COMSYN & FLEXCHX Webinar 19 January 2021, 10:00-12:30 CET

Compact Gasification and Synthesis for Flexible Production of Transport Fuels and Heat

COMSYN FLEXCHX

VTT ENERSTENA INERATEC DLR HELEN LIETUVOS ENERGETIKOS INSTITUTAS AB KAUNO ENERGIJA NESTE

ORLEN UniCRE GKN SINTER METALS wood. AFRY Grönmark JM Johnson Matthey

Practicalities of the webinar

- You are welcome to write questions to the chat box as you listen – we will answer at the end of the webinar
- All attendees are muted.
- The webinar will be recorded.

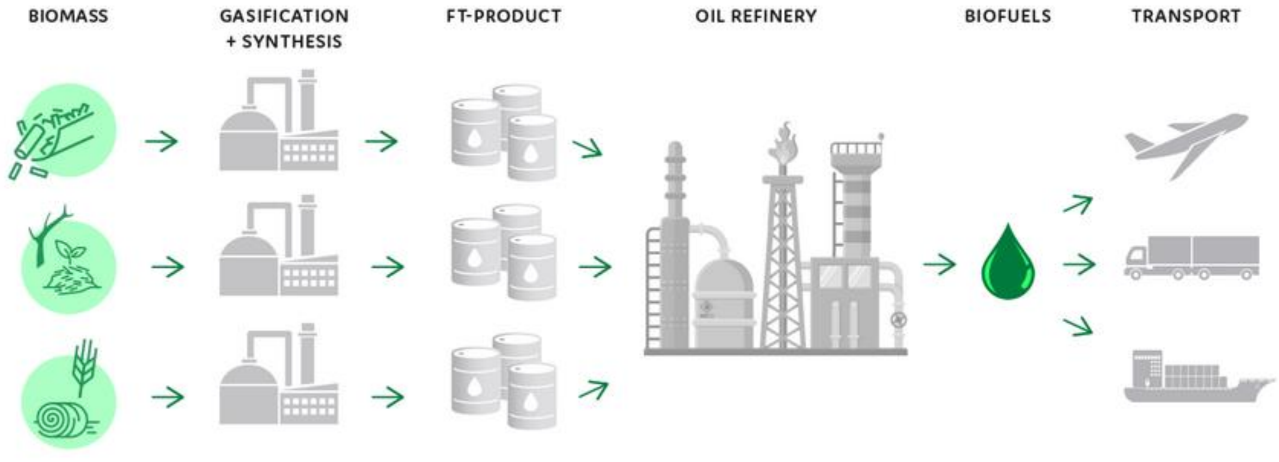
The material presented will be available in the websites:

COMSYN https://www.comsynproject.eu/
FLEXCHX http://www.flexchx.eu/index.htm

Compact Gasification and Synthesis process for Transport Fuels

COMSYN

www.comsynproject.eu



PROJECT FACTS

2017 – 2021

7 partners

5.1 M€ budget

Pilot scale validation from biomass gasification to final product

Decentralized primary conversion of biomass in 30 – 150 MW units.

Technology development for primary conversion, Fischer-Tropsch synthesis and oil refinery feeding systems.

VTT | INERATEC | GKN SINTER METALS | ORLEN UniCRE | DLR | wood. | AFRY ÅF PÖYRY

FlexCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

FLEXCHX

Flexible combined production of power, heat and transport fuels from renewable energy sources

- Duration: 38 M, March 2018 – April 2021
- H2020 funding: 4 489 545 €
- Coordinator: VTT, Esa Kurkela
- Consortium,10 partners:
  VTT (Finland), Enerstena (Lithuania), INERATEC (Germany), DLR (Germany), HELEN (Finland), Kauno Energija (Lithuania), Lithuanian Energy Institute (Lithuania), NESTE Engineering Solutions (Finland), Johnson Matthey (UK) and Grönmark (Finland)

VISION

- To realise a process for **optimal use of the seasonal solar energy supply and available biomass resources**
- Satisfy the seasonal demand for heat and power, and to produce low-GHG fuels for the transport sector.

VTT · ENERSTENA GROUP · INERATEC · DLR · HELEN · AB KAUNO ENERGIJA · LITHUANIAN ENERGY INSTITUTE · NESTE · JM Johnson Matthey Inspiring science, enhancing life · Grönmark

Speakers

Johanna Kihlman, VTT
COMSYN Coordinator

Sanna Tuomi
VTT

Esa Kurkela, VTT
FLEXCHX Coordinator

Harald Balzer
GKN

Adrew Steele
Johnson Matthey

Christian Frilund
VTT

Tim Boeltken
INERATEC

Mikko Wuokko
Neste Engineering Solutions

Jan Jencik
ORLEN UniCRE

Vincenzo Tota
Wood

Ralph-Uwe Dietrich
DLR

Contents

10:00 – 10:10	Welcome and introduction Johanna Kihlman, VTT
10:10 – 10:20	Concepts for distributed primary biomass conversion and central refining Sanna Tuomi, VTT
10:20 – 10:35	Gasification technologies for small-to-medium scale syngas plants Esa Kurkela, VTT
10:35 – 10:45	Hot filtration Harald Balzer, GKN Sinter Metals Filters
10:45 – 10:55	Catalytic reforming Andrew Steele/Benjamin Rollins, Johnson Matthey
10:55 – 11:05	Sorbent-based final gas clean-up Christian Frilund, VTT
11:05 – 11:20	Compact Fischer-Tropsch synthesis Tim Boeltken, INERATEC
11:20 – 11:40	Use of FT product at oil refineries Processing alternatives Mikko Wuokko, NESTE Engineering Solutions Vision of ORLEN UniCRE Jan Jencik, ORLEN UniCRE
11:40 – 11:55	Techno-economic studies for COMSYN process Vincenzo Tota, Wood
11:55 – 12:10	Techno-economic studies for FlexCHX process Ralph-Uwe Dietrich, DLR
12:10 – 12:15	Concluding remarks Esa Kurkela, VTT
12:15 – 12:30	QA session

These projects have received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919 FLEXCHX and No 727476 COMSYN.

Concepts for distributed primary biomass conversion and central refining

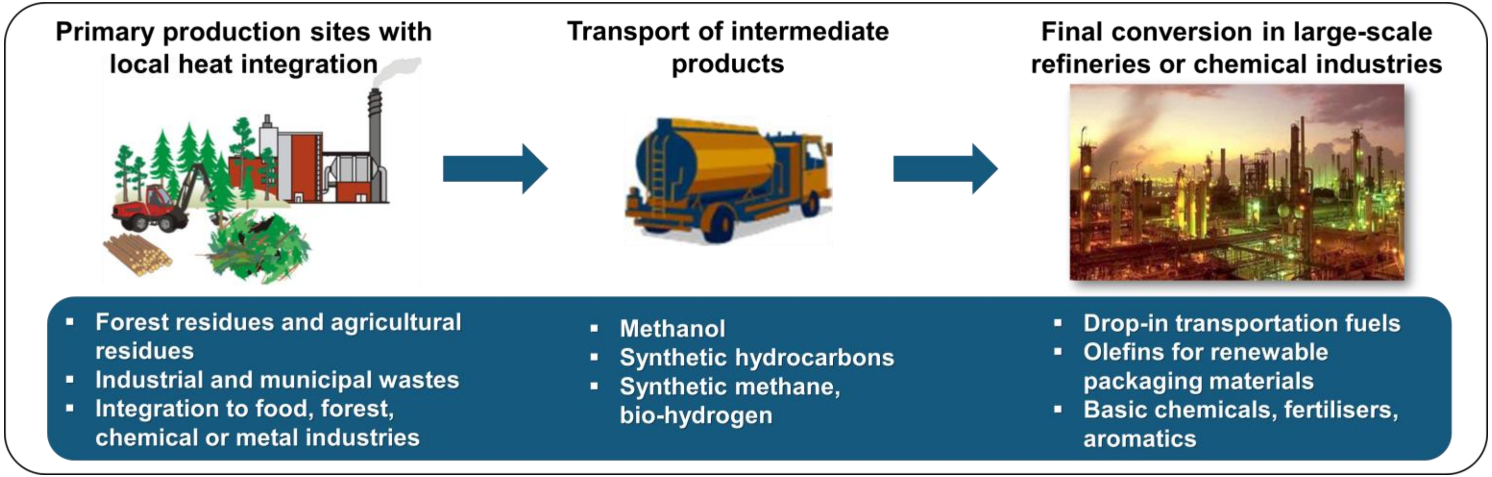
Sanna Tuomi, VTT

COMSYN / FLEXCHX Webinar
January 19th, 2021

Outline

- Double integration principle
- Demand for flexible production of heat, power and transportation fuels
- FLEXCHX concept
- Gasification concepts for small-to-medium scale production of transportation liquids

Double integration principle in synthetic fuels production



PRIMARY CONVERSION

- Distributed production of FT syncrude in small-to-medium scale gasification/synthesis units located **close to biomass resources**
- **Integrated to local district heating networks or heat-consuming industries** (overall efficiency > 75-80 %)

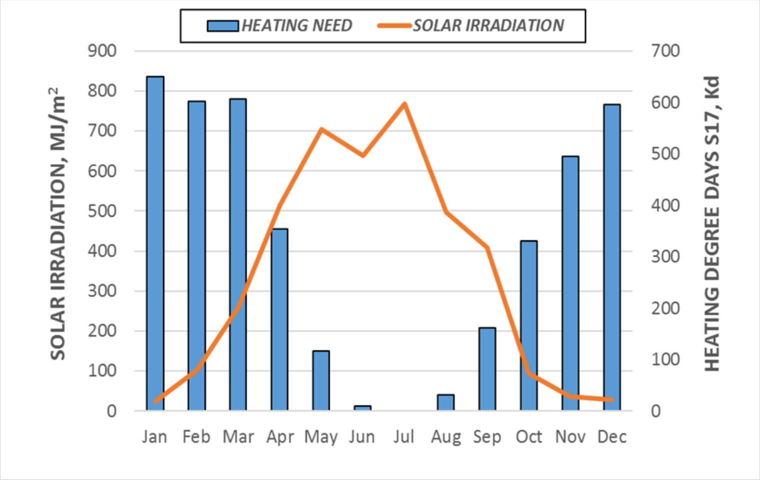
FINAL CONVERSION

- **Final refining** of FT products into drop-in transportation liquids takes place in **existing oil refineries**
- **Advantages:** benefits from economies of scale, product portfolio can be tailored according to market demand

Demand for flexible production of fuels, heat and power – background

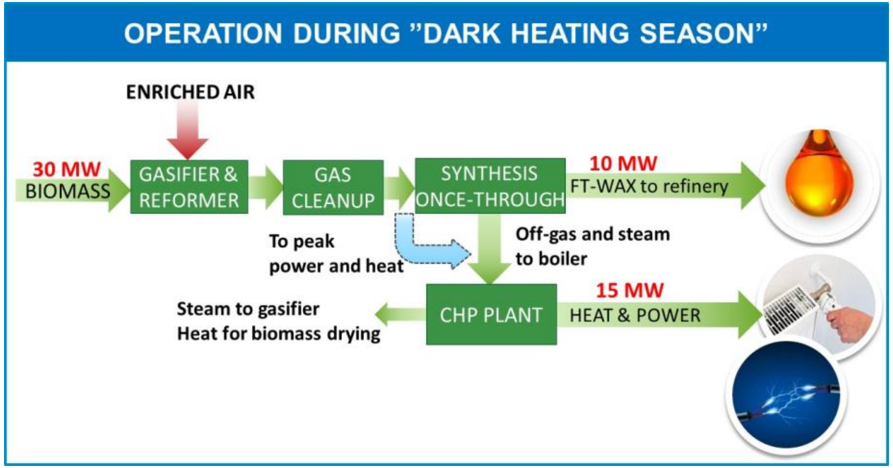
ENERGY TRANSITION

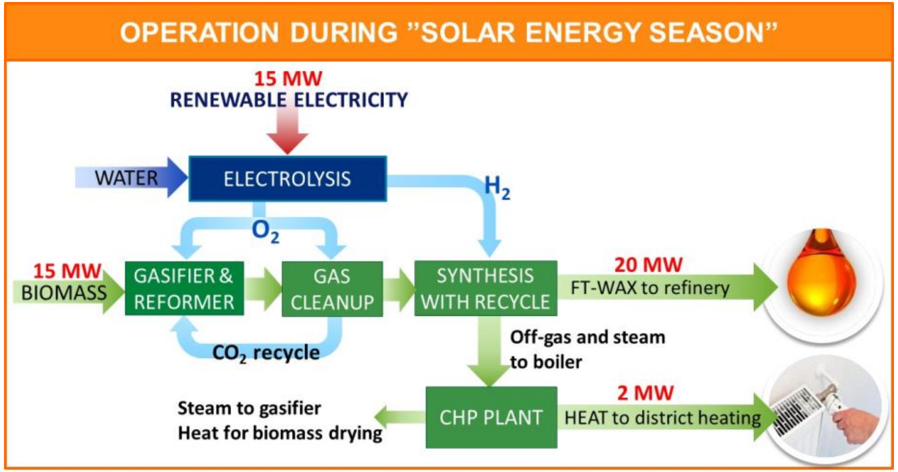
- The share of variable renewable energy (wind and solar) is strongly increasing and will become the main source of electricity production in Europe by 2050.
- One specific challenge of the energy system especially in Northern and Central Europe is the **poor match between the availability of solar energy and the demand for heating**.
- Thermal power plants (originally designed to operate as baseload units) are facing challenges in the changing energy system and should be operated flexibly – **balancing power production and electricity storing needed**.
- Decarbonisation of the transport sector, particularly the ‘difficult-to-electrify’ sectors (heavy duty, aviation, maritime), will largely base on the use of **advanced biofuels**.



