



CENER

CENTRO NACIONAL DE ENERGÍAS RENOVABLES NATIONAL RENEWABLE ENERGY CENTER OF SPAIN

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BIO2C – Biorefinery and Bioenergy Centre



Integrated trial and demonstration platform designed to develop:

- processes,
- equipment and specific components,
- new bioproducts and biofuels,
- bio-refinery concepts.

Process Development Units (PDUs) for bioproducts and advanced biofuels on a pilot scale level as an intermediate step towards the industrial **scale-up** of these technologies. **Services**, among others:

- Testing and Analysis
- Product and Process Development
- Tailor-made research Contracts
- Participation in R&D Funded projects (i.e H2020)
- External staff stages and training



BIOCHEMICAL PROCESS UNIT

PILOT PLANT

Pretreatment



- Continuous horizontal reactor
- Feed flow: up to 5 kg/h
- Pressure up to 14.5 bar
- Temperature up to 200°C
- High flexibility in feedstocks

Enzymatic Hydrolysis



- High solids enzymatic hydrolysis stirred tank reactor
- 200l capacity
- Temperature: 20-80 °C
- Atmospheric pressure

Fermentation



- Fully monitored bioreactors
- 40l and 100l capacity
- Temperature: 23-85°C
- Adjustable agitation speed, air/gas ratios, pH, nutrients

BIOCHEMICAL PROCESS UNIT

INDUSTRIAL PLANT

Modular and flexible facility. Main equipments:

- Biomass feeding system
- High solid enzymatic reactors ($2 \times 3 \text{ m}^3$)
- Solid- liquid separation,
- Detoxification and liquid fraction conditioning
- Fermentation train consisting of several monitorized bioreactors ($1, 3$ and 6 m^3)



PRIVATE PROJECTS (EXTRACT)

Private Customer 2013 UPSCALLING OF A FERMENTATION PROCESS (CONFIDENTIAL)



Detail of one of the fermenters in the Biochemical Process Unit

PROJECT SCOPE

Scaling up of a fermentation process of conversion of wheat straw into industrial oils, including: pretreatment, enzymatic hydrolysis, filtration, fermentation, centrifugation and drying.

CENER ROLE

- Project coordination: including equipment from vendors (plate filter, centrifuge, drier)
- Plant operation
- 3 test campaigns (2 x 3000 litter enzymatic hydrolysis, 3000 litter fermentation)

Private Customer 2016-2018 OPTIMIZATION AND UPSCALLING OF A FERMENTATION PROCESS (CONFIDENTIAL)



Screen control of the 1000 L bioreactor

PROJECT SCOPE

Optimization and scaling up of a fermentation process for agrobiological product production

CENER ROLE

- Product chromatographic characterization protocol development
- Fermentation test for production process optimization and upscaling up from flask to 1000 liters
- Economic and sustainability assessment

Private Customer 2017 UPSCALLING OF A FERMENTATION PROCESS for PHB production



Detail of one of the fermenters in the Biochemical Process Unit

PROJECT SCOPE

Scaling up of a fermentation process of conversion of cereal residue into Polyhydroxybutyrate (PHB), including:

- enzymatic hydrolysis,
- decanter,
- fermentation and
- centrifugation

CENER ROLE

- Project coordination: including equipment from vendors (decanter, centrifuge)
- Plant operation
- 1st stage upscaling to 100L
- 2nd stage upscaling to 3000L

Private Customer 2017 UPSCALLING OF A FERMENTATION PROCESS for 2,3 BD production



Detail of one of the fermenters in the Biochemical Process Unit

PROJECT SCOPE


Scaling up of a fermentation process of conversion of organic fraction of municipal solid waste into into 2,3 BD including:

- enzymatic hydrolysis,
- decanter,
- fermentation and
- centrifugation

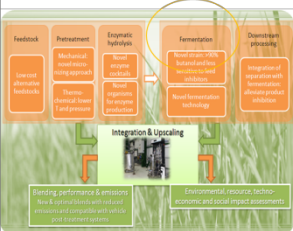
CENER ROLE

- Project coordination: including equipment from vendors (decanter, centrifuge)
- Plant operation
- 1st stage upscaling to 100L
- 2nd stage upscaling to 3000L

FUNDED PROJECTS (EXTRACT)



Next Generation Bio-butanol
2015-2018



PROJECT SCOPE

To overcome the technical and economic constraints to the use of biobutanol as an advanced biofuel.

