH	6.15	8.35
FETP	kg 1,4-DB eq./ tMeOH	0.51	0.19
HTP	kg 1,4-DB eq./ tMeOH	36.69	7.06
MDP	kg Fe eq./ tMeOH	2.51	2.81
POFP	kg NMVOC/ tMeOH	0.15	0.149
TETP *10³	kg 1,4-DB eq./ tMeOH	9.18	4.61

Concluding remarks

- Different types of biomass are/will be considered in the CONVERGE project for biomass transformation into bio-methanol
- The attention was focused on forest residues biomass
- Cereal straw and residual lignin will be considered in future evaluations
- Calculation of technical KPIs for CONVERGE concept have been performed
- Economic analysis is an on-going task
- Environmental impact was evaluated for the main process (base case and CONVERGE concept) but upstream and downstream processes should be included in the analysis (on-going task)

Thank you for your attention!

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Acknowledgements

The CONVERGE project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 818135