FLEXCHX: Hybrid process for flexible production of power, heat and transport fuels

VTT

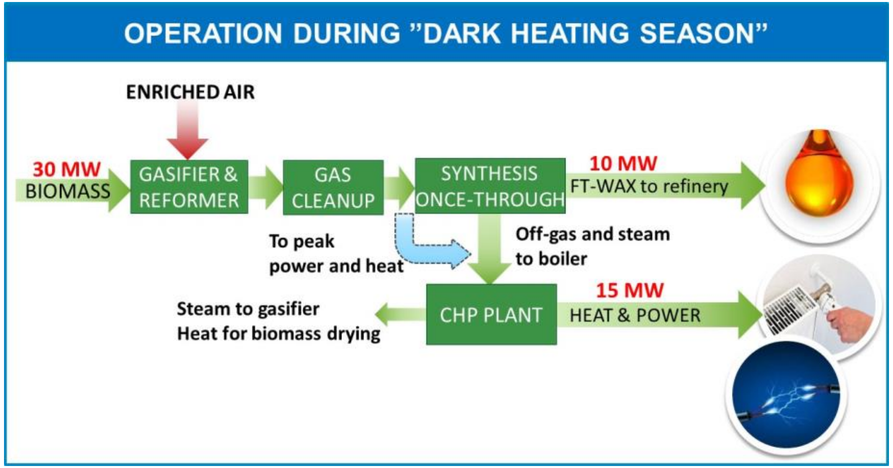


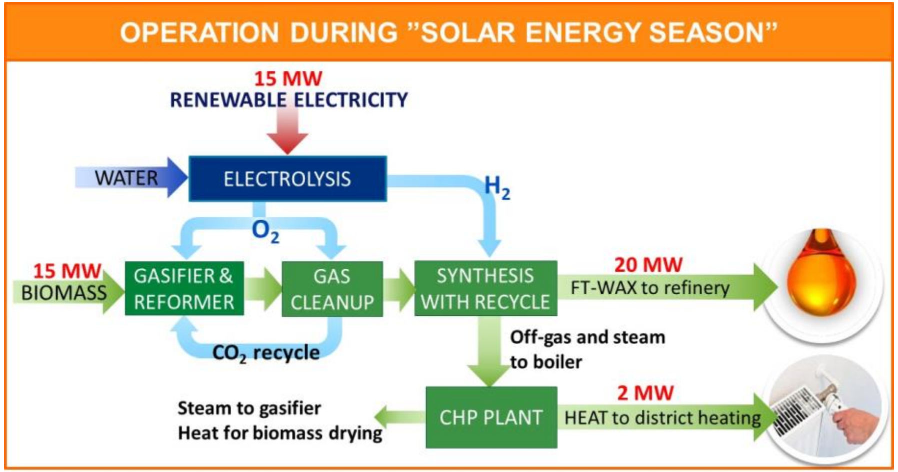


The **FLEXCHX concept** addresses these challenges by:

1) offering CHP and district heating companies new business possibilities in combining fuel and heat production, and
2) providing balancing capacity for the future energy system.

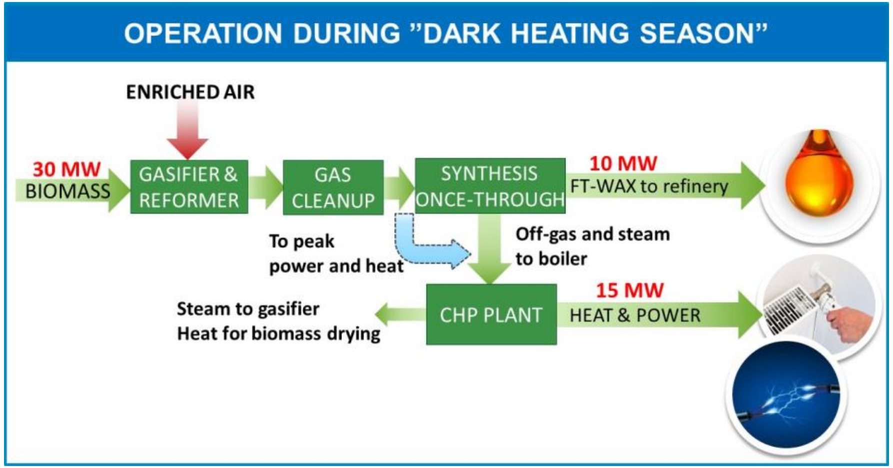
FLEXCHX: Hybrid process for flexible production of power, heat and transport fuels

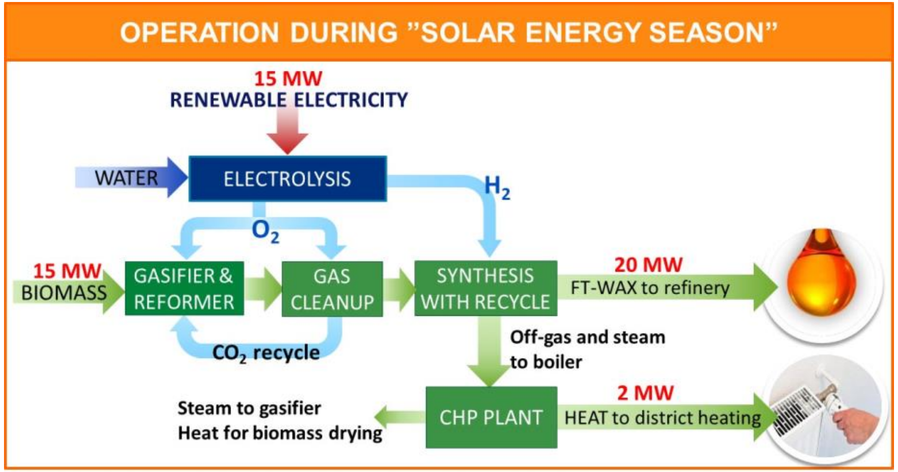




- Electrolysis + biomass gasification + Fischer-Tropsch synthesis
- Tri-generation of power, heat and intermediate energy carrier (FT syncrude) for the transport sector
- Two operation modes: “winter mode” and “summer mode”

FLEXCHX: Hybrid process for flexible production of power, heat and transport fuels





- Biomass as the only energy source
- Energy conversion efficiency to FT syncrude, heat and power > 80 %

- Biomass and renew. electricity as energy sources
- Energy conversion efficiency to FT and heat > 65 %
- Up to 90 % of biomass carbon converted to FT syncrude.

Gasification concepts for small-to-medium scale production of transportation fuels

VTT

MATURITY

FLEXCHX

PRESSURISED FIXED-BED OXYGEN-BLOWN GASIFICATION

Development started in 2018
Scale: < 50 MWth

COMSYN

LOW-PRESSURE DUAL FLUID-BED STEAM GASIFICATION

Development started in 2012
Scale: > 100 – 150 MWth

PRESSURISED CFB OXYGEN-BLOWN GASIFICATION

Demonstrated in 2009-11
Ready for commercialisation
Scale: > 150 MWth

SCALE

Thank you!

The projects have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476 (COMSYN) and No 763919 (FLEXCHX).

COMSYN & FLEXCHX Webinar 19 January 2021, 10:00-12:30 CET

Compact Gasification and Synthesis for Flexible Production of Transport Fuels and Heat

Gasification Technologies for small-to-medium scale syngas plants

Esa Kurkela, VTT

COMSYN

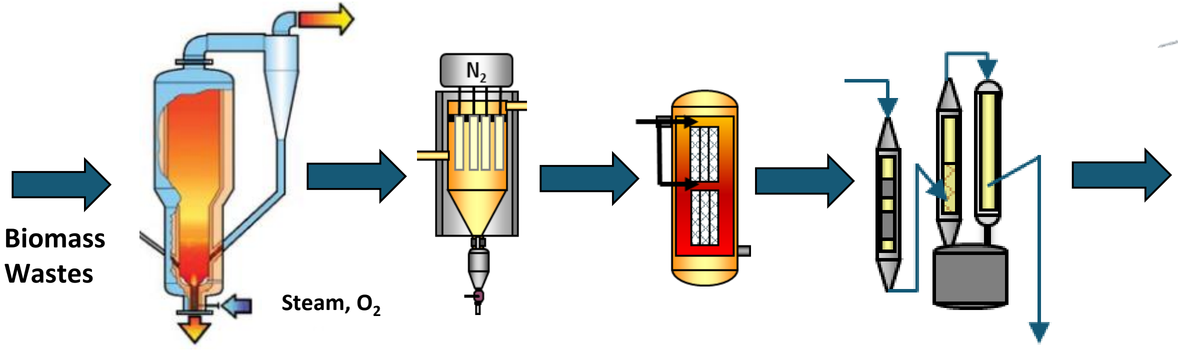
FLEXCHX

VTT ENERSTENA INERATEC DLR HELEN LIETUVOS ENERGETIKOS INSTITUTAS KAUNO ENERGIJA NESTE ORLEN UniCRE GKN SINTER METALS wood. AFRY Grönmark Johnson Matthey

Key steps in gasification based synfuels process

Electrolysis can be integrated in several ways to boost syngas production and to increase carbon efficiency

Gasification | **Filtration** | **Reforming** | **Ultra-cleaning**



FT-products
Methanol
SNG
H2

Selection of the optimal gasifier depend on target scale and feedstock

- Pressurized O_2-blown CFB for > 150 MW input
- Dual Fluidized-Bed steam gasification for 50 – 150 MW
- Pressurized Staged Fixed-Bed gasifier for 10 – 50 MW (TRL 5)

Synthesis gas production at different scale

MATURITY

Ready for commercialisation
> 150 MW_{th}

PRESSURISED CFB OXYGEN-BLOWN GASIFICATION

LOW-PRESSURE DUAL FLUID-BED STEAM GASIFICATION

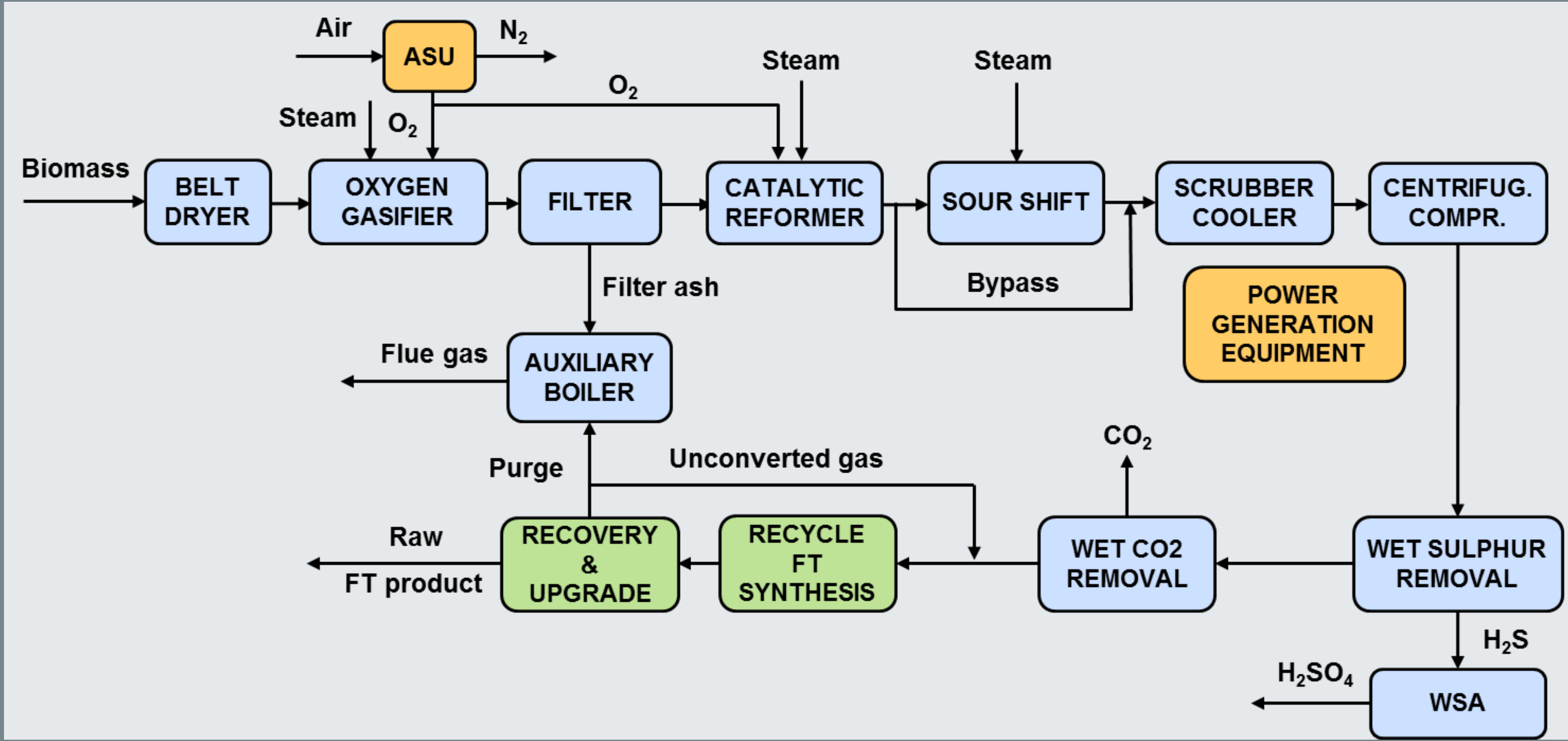
Developed to TRL 5-6
~ 50 – 150 MW_{th}
- National project BTL2030
- H2020-project COMSYN
- H2020-project REDIFUEL
- H2020-project BioSFera