To develop highly efficient production processes and convert sustainable feedstocks for the next generation of biobutanol.

CENER ROLE


Project Technical Coordinator.

Integration and scale-up at pilot scale of bio-butanol production (100 L).

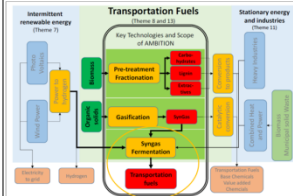
Fermentation batches have run successfully even more when the fermentation process is coupled with the pervaporation unit. To this end, the fermenter was integrated with a pervaporation membrane module for this first time on pilot scale.

European Union
Horizon 2020
Research & Innovation

<http://butanext.eu/>



Advanced biofuel production with energy system integration
2016-2019



PROJECT SCOPE

To develop a long-term joint European Community Research & Innovation Agenda (ECRIA) on the integration of biofuels production and surplus grid electricity valorisation.

To solve key bottlenecks in biomass conversion technologies, i.e. efficiency, pre-treatment, gasification, gas cleaning to valorize lignin-rich residue & syngas fermentation for the sustainable production of biofuels & chemicals


CENER ROLE

To lead the upscaling (40L), optimization and validation of 2 syngas fermentation routes for 1-butanol and butyric acid production, using self produced syngas in a 2MWt fluidized bed gasifier.


Sustainability Assessment

European Union
Horizon 2020
Research & Innovation

www.ambition-research.eu



Scalable Technologies for Urban Biowaste Recovery
2018-2022



PROJECT SCOPE


SCALIBUR aims at closing the gap between technological feasibility and industrial applications of urban biowaste valorisation by enhancing strategic cooperation between sectors.

CENER ROLE

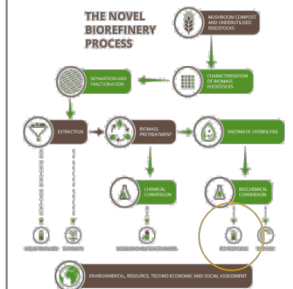
OFMSW valorization by enzymatic hydrolysis and fermentation in BIO2C demonstration plant (TRL7), for a later production of bio-based polyesters and biopesticides

Sustainability assessment

European Union
Horizon 2020
Research & Innovation



A novel biorefinery concept for mushroom compost
2016-2019



PROJECT SCOPE

To develop and demonstrate a new innovative biorefinery concept based on the cascading use of spent mushroom substrate (SMS) supplemented by wheat straw & other seasonal underutilised lignocellulosic feedstocks.

To avoid disposal and allow for the production of some biodegradable bio-based products and bioactive compounds,

CENER ROLE

Project Coordinator

To lead the research line of SMS conditioning and two step fractionation process of the SMS into three valuable fractions (extract, high glucan solid and enriched lignin liquid),

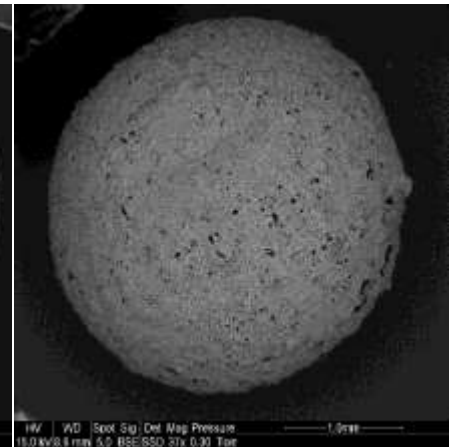
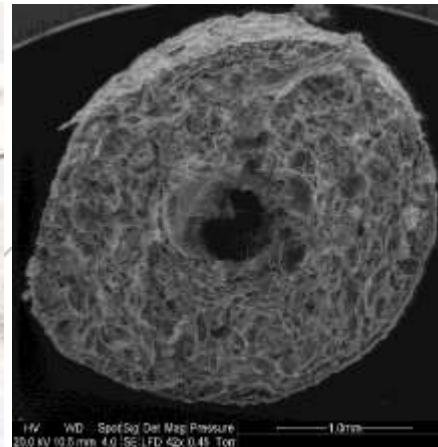
Secondary conversion related to sugar fermentation for biopesticides production

Sustainability Assessment

European Union
Horizon 2020
Research & Innovation

THANK YOU VERY MUCH!