PRESSURISED FIXED-BED OXYGEN-BLOWN GASIFICATION

Developed to TRL5
< 50 MW_{th}
- H2020-project FLEXCHX

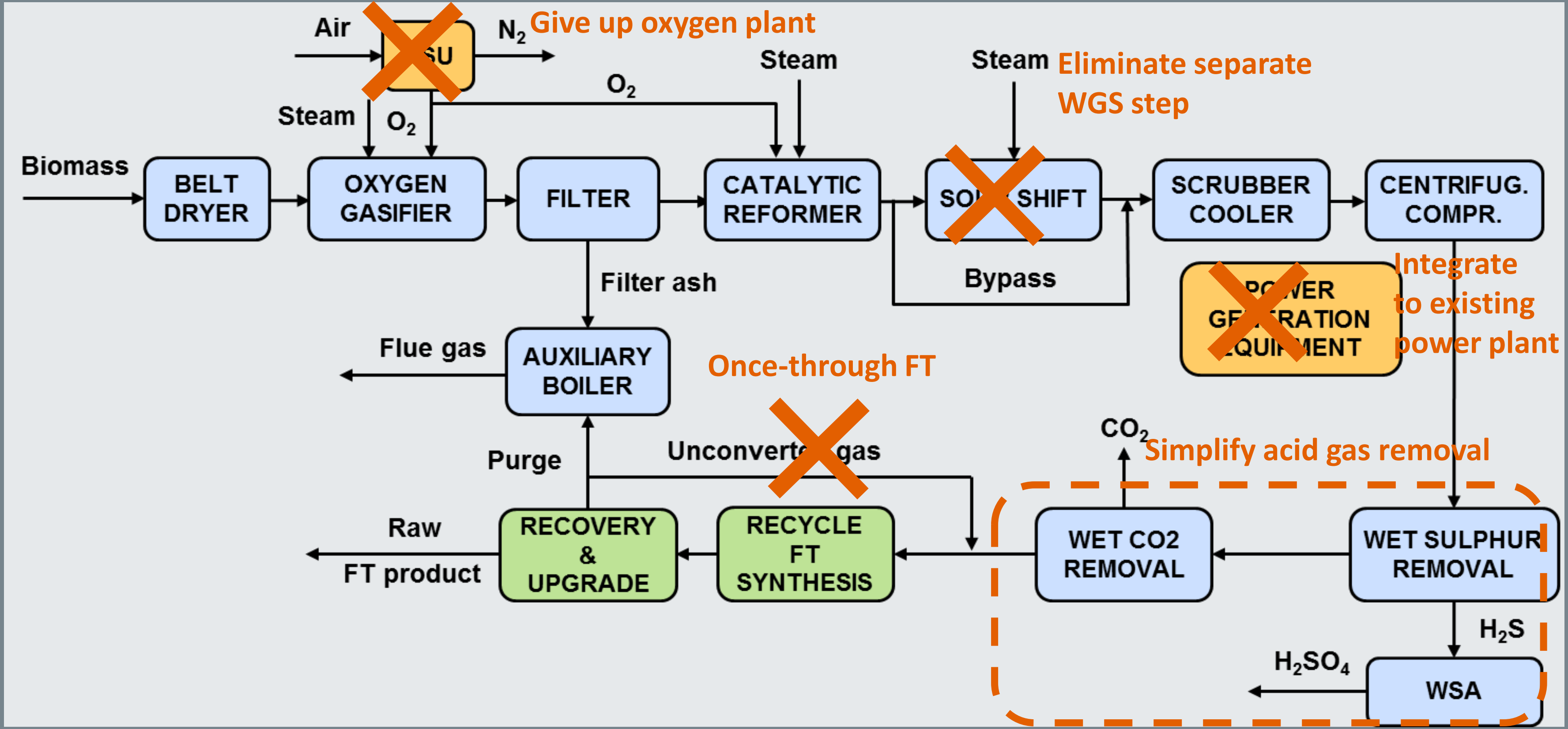
SCALE

Large-scale BTL plant based on pressurized oxygen-blown fluidized-bed gasification



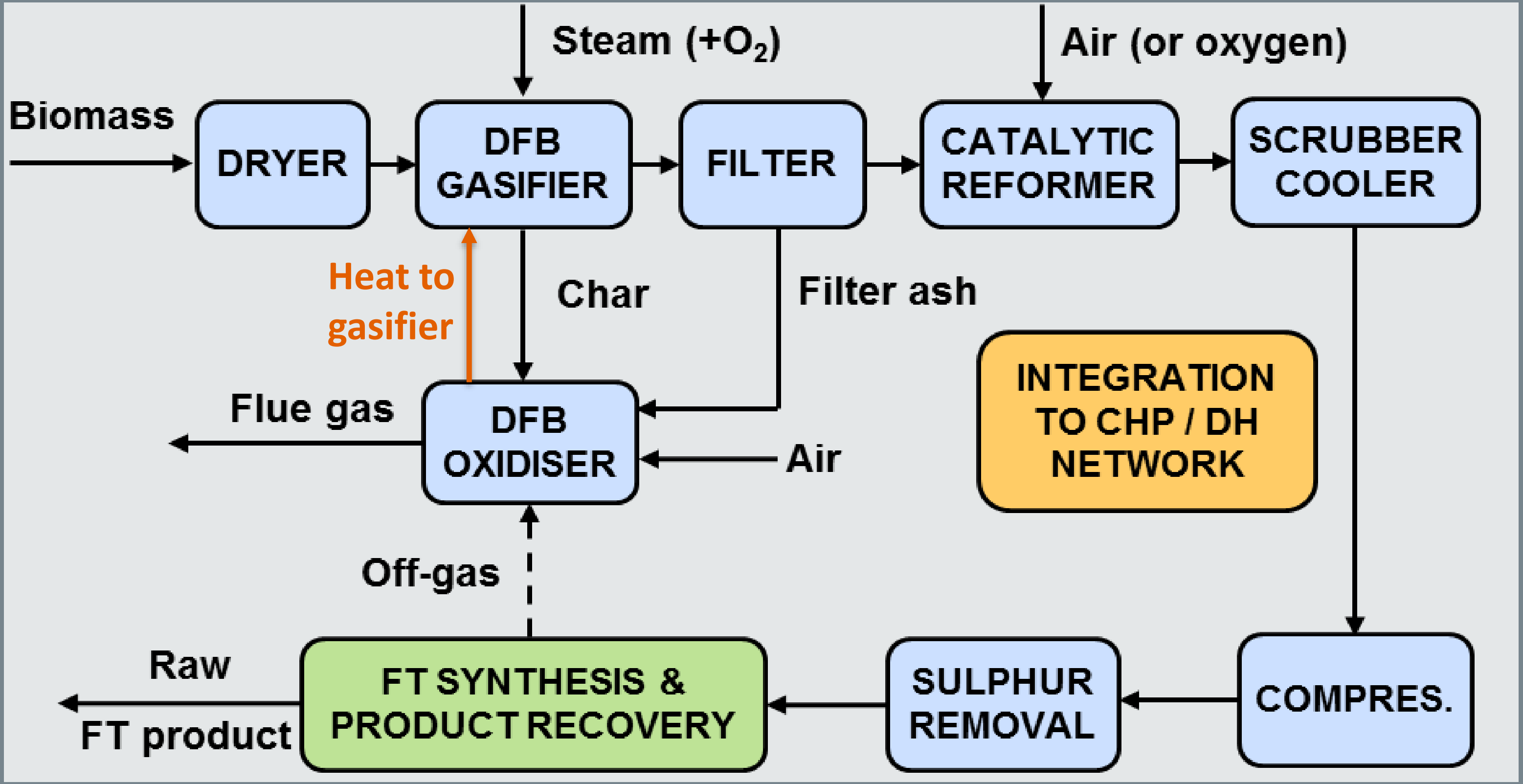
Simplified design for medium scale production of transport fuels – COMSYN approach

VTT



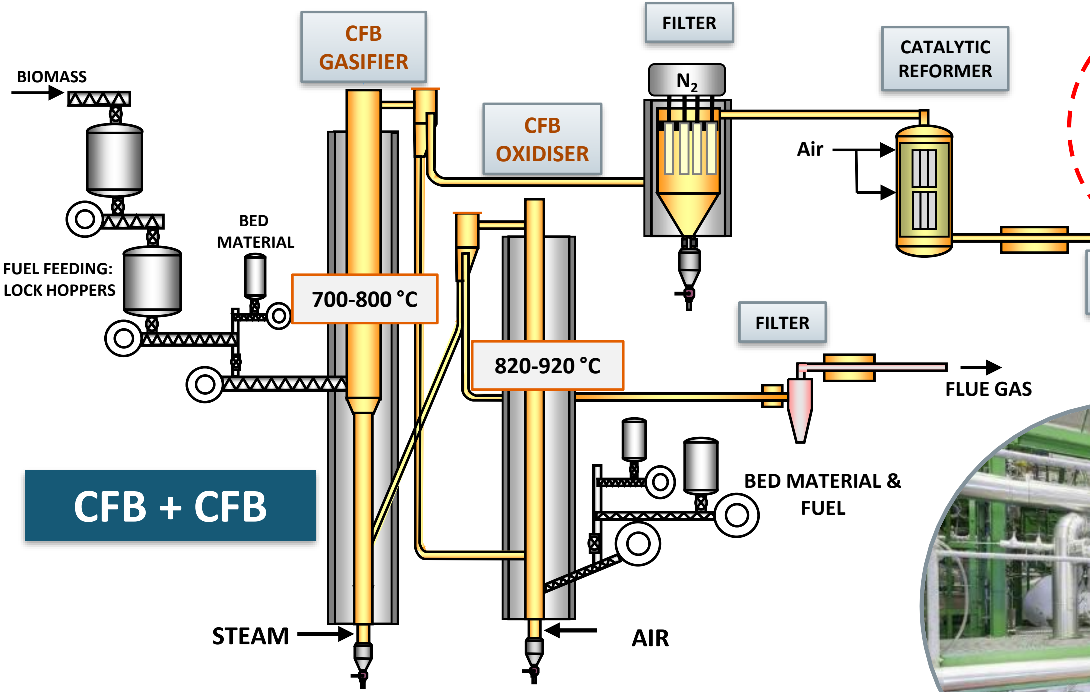
Medium-scale Low CapEx process for combined FT liquids and heat production

VTT



DFB pilot at Bioruukki

basic gasification concept of COMSYN project



VTT Technology Publication
https://www.vttresearch.com/sites/default/files/pdf/technology/2018/T347.pdf

Syngas concepts based on CFB reactors can be designed based on industrial experiences from fuel gas applications

VTT

JOUTSENO LIME KILN 2012

LAHTI 60 MW

LAHTI II, 160 MW WASTE-TO-ENERGY

REPLACEMENT OF FOSSIL FUELS IN BOILERS AND KILNS
- wood, agrobiomass
- 10 - 200 MW fuel

LIME-KILN GASIFIERS

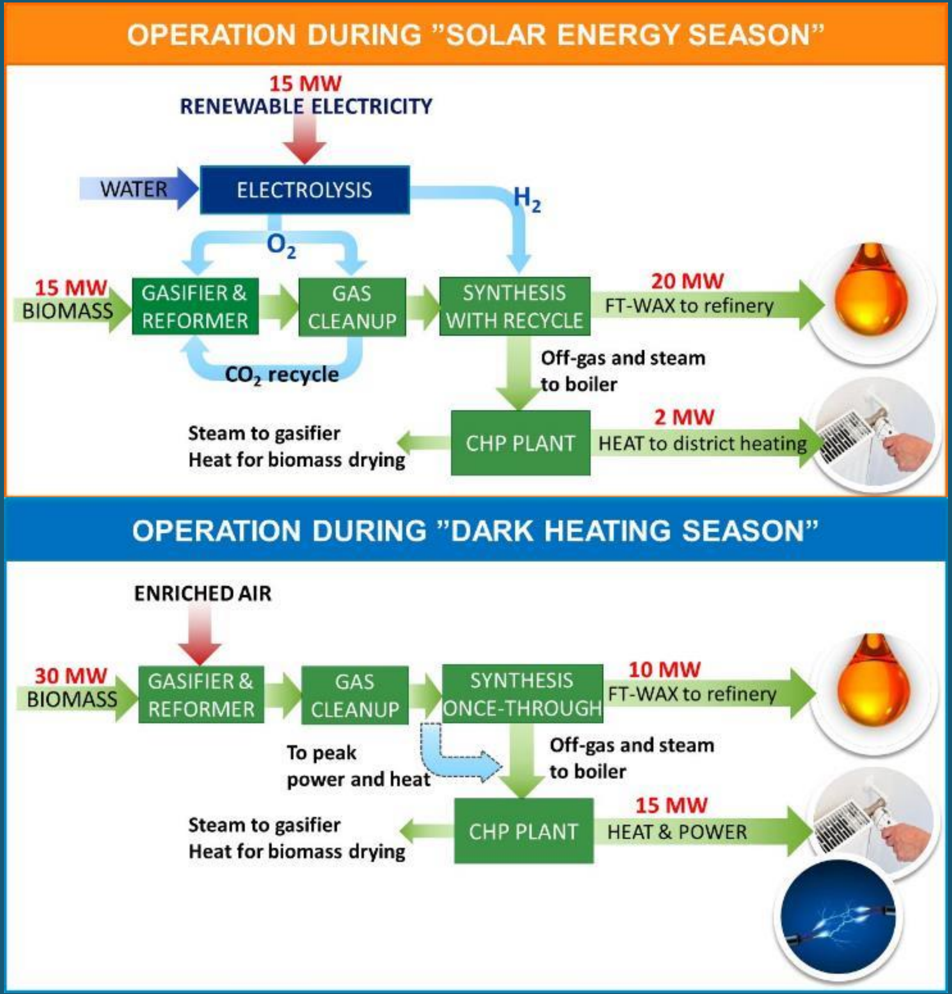
BIOMASS/WASTE GASIFIERS FOR POWER

NOVEL WASTE CONVERSION PLANTS
- high electric efficiency
- recovery of metals and phosphorus

1985 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030

GASIFIER DEVELOPMENT

R&D AND PILOTING AT VTT

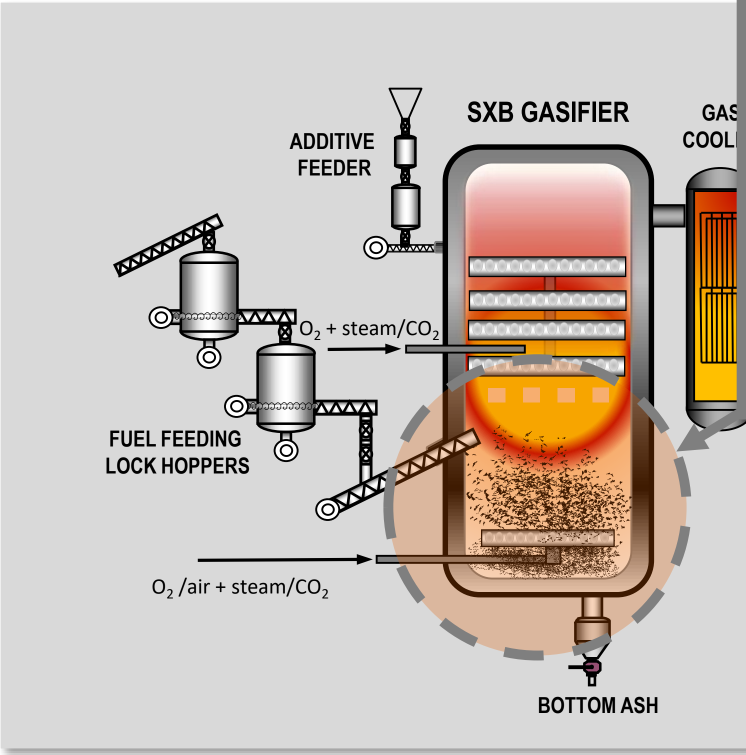


Basic idea of FLEXCHX

- To realise a process for **optimal use of the seasonal solar energy supply and available biomass resources**
- Satisfy the seasonal demand for heat and power, and to produce low-GHG fuels for the transport sector
- This concept can be best realized in oxygen-blown gasification processes

Pressurised Stag
Gasificati

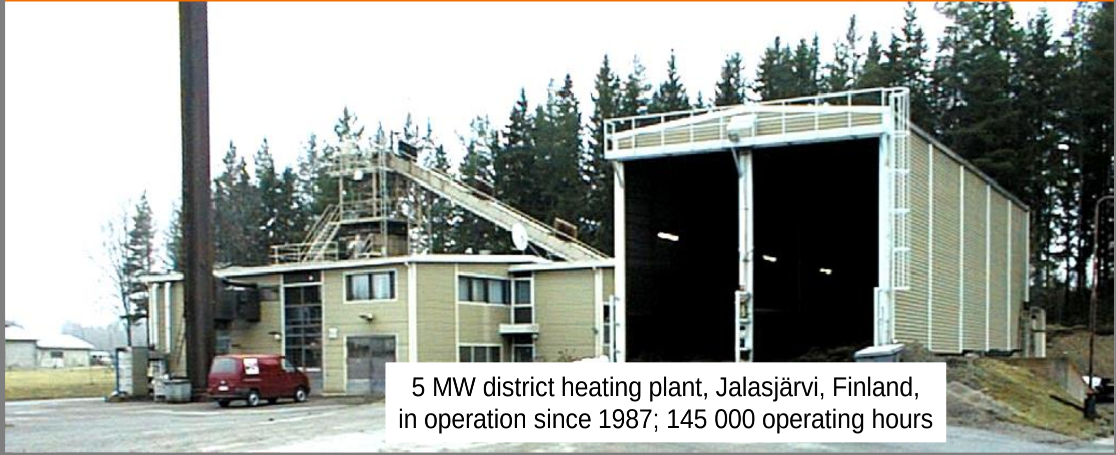
Gasification proces
Industrial target: 5 - 5



UPDRAFT GASIFIER "BIONEER" for boilers & kilns

VTT

- tar containing gas
- high carbon conversion
- 10 commercial plants in Finland and Sweden
- Robust, reliable and fully automated plants



5 MW district heating plant, Jalasjärvi, Finland, in operation since 1987; 145 000 operating hours

Process validation at SXB pilot plant

Three test campaigns in February - June 2020

1.
- Test run SXB 20/07 with bark pellets and wood chips
- 4 Set Points, Total gasification time: 58 hours

2.
- Test run SXB 20/11 with wood, bark and sunflower husk pellets
- 7 Set Points, total gasification time: 70 hours

3.
- Test run SXB 20/24 with wood and sunflower husk pellets
- 7 Set Points, total gasification time: 85 hours

WOOD

BARK

WOOD CHIPS

SUNFLOWER HUSK

Validation tests for the complete gasification, gas cleaning and FT-synthesis process

- **Total gasification operation: 213 h**
- **Operation time with integrated gasification/FT: 174 h**
- **FT products produced during the test: roughly 173 kg**

Raw material and final product

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

VTT

Conclusions

- Three gasification processes have been developed in Finland for converting biomass residues to clean synthesis gas
  - Pressurized steam/oxygen-blown CFB gasifier for large plants > 150 MW (TRL 7)
  - Dual fluidized-bed steam gasifier for intermediate size, 50-150 MW (TRL 5)
  - Pressurized fixed-bed gasifier for smaller plants, < 50 MW (TRL 5)
- Catalytic reformer plays a key role in converting tars and hydrocarbon gases into syngas and in controlling the H_2-to-CO ratio of syngas
- Biomass gasification can be efficiently integrated to electrolysis:
  - Recycling of CO_2 maximizes the conversion of biomass carbon to CO
  - Additional H_2 can be readily used to convert CO to FT products
  - Electrolysis O_2 is used in the gasifier and in the reformer
  - The same process can be operated with biomass alone when power is expensive

COMSYN/FLEXCHX online Workshop Hot gas filtration

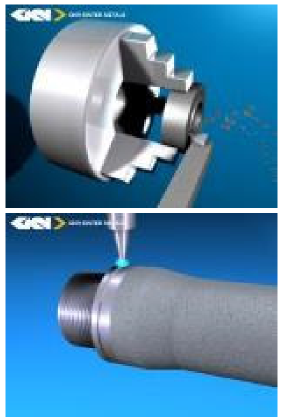
19.01.2021 Harald Balzer

content

- GKN manufacturing process overview
- Material and Process development
- Powder and filter specification
- Filter operation studies

Manufacturing process

- Aim: Material and Process development of a corrosion and heat resistant FeCrAlSi-Alloy as filter material for Sulfur containing gases up to 900°C



MCrAlY Powder
Different sievings for different filter grades

Cold Isostatic compaction

Heat Treatment 1: Sintering

Secondary Operations:
Turning, Welding

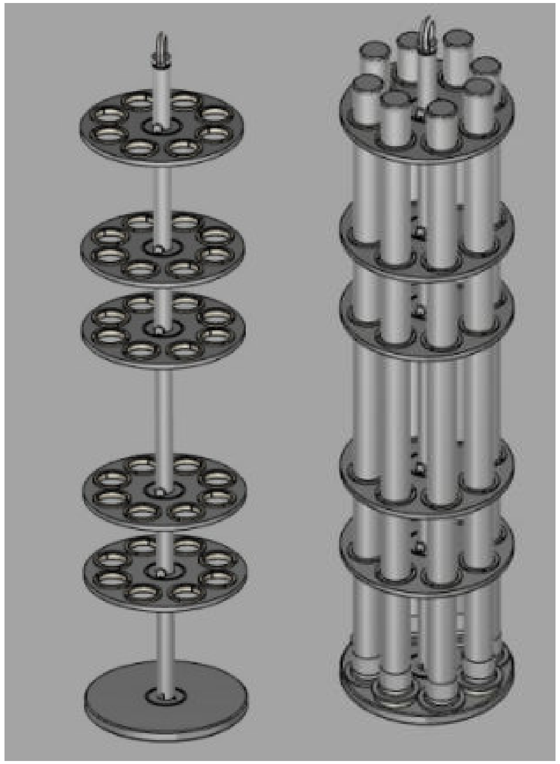
Heat Treatment 2: Oxidation

COMSYN

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

Heat treatment development

- New material critical for heat treatment process: liquid phase formation depending on temperature
- Roundness (important for welding operation and high burst pressure), straightness (important for max. pitch in the filter plate) often not sufficient
- Heat treatment frame and proper chosen heat treatment parameter stabilizes the filter during sintering
- Continuously enlarging the filter length from 1000 up to 1550 mm length



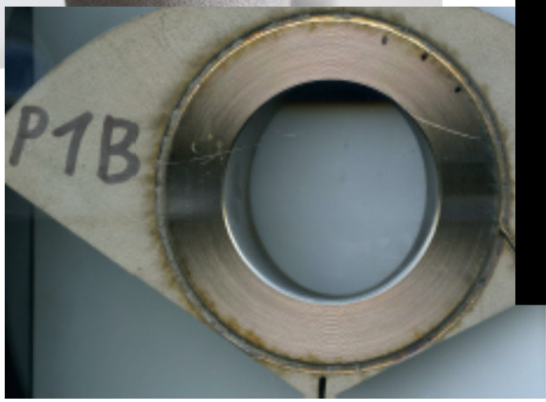
Heat treatment frame and delivered 1.2m filter elements

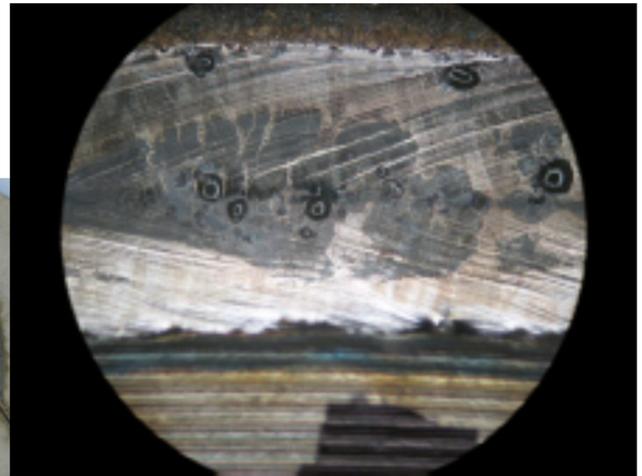
COMSYN

COMSYN project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727476

Secondary operation: laser welding

- Welding development: laser welding porous filter material and solid connectors or Filter plate
- Before positioning in filter plate the filter end is turned to achieve the needed roundness
- Results for laser welding on a pre heated device: much less micro cracks on the slope marked on the filter element





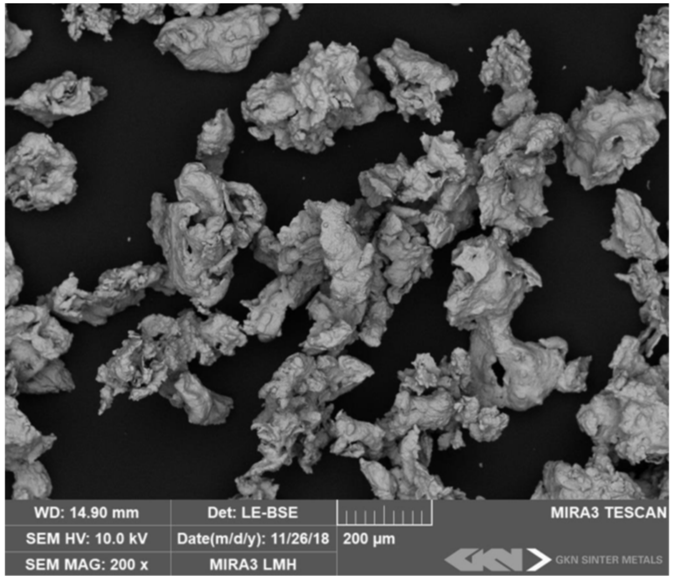
COMSYN

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

Typical values for fine and coarse filter quality

Material:	**FeCrAlSi (1.4767 mod.)**			
Chem. Composition [M-%]:	Fe	Cr	Al	Si
	Bal.	19~22	4~5	~2,5
Application Temperature [°C]: (in oxidising media)	max. 900°C			

Filter Grade SIKA	**RHT 2IS**	**RHT 12IS**
Grade Efficiency [µm]*: x_T = 95% (0,1m/s)	0,25	0,5
Density [g/cm³]:	4,8	4,4
Porosity [%]:	30	40
Flow [m³/m²/h]:		25
Bubble Point [mbar]:	40	20
Pore size distribution: [µm] d_{min}	1	2
MFP	5	14
d_{max}	18	37
Permeability coefficient α [m²]	$4,1*10^{-12}$	$5,5*10^{-12}$
β [m]	$0,9*10^{-6}$	$1,3*10^{-6}$



Typical water atomized powder shape

COMSYN

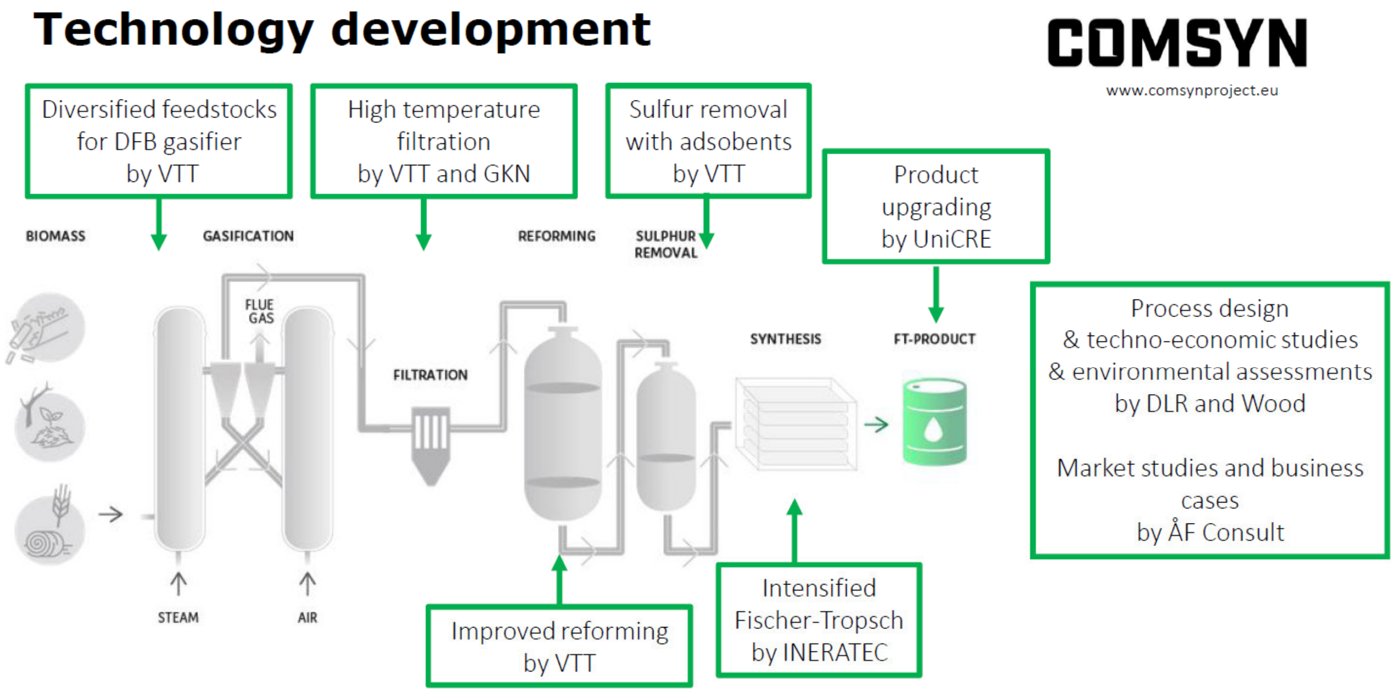
COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