FACILITIES FOR WASTES AND BIO-RESOURCES MANAGEMENT



CEA, LEADER IN R&D OF RENEWABLE ENERGIES

9 centers
16000 empl.
4,1 Md€/y
195 start ups
743
patents/year

DEFENSE

**FUNDAMENTAL
RESEARCH**

**HEALTH AND
INFORMATION
TECHNOLOGIES**

LOW CARBON ENERGIES

FROM APPROACH TO ENERGY
cea tech

7 sites
4 500 empl.
600 M€/y
50 start ups
500 patents/an



Leti List liten



TRANSPORT



BUILDINGS



INDUSTRY



MATERIALS

3 sites
1 200 empl.
170 M€/y
235 patents/y

R&D GOAL

Biomass and waste

Wood



Agricultural residues



Tires



Sludges



Microalgae



Refused derived fuels (RDF)

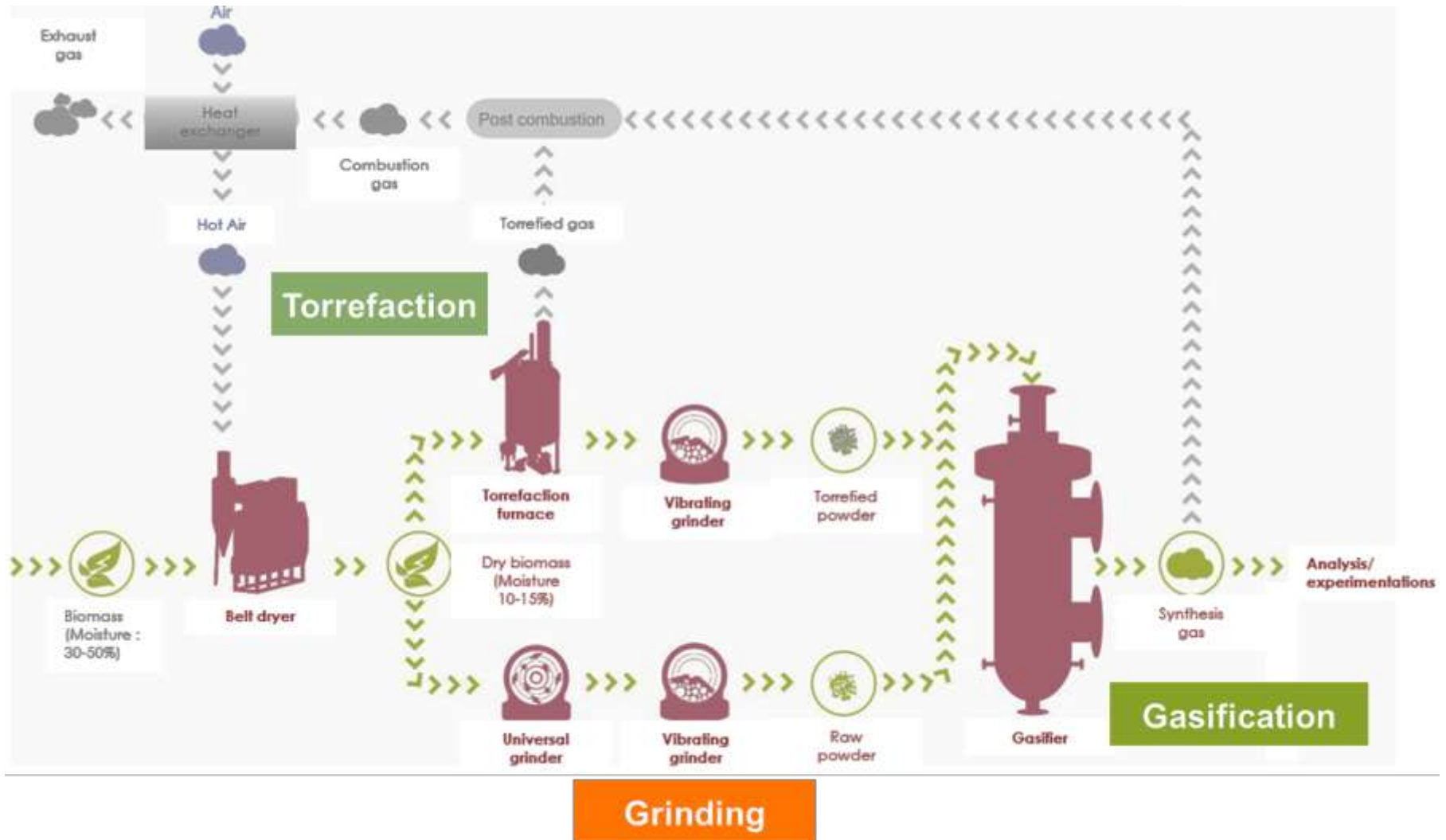


Heat & power

Solid, liquid and
gaseous fuels

Biomaterials

GENEPI RESEARCH FACILITY



TECHNOLOGY DEVELOPMENT ACTIVITIES

Pretreatment

Grinding

Torrefaction

Drying

Pyrolysis

Blending

Pelletizing

Conversion

Gasification

Flash
pyrolysis

Hydrothermal
carbonization

Combustion

Anaerobic
digestion

Hydrothermal
liquefaction

Fermentation

Supercritical
water gasif.

Hydrolysis
Esterification

Post-treatment / Purification

Methanation

Thermal
cracking

Separation,
extraction

Refining

Syngaz
purification

Catalysis

Torrefied product
Powders
Pellets
Organic molecules
Activated carbon
Biochar

Syngas
Solid fuel (char)
Bio-oil
Ash, minerals
Clean water
CO₂

Biofuels (diesel, methanol)
SNG
Bio-oil, Bio-crude
Building block molecule
Ethanol, bio-butanol, H₂

EXPERTISE AND SKILLS

- Resource characterization
- Process engineering and thermodynamics
- Inorganic species behavior and agglomeration control
- Design, instrumentation and implementation of experimental pilots