COMSYN project: process flow chart

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

COMSYN

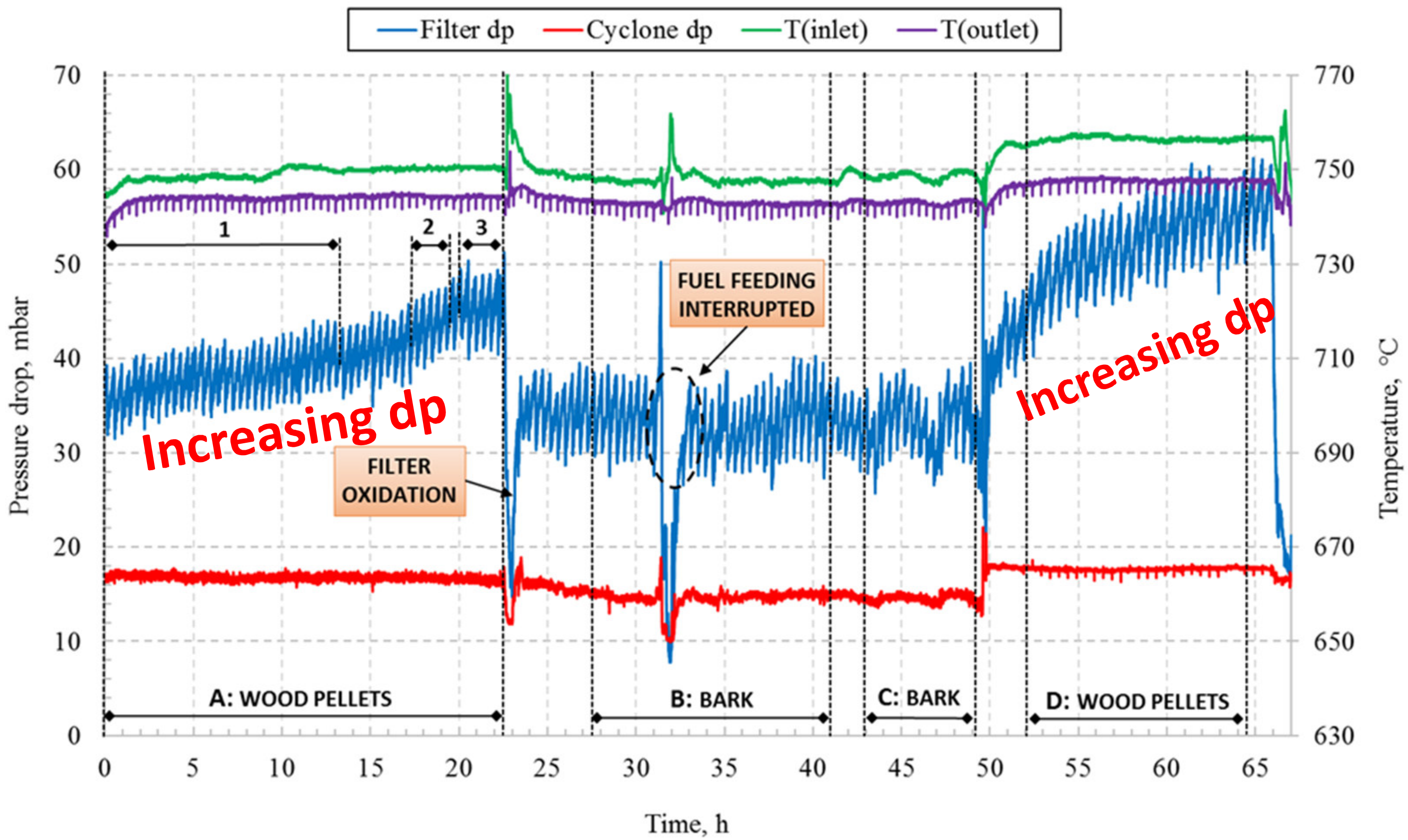
www.comsynproject.eu



VTT · INERATEC · GKN SINTER METALS · UniCRE · Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center · wood. · Making Future.

Opened filter vessel at VTT site

Filter operation studies



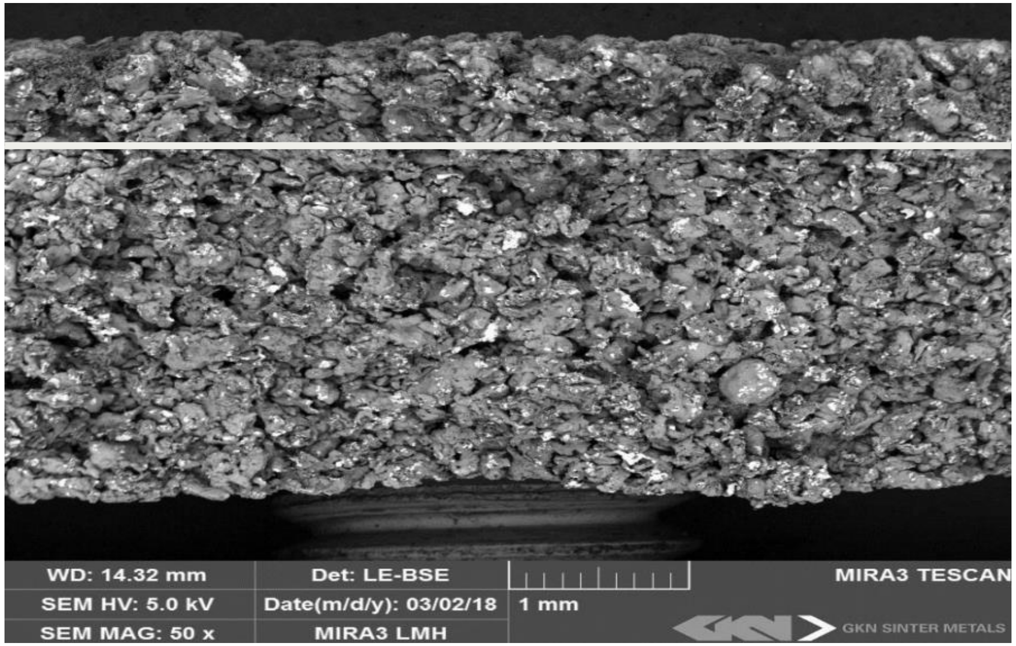
- Filter blinding was encountered in some set points – particularly with wood pellet
- The combination of high tar load and low particulate concentration are particularly favorable conditions for filter blinding.

COMSYN

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

Metallographic examination of the used filter element

- After 300 hours of operation in biomass gasification conditions, one of the filter elements was removed from the filter unit and examined at GKN.
- Ashes were found only on top of the filter element
- No material inside the pores - proper filter grade was selected



BSE image of filter cross section

COMSYN

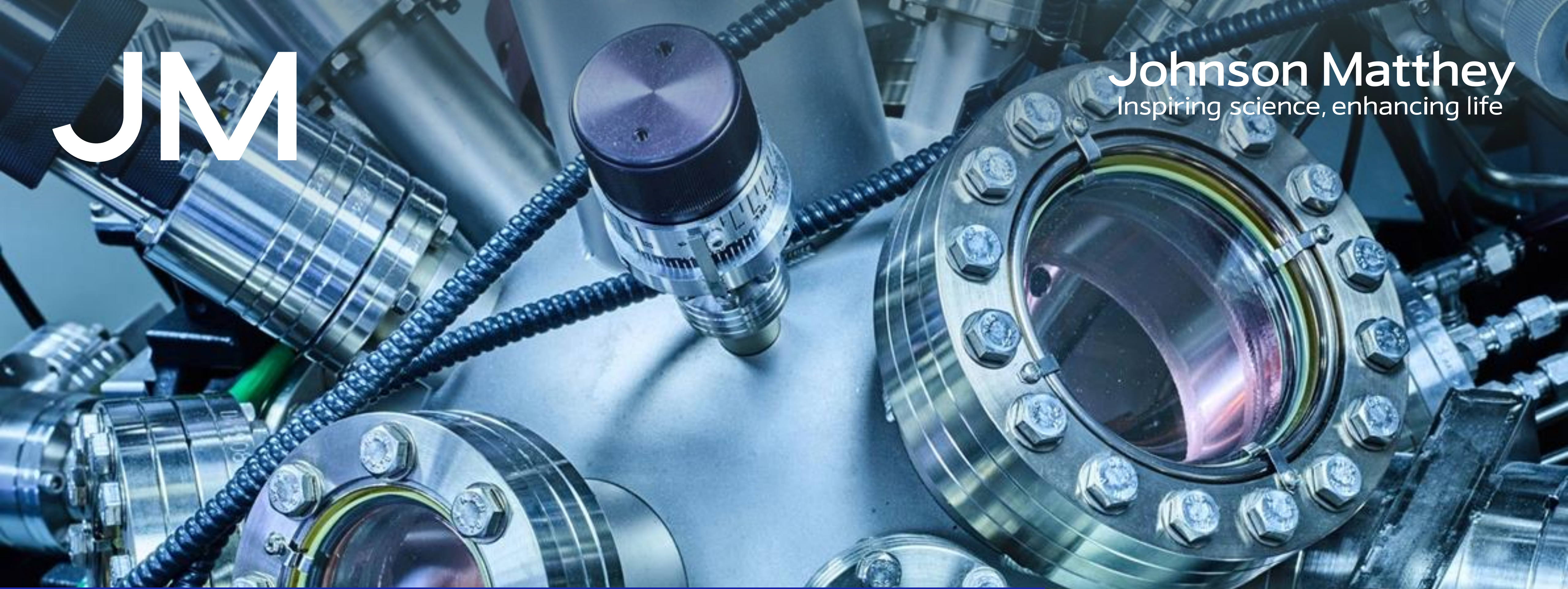
COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

Summary and outlook

- Main process steps in atomizing, compaction, heat treatment and laser welding were successfully developed during COMSYN project
- The actual max. length of the filter elements is 1550mm
- Stable filtration is possible if filter clogging with tar can be prevented (12µ filter grade in liquids)
- Metallographic investigations after long term tests show no corrosion during operation. No corrosive species (Chlorine, Alkaline and esp. Sulphur) were found inside the filter material
- Future development will focus on evaluation of new filter material in multifuel processes (e.g. municipal waste) and scale up the filter systems for small and medium sized gasification plants (1-50 MW)

COMSYN

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476



Johnson Matthey
Inspiring science, enhancing life

Catalytic reforming in FLEXCHX
Benjamin Rollins

19 January 2021

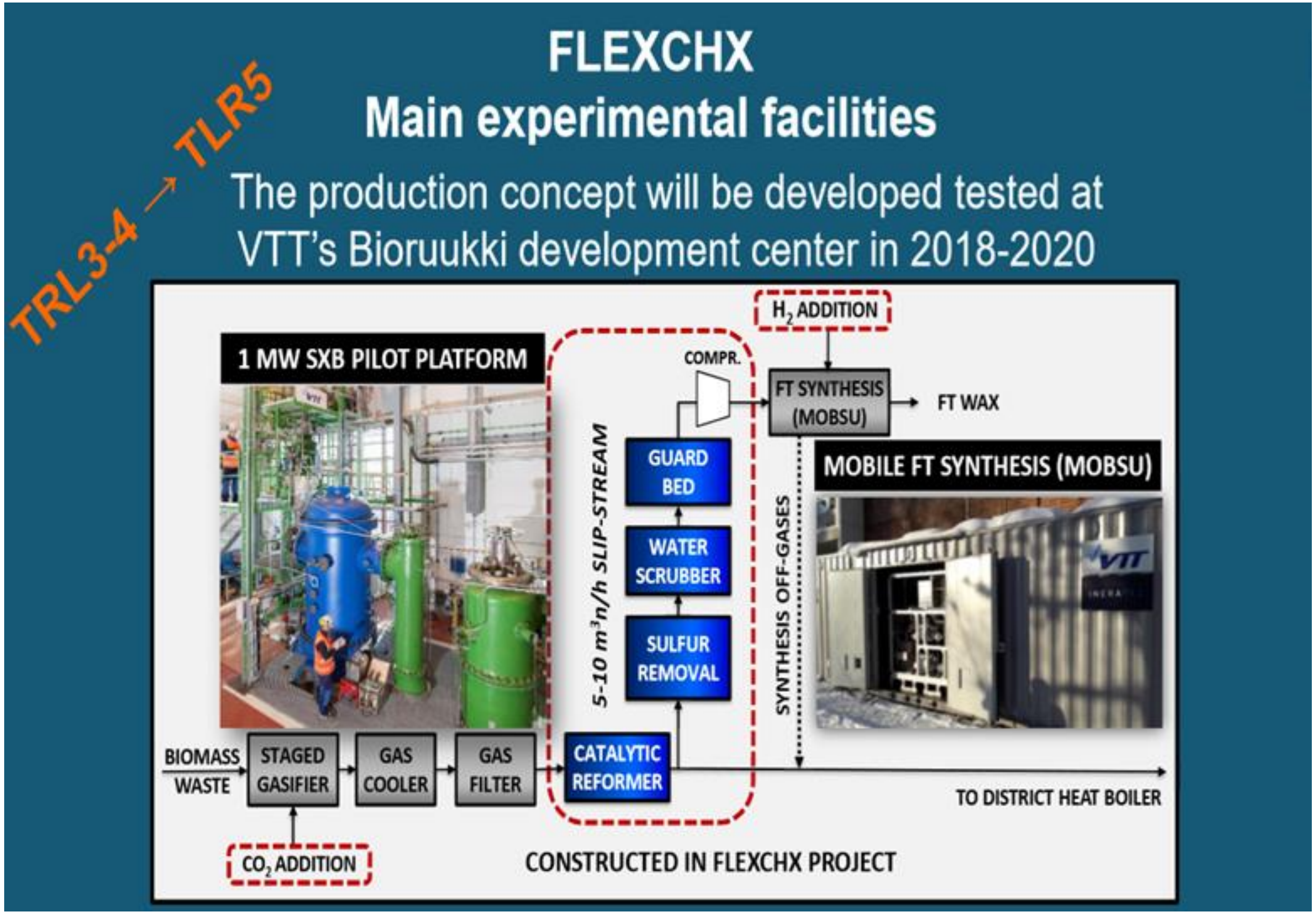
Steam reforming of tars and methane

- Biomass gasification produces syngas as well as heavy organic compounds, known as tar.
- These tars are typically aromatic compounds as well as benzene and naphthalene.
- Tar species quickly foul the machinery in a biomass gasifier and make the syngas unusable for applications such as fuel cells.
- A major part of the FLEXCHX project was to develop a robust and effective steam reformer catalyst to effectively convert this tar to additional syngas.

$$C_xH_y + xH_2O \longrightarrow xCO + (y/2+x)H_2$$

Typical steam reforming reaction equation

FLEXCHX pilot testing



The 1 MW SXB-gasifer plant, the 0.5 bbl/day MOBSU-FT unit located at VTT's Piloting Centre Espoo, Finland and the modifications to be executed in FLEXCHX.

FLEXCHX pilot testing

Flexible hybrid process for combined production of heat, power and renewable feedstock for refineries

Authors: Kurkela, Esa [1]; Kurkela, Minna [1]; Frilund, Christian [1]; Hiltunen, Ilkka [1]; Rollins, Benjamin [2]; Steele, Andrew [2]
;
Source: Johnson Matthey Technology Review
Publisher: Johnson Matthey
DOI: https://doi.org/10.1595/205651321X16013744201583

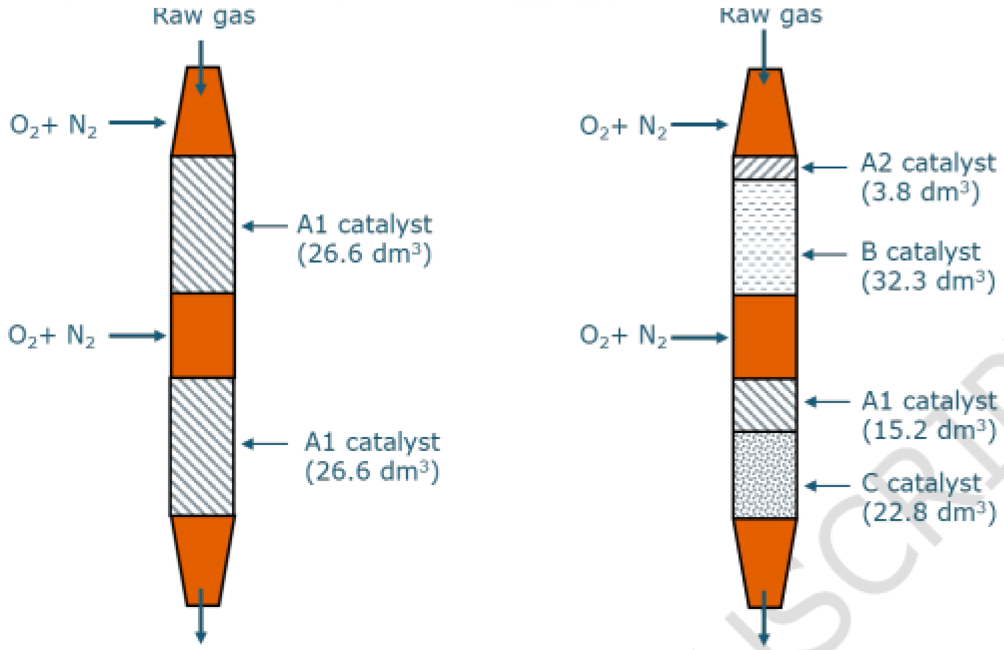


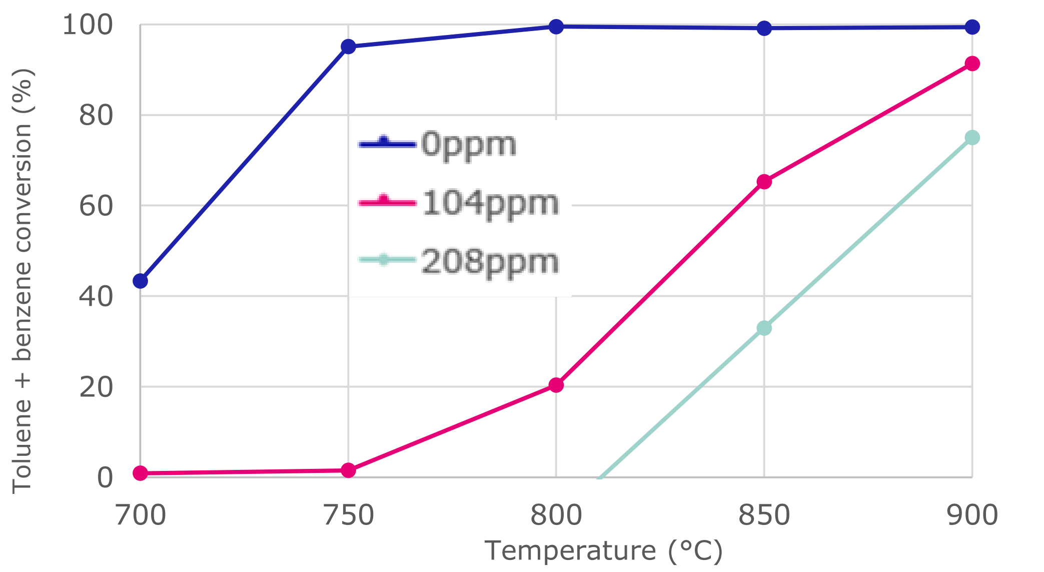
Fig 3. The reformer concepts and catalyst volumes used in the test campaigns.

Table 2. Feedstock analyses as used in the gasification campaigns of SXB pilot plant.

	Wood pellets	Bark pellets	Wood chips	Sunflower husk pellets
Particle size, mm	10-20	8	0-10	8
LHV MJ/kg (dry basis)	18.4	18.8	18.1	18.4
HHV, MJ/kg (d.b.)	19.8	20.1	19.5	19.6
Moisture, wt%	7.4	9.2	10.0	10.3
Proximate analysis, wt% d.b.				
Volatile matter (d.b.)	82.5	72.2	85.7	75.0
Fixed carbon (d.b.)	17.1	23.5	13.9	22.1
Ash, wt% (d.b.)	0.4	4.3	0.4	2.8
Ultimate analysis, wt% (d.b.)				
C	49.8	51.7	48.6	52.1
H	6.3	6.1	6.5	5.8
N	0.13	0.5	0.1	0.7
Cl	< 0.005	0,01	0.004	0.06
S	0.01	0.03	0.01	0.14
O as difference	43.7	41.7	44.4	38.6
Ash	0.4	4.3	0.4	2.8

Challenges facing reforming catalyst

- Reforming catalysts are typically based on nickel or PGMs such as platinum or rhodium.
- Nickel catalysts are cheaper but suffer more from issues surrounding coke formation and irreversible sulphide formation.
- PGMs are more expensive but typically have much better durability and can be used at lower loadings.
- Reforming is an endothermic process. There is a negative feedback as increases conversion lowers the gas temperature.



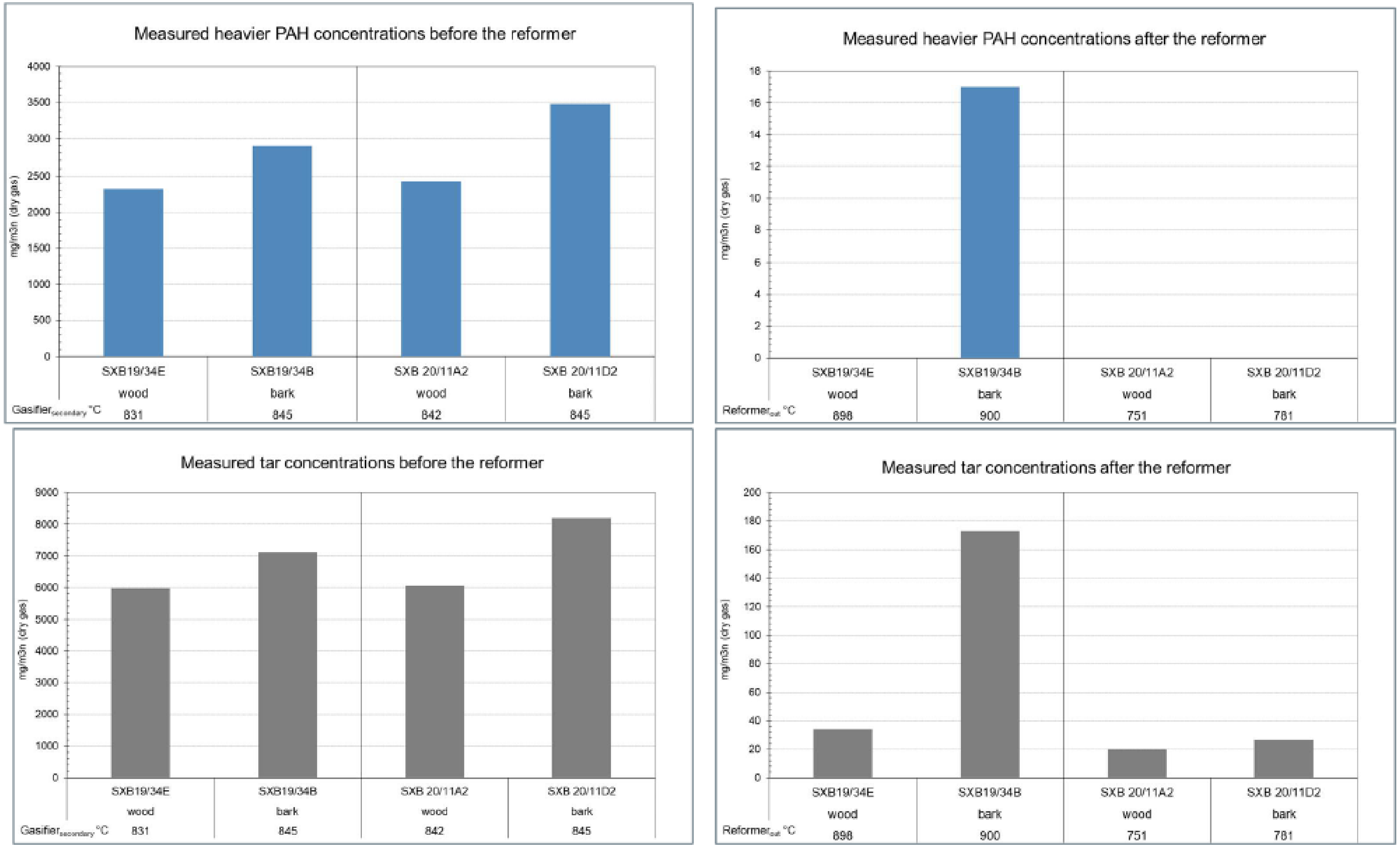
Conversion of toluene and benzene under identical conditions except for varying concentrations of H_2S for a rhodium based catalyst.

Steam reforming catalysts

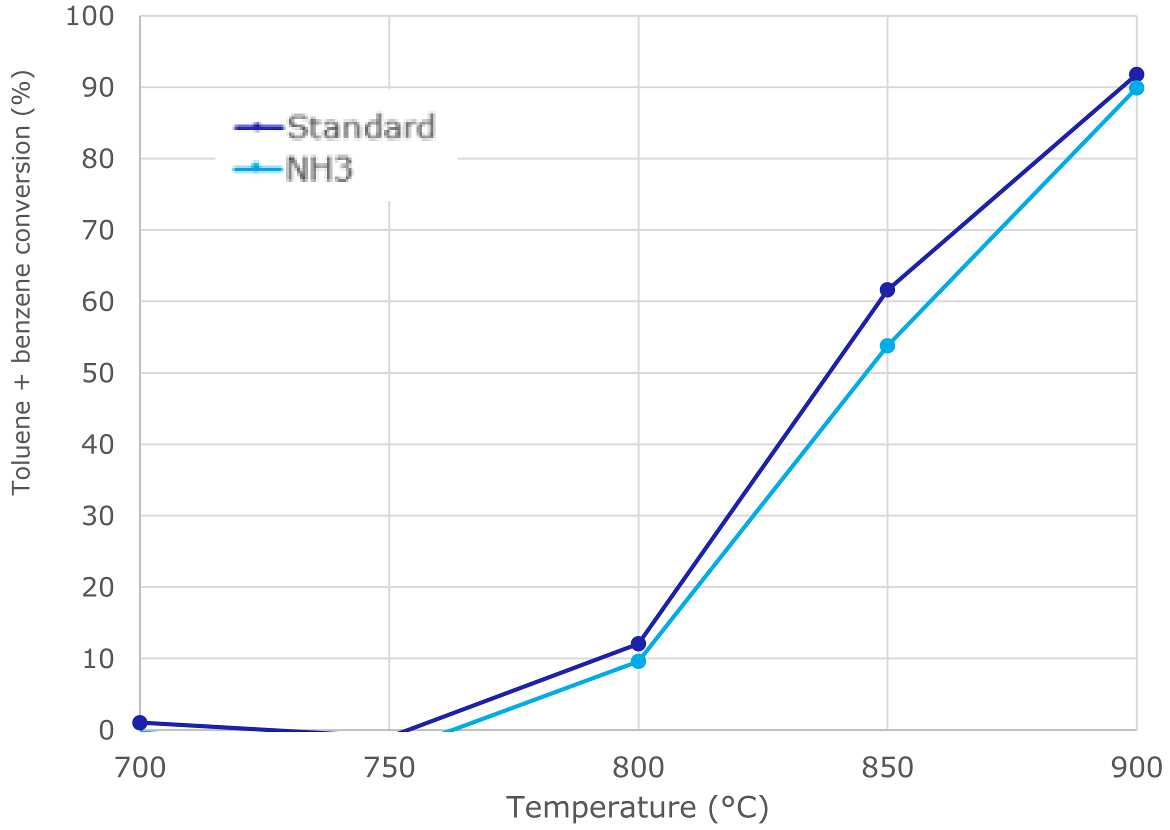
- A variety of different catalysts were supplied as part of the FLEXCHX project.
- Each served a different purpose.
- Screened in JM test rig.
- Initial, bulk tar reforming was carried out with a rhodium based catalyst, this catalyst has good thermal stability and activity.
- Later methane reforming was carried out with catalysts containing platinum which has a higher methane conversion.
- Nickel based catalysts were also included as a heat shield for the PGM catalysts.