- Process upscaling : pilot and demonstration performance analysis
- Modeling of torrefaction, pyrolysis and gasification physical and chemical reactions.
- Analysis of liquid, solid and gaseous products, tars and trace pollutants
- Process simulation (Proseet, Prosim)
- Economical evaluation of the various bioenergy routes (multi-scale, multi-criteria, multi-resource, multi-applications)

MAIN PARTNERS

Industrials

Pretreatment



Conversion



Post-treatment



Academicals





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GREEN ENERGY AND SUSTAINABLE MATERIALS FROM SEWAGE SLUDGE

Pavlina Nanou, Jan Pels, Levien de Lege



ECN › **TNO** innovation
for life

Pitch perfect and boost the European bio-economy event
7th of November 2018

EXPERIMENTAL APPROACH - LAB TESTING



Sewage Sludge
(Digested and Undigested)



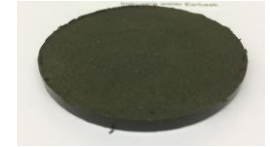
20-L autoclave vessel
150-250°C



Filtration

Liquid effluent

Solids



Anaerobic digestion



Mechanical Pressing & Characterisation

- Mass yield
- Dry matter content
- Calorific Value
- Elemental analyses

TORWASH® = TORREFACTION + WASHING

- › Upgrading of biomass that has too much water or too much salt
- › Unique concept:
 - › It enables efficient mechanical dewatering
 - › It enables complete removal of salts
 - › Mild process conditions allow digestion of the effluent
 - › No use of flocculants
 - › ECN patent WO 2013/162355
- › Goal: maximum energy and materials
 - › 1st product: solid biomass fuel
 - › 2nd product: biogas from digestion of effluent
- › Potential for controlled release of phosphorus

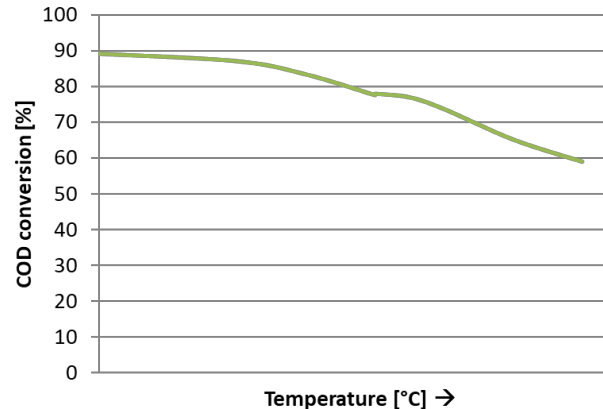


Solid Biofuel Pellets

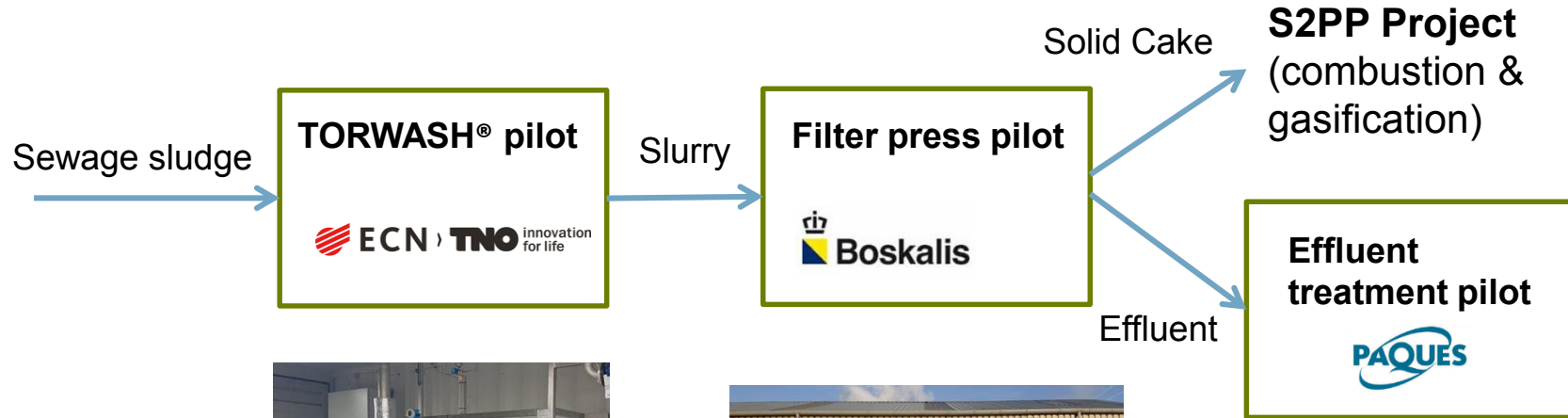
DIGESTED AND UNDIGESTED SEWAGE SLUDGE LAB SCALE RESULTS

- › TORWASH® and dewatering of sewage sludge results in a pressed cake with 61-67 wt% dry matter
- › Both effluents are well digestible
- › Net calorific value of solid product increases to 14-18 MJ/kg
- › Phosphorus largely in solution, but may be manipulated

	dry matter content wt%
After centrifuge, before TORWASH®	8
After TORWASH® and dewatering Digested sludge	61
After TORWASH® and dewatering Undigested sludge	67



PILOT TESTING AT WWTP ALMERE, NL



POTENTIAL SAVINGS FOR ALMERE: 1,1 M€

Almere	Dry matter	Volume [ton]	Disposal costs*
Centrifuge	8%	56 000	M€ 3.4
Existing Press	21%	21 000	M€ 1.3
Best Press	24%	19 000	M€ 1.1
TPH	30%	15 000	M€ 0.9
TORWASH	65%	3 100	M€ 0.2