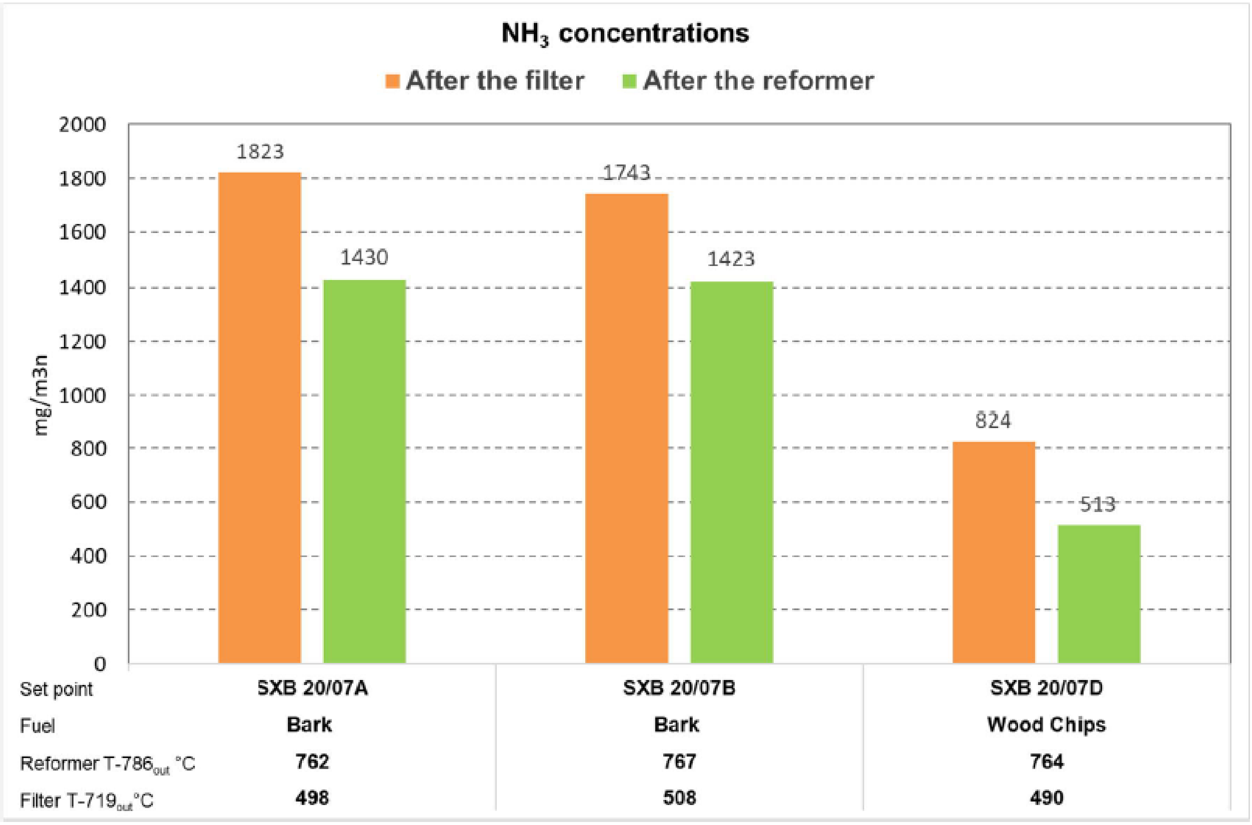
A selection of PGM and nickel based reformer catalysts.

Pilot plant reformer results



Pilot plant reformer results – effect of poisons





- The presence of ammonia doesn't seem to affect the conversion of tars but it still need to be removed before Fischer Tropsch synthesis unit.

- The reformer catalyst helps to remove some ammonia before the gas purification system.

Johnson Matthey
Inspiring science, enhancing life

Impact of FLEXCHX

Technical Impact:

- JM have strengthened their competencies of the reforming of hydrocarbons in bio-syngas.
- The effect of temperature and poisons on durability has been extensively studied.
- Catalyst cost models have been refined.
- Highlight: JM materials used throughout the reforming process flowsheet.
- ✓ OVERALL: JM reforming catalyst has been demonstrated for > 160 hrs @ 1MW scale.

Material and science Innovation:

- Developmental catalysts have been successfully tested at pilot-plant scale (providing a reference).
- Novel reforming opportunities investigated.
- Use of PGM catalysts helps mitigate the effects of H_2S poisoning and provides durable, highly active catalysts.

FlexCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Sorbent-based final gas clean-up

Christian Frilund
19.1.2021

VTT – beyond the obvious

Final gas cleaning
Targets

Impurities (ppm_v)	Fluidized bed gasification (steam), post-filtration+reforming: Woody-residues	Agro-residues	Purity requirement (FT cat.): Leibold et al. (SASOL)[1]	Boerrigter et al.[2]
H_2S	20 - 200	40 - 400	< 0.01	< 1
COS	2 - 20	1 - 40		
HCN	0.5 - 5	1 - 10	< 0.02	< 1
NH_3	50 - 500	100 - 1000		
Halides	< 2	< 5	< 0.01	< 0.01
Alkalis	< 1	< 1	< 0.01	< 0.01
Tars	< 100	< 200	Below dew point	Below dew point

- Catalytic synthesis: Strict gas purity requirements

1 Leibold et al.https://doi.org/10.1016/j.powtec.2007.05.012
2 H. Boerrigter et al. Green Diesel from Biomass via Fischer-Tropsch synthesis: New Insights in Gas Cleaning and Process Design, Pyrolysis Gasif. Biomass Waste, Expert Meet. (2002)

Final gas cleaning

Challenges:

- Deep removal requirement
- Multicontaminant gas composition
- Varying concentrations due to biomass heterogeneity

Conventional gas cleaning solutions:

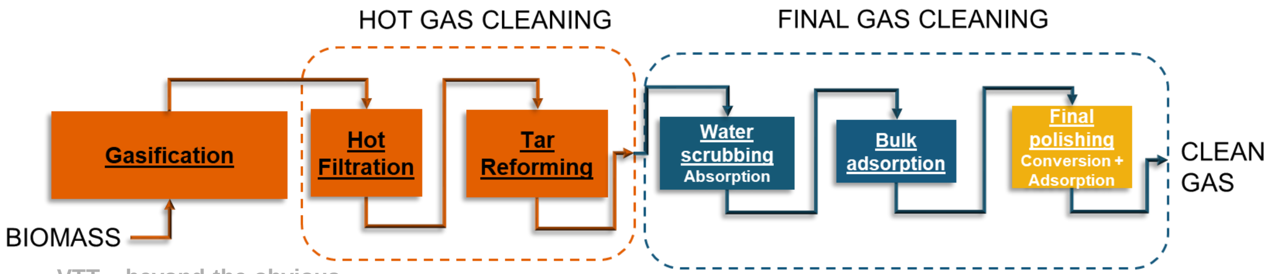
- Solvent scrubbing methods
- Rectisol/Selexol-type absorption processes don’t ”downscale” well

  → up to 20+ % of BtL plant total CapEx

Low-CapEx cleaning concept

- Contaminant removal by dry-bed adsorption and organic solvent-free scrubbing
- Over 20 % lower CapEx and OpEx to conventional wet-scrubbing solutions

- Tailored for biomass-specific gas impurity matrix/levels
- Raw syngas relatively ”clean” due to optimized hot gas cleaning → Simpler final gas cleaning technically/economically viable
- Optional selective CO_2 removal by pressurized water scrubbing
  - 50 – 80 % CO_2 removal rate



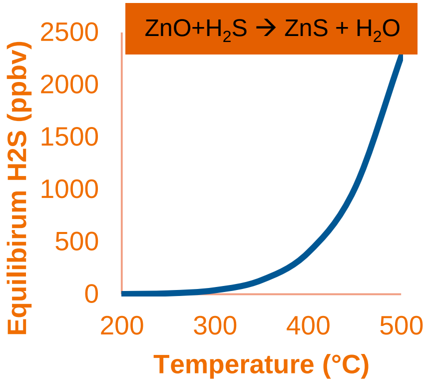
Adsorbent materials

Metal Oxides

$$MeO_x(s) + xH_2S(g) \rightarrow MeS_x(s) + xH_2O(g) \qquad \Delta H_r < 0$$

- ZnO capable of adsorbing inorganic compounds
  - Requires elevated temperatures, > 200 °C, to be effective

Oxide	Cost ($/kg)
Fe_2O_3	< 0.5
TiO2	1-3
ZnO	1-3
CuO	4-10
MnO	4-10
ZrO_2	4-16
NiO	6-10
CoO	14-20
CeO	16-20
Cr_2O_3	16-20
MoO_3	16-20

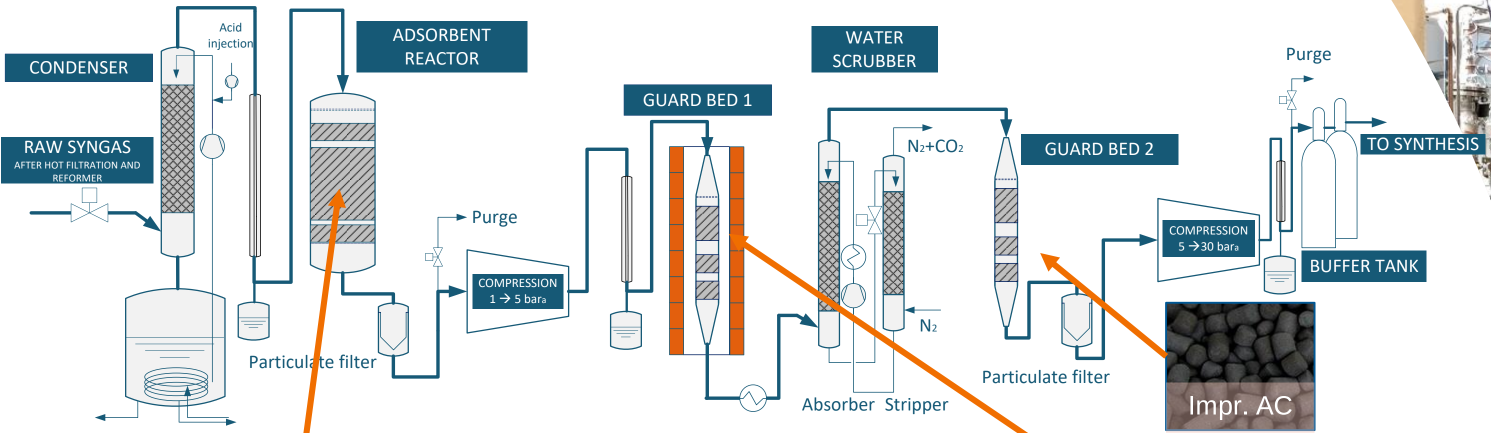


Activated carbons (AC)

- ACs can adsorb both organic and inorganic compounds
  - Active at low temperatures (< 100 °C)
  - Oxidative H_2S removal identified as particularly effective:

$$H_2S + \frac{1}{2}O_2 \rightarrow S(s) + H_2O \qquad \Delta H_r < 0$$

PDU-Scale Final gas cleaning



Adsorbent materials

- Hybrid of activated carbon (AC) and ZnO adsorbents
- Dual function of ZnO-based adsorbent:
  - COS hydrolysis catalyst
  - H_2S adsorption

VALIDATION TEST RUNS FOR ENTIRE PROCESS; FROM GASIFICATION TO FT SYNTHESIS

Biomass → Gasification and hot gas cleaning → Final gas cleaning & compression → Intensified FT synthesis → 0.35-0.4 kg/h Syncrude

The projects have received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727476 (COMSYN) and No 763919 (FLEXCHX).

Campaign results

- The final gas cleaning process achieved full removal of all analyzed syngas impurities in:
  - Woody-residue biomass
  - Agro-residue biomass
- Achieved syngas purity levels suitable for catalytic synthesis
- Demonstrated the feasibility of simplified final gas cleaning (when combined with optimized hot gas cleaning

	After hot gas cleaning	After final gas cleaning	
	Avg. (ppmv)	Max. (ppmv)	Avg (ppmv)
S-Species	90 - 340	0.3	<0.1/ 0
N-Species	270 - 720	0/b d	0/b.d
Halogens	n.a (1 - 5)	0/b.d	0/b.d
Metals	n.a	n.a	n.a
Benzene and tars (g/Nm^3)	0.2 - 0.4	0/b.d	0/b.d
Oxygen (vol %)	0	0/b.d	0/b.d

n.a not analyzed
b.d below detection limit

Conclusion

- Expensive wet-scrubbing gas cleaning technology replaced by adsorbent-based process
  - Tailored for biomass impurity profile
  - Economical at smaller scale
- Realization of process concept from idea to reality
  - Successful validation of gas cleaning process in full BtL configuration
  - Full removal of harmful species from real syngas

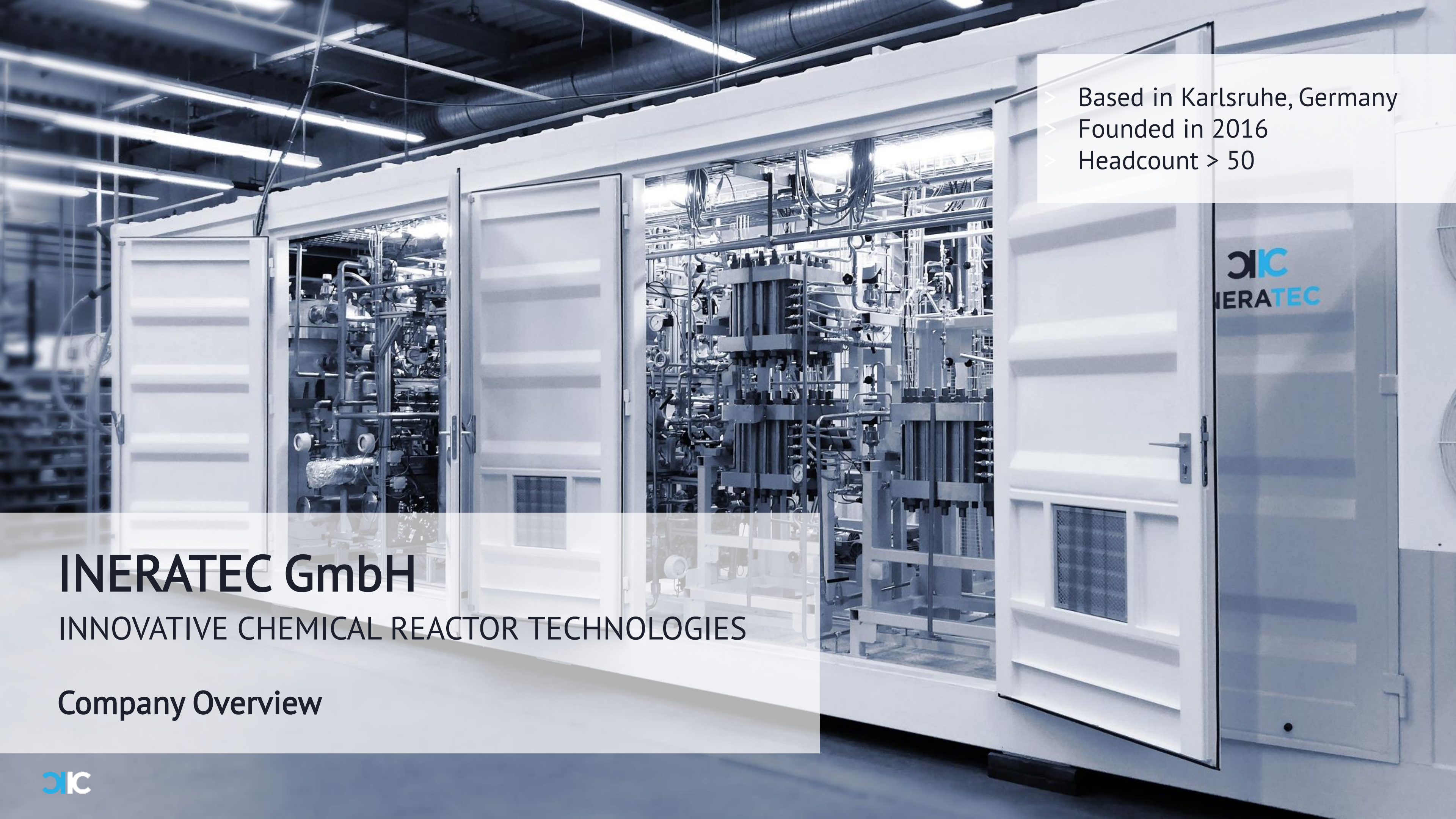
VTT

beyond the obvious

The projects have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476 (COMSYN) and No 763919 (FLEXCHX).