* € 60 per ton “as received” in all cases



repeatedly obtained for various raw materials

MORE INFORMATION

Consortium partners



Financial support



Rijksdienst voor Ondernemend
Nederland

Project Leader

Dr. ir. Pavlina Nanou

Technical Lead

Biomass Upgrading to Fuels

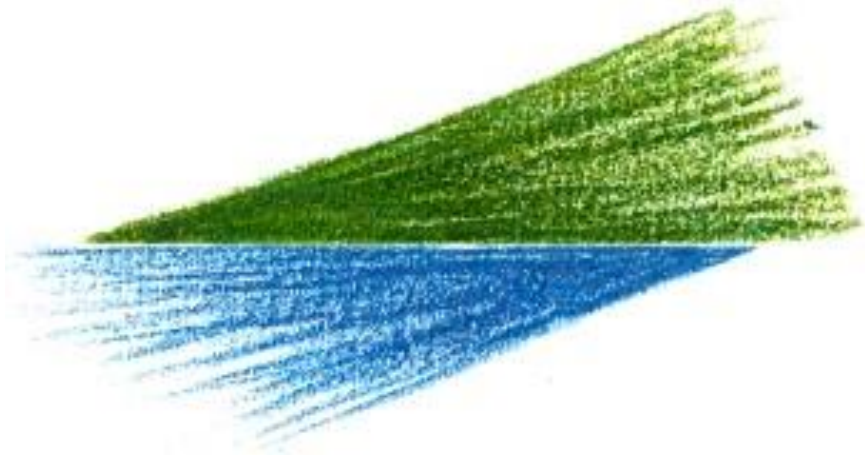
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The Netherlands	The Netherlands

Green Bio Power b.v.

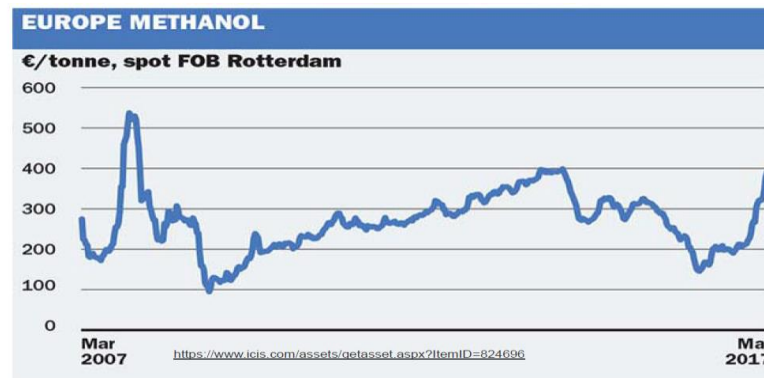


CO₂ to Methanol

Product development
Ing J.H.F Veldhuis MBA
Businessdevelopment

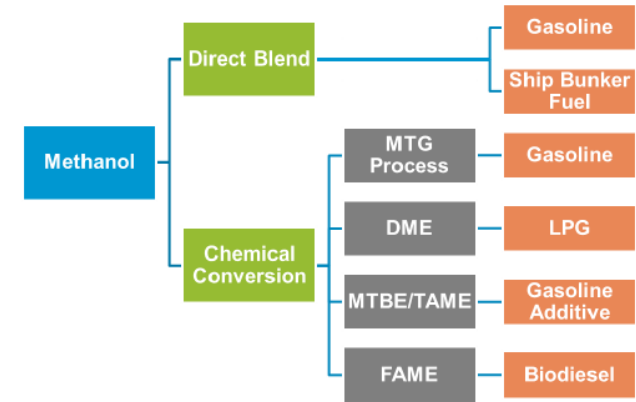
Methanol market

- 72 Mtonne per year production globally (Main producer and consumer)
- 2/3 is produced by Natural gas Steam reforming, 1/3 Coal gasification
- Market is moving from Chemicals to Energy fuel
- Methanol can be used as: Blending fuel (15 % in gasoline), Monofuel or Hydrogen carrier
- High octane number: 115, No PM emissions, low NOX/SOX
- Offtakers: Marine fuel, Heavy duty trucks
- Cost price SMR/Coal gasification route: USD 326-376/tMeOH
- Sales price Methanol:

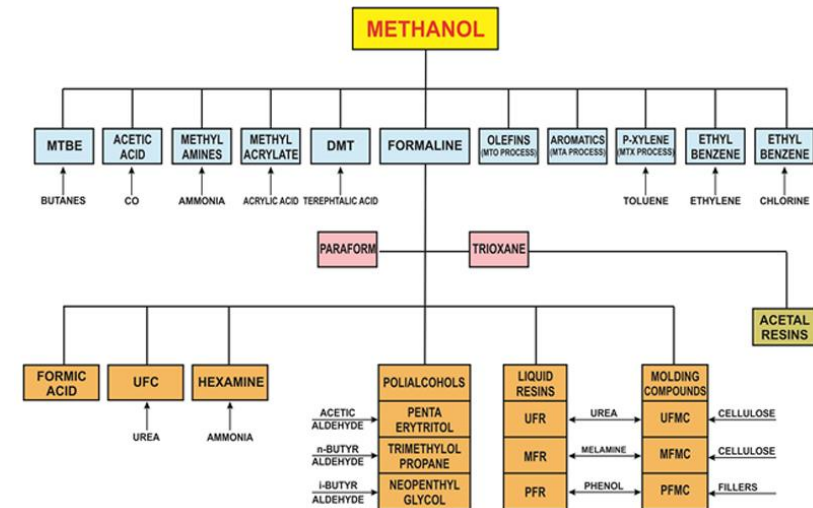


Methanol market

- Methanol as fuel



- Methanol as building block

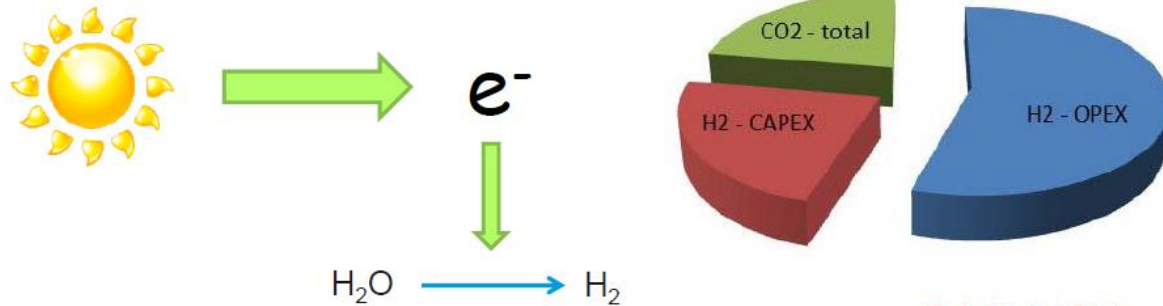


Renewable Methanol

- H₂ made from Electrolysis, Europe
- In these regions USD 60/MWh is possible with load factor (around 4500 h, >4000 h required)
- Large Electrolyser costs (400 MW): USD 450 per kW → USD 3-4 /Kg H₂
- Methanol price: USD 700 /tonne
- Syngas can be also made from Wood, Biomass
- Cost Methanol: varying from USD 225-1300/t for wood, USD 280-700 for waste

Twente case

- Electricity price: 10 USD/MWh



OPEX (electrolysis) (60 kWh/kg H₂; 0,1875 kg H₂/kg MeOH)
 CAPEX (, ,) (@ 1000 € / kW_{el}; 8000 h; 10 yr)

CO₂ (50 \$/ton CO₂; 1.375 kg CO₂/kg MeOH)

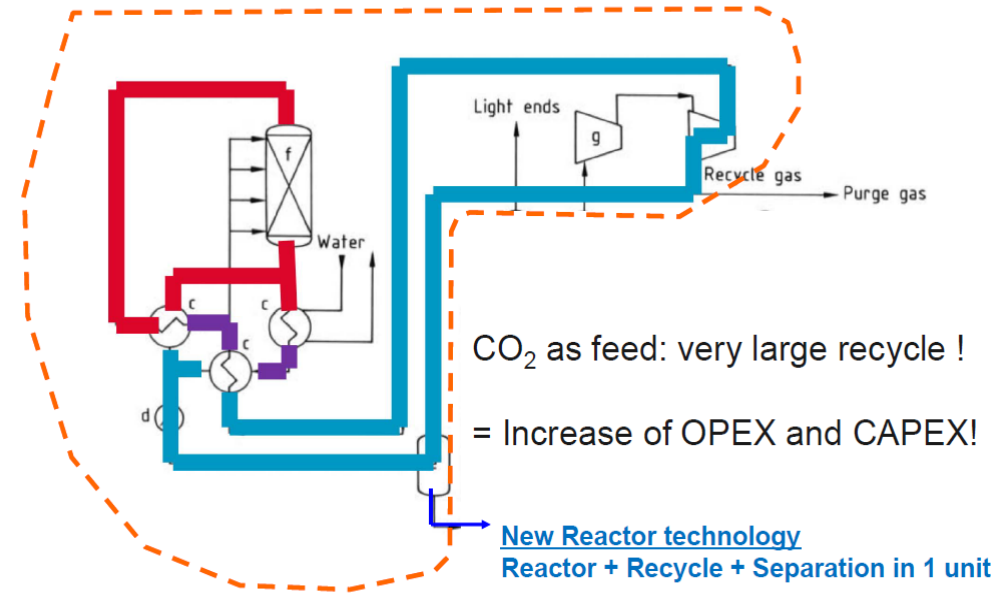
@ 0.01 € / kWh_{el}

0.11 € / kg MeOH
 0.14 € / kg MeOH

0.07 € / kg MeOH

320 € / ton MeOH

For cost-competitiveness: electricity at max. around 0.01 € / kWh_{el} is needed !



Process implications when shifting from CO to CO₂

Companies present in “bio”methanol



CRI first of its kind Emissions-to-Liquids facility in Iceland
George Olah (GO) Renewable Methanol Plant, Svartsengi, Iceland

First commissioning: 2012

Capacity expansion: 2015

CCU throughput: 5,600 t/yr CO₂

Electrolyzer capacity: 800 t/yr H₂ (1200 Nm₃/hr)

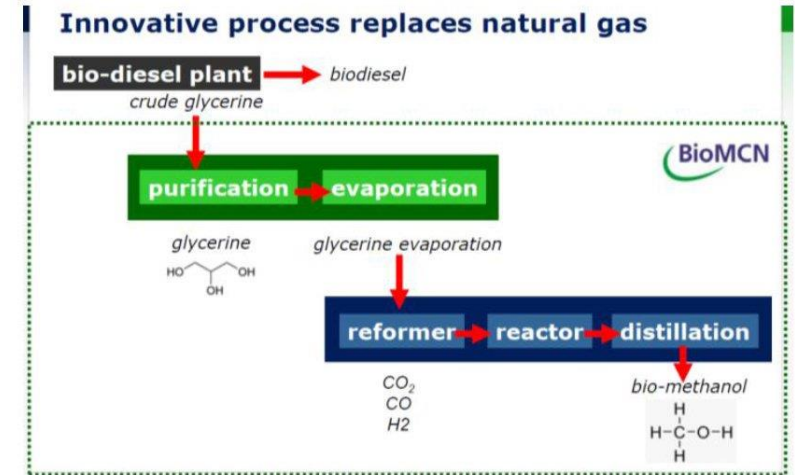
Production capacity: 4,000 t/yr methanol

Enerkem in Rotterdam: partnerships will help accelerate Enerkem's global expansion

In 2018, a consortium of companies comprising Air Liquide, AkzoNobel Specialty Chemicals, Enerkem and the Port of Rotterdam has signed a project development agreement covering initial investments in an advanced waste-to-chemistry facility in Rotterdam. The facility will be the first of its kind in Europe to provide a sustainable alternative solution for non-recyclable wastes, converting waste plastics and other mixed wastes into new raw materials.



Infographic courtesy of Akzo Nobel



Carbon Recycling International -



Enerkem



Follow up in project Twente

- CO₂ to Methanol is part of industrial bio-energy project Twente: CO₂ utilization
- Part of Power to Products program: green gas, bio-LNG , Methanol out of Bio Methane
- October 2018: Greenpower Twente offers a development program with new innovative Methanol reactor and scale up in collaboration with TU Twente