Christian Frilund
christian.frilund@vtt.fi

www.vtt.fi



- Based in Karlsruhe, Germany
- Founded in 2016
- Headcount > 50

INERATEC GmbH

INNOVATIVE CHEMICAL REACTOR TECHNOLOGIES

Company Overview

PROBLEM

WE ARE DEPENDING ON HYDROCARBONS MADE FROM OIL AND GAS

WORLDWIDE ENERGY CONSUMPTION 2035: >55% OIL AND GAS

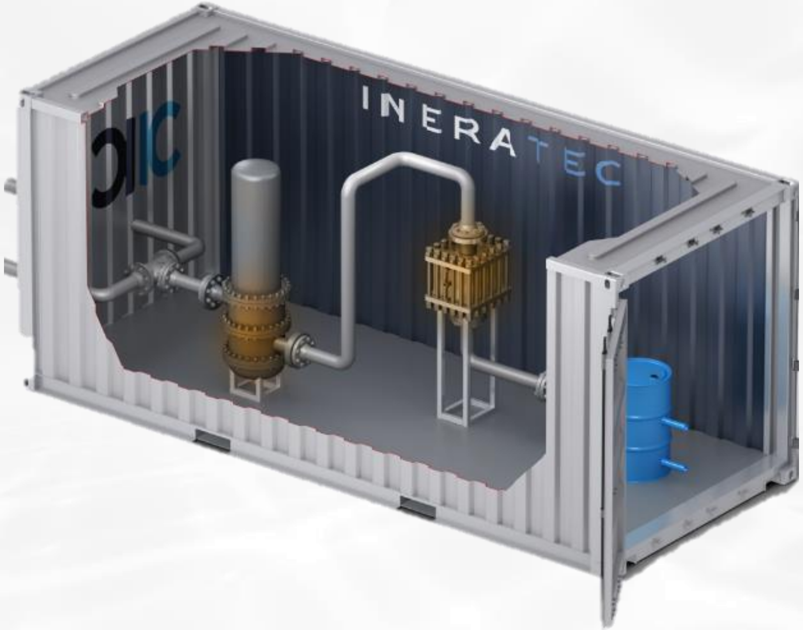
ANNUAL CO_2 EMISSIONS: >35,000,000,000 TONS

SOLUTION

COMPACT CHEMICAL PLANTS THAT PRODUCE RENEWABLE HYDROCARBONS

CH_4
Gas-to-X

CO_2 + H_2
Power-to-X



Renewable
Fuels and Materials

Greenhouse Gas Recycling by INERATEC®

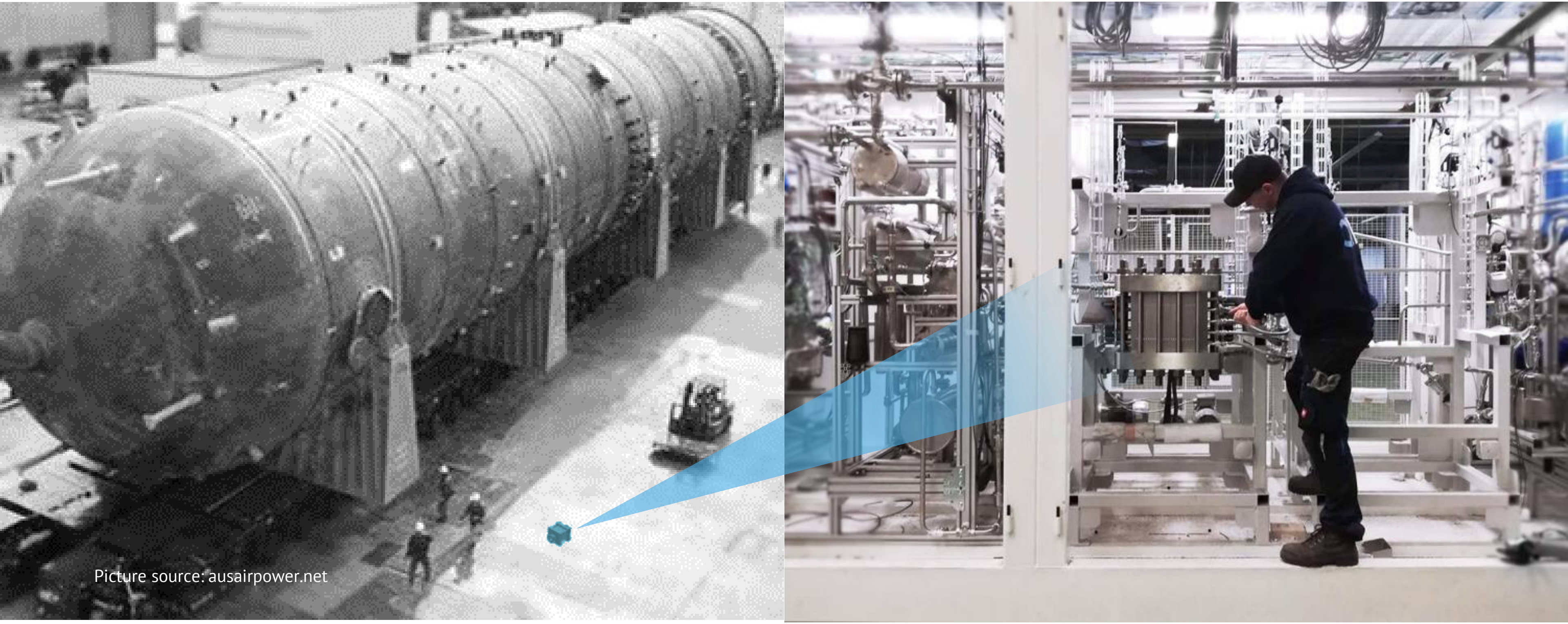
CONVENTIONAL

COMPETING TECHNOLOGIES DO NOT MATCH WITH RENEWABLE ENERGIES

Source: ausairpower.net

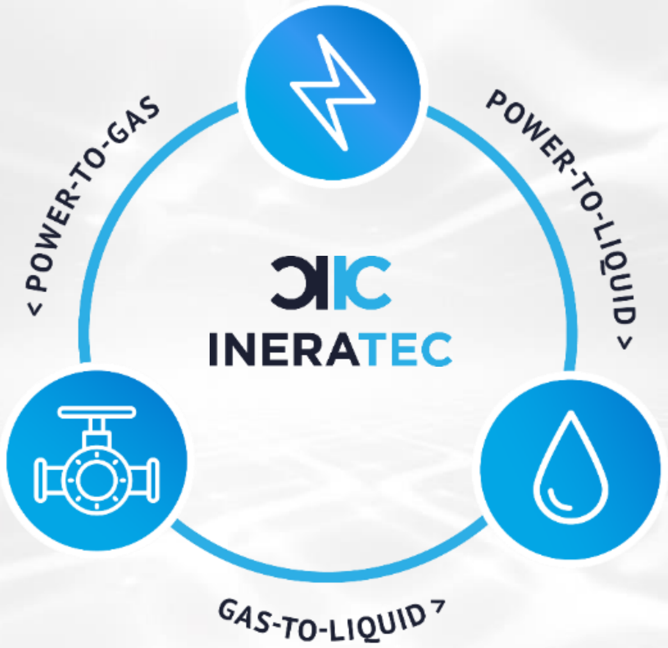
INNOVATION

MOST COMPACT CHEMICAL REACTOR TECHNOLOGY IN THE WORLD



PROCESSES

POWER-TO-GAS, POWER-TO-LIQUID AND GAS-TO-LIQUID



COMSYN

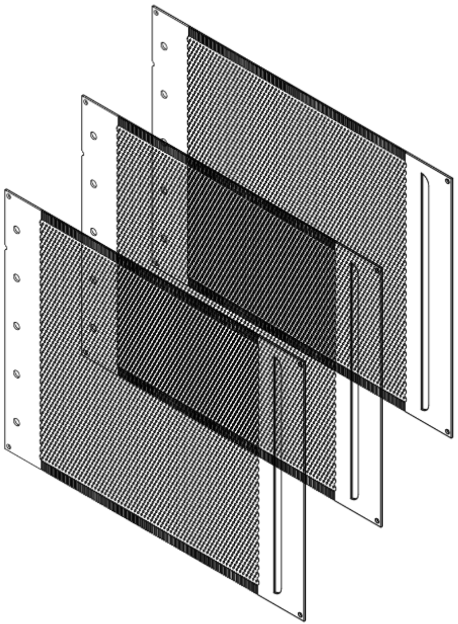
PROJECT OBJECTIVES

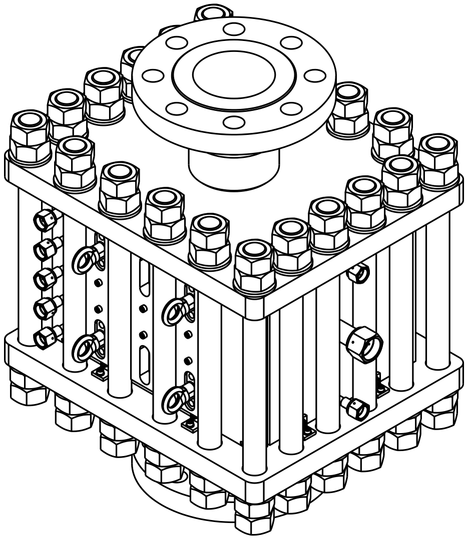
VTT

COMSYN

- Optimizing the operating conditions for max. paraffin yield
- Reactor testing with purified gas from VTTs gasification: Long term stability of FT-technology
- Design and establishing the manufacture for reactor modules with 8 bpd size

MICROSTRUCTURED REACTORS





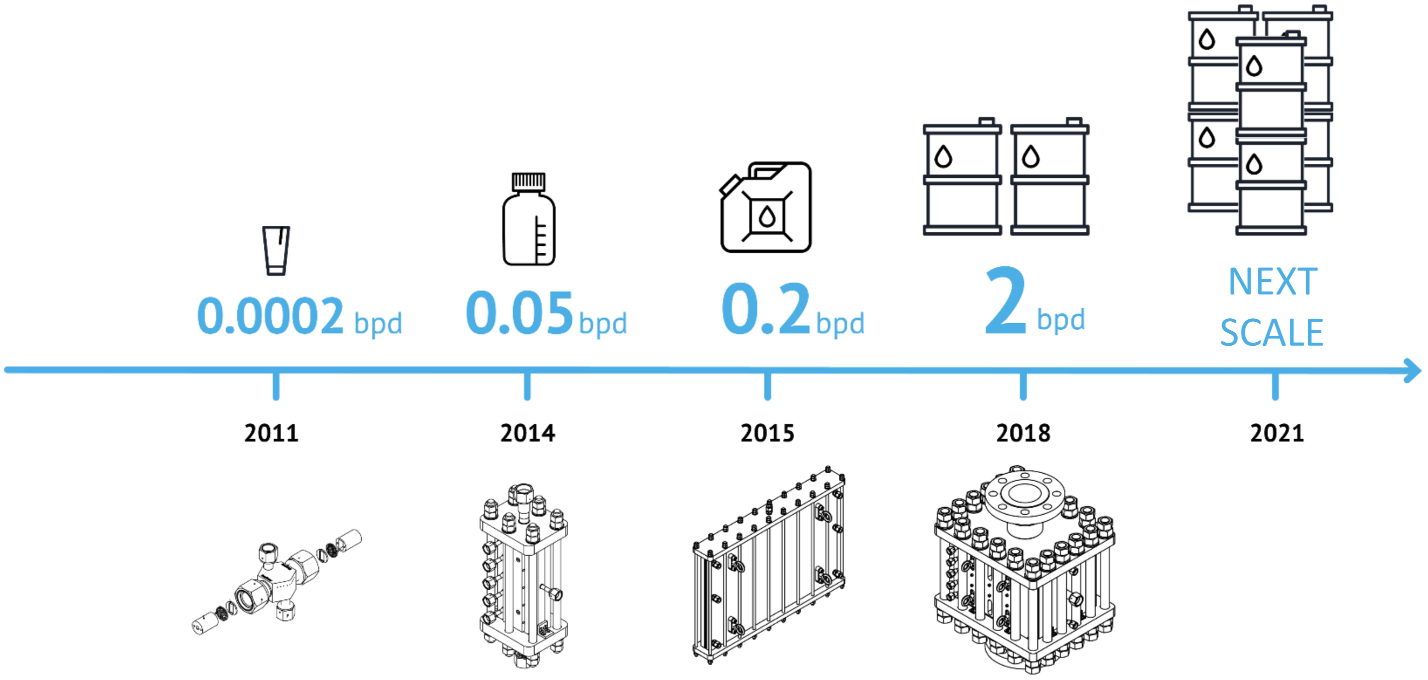
- Design and establishing the manufacture for reactor modules with 8 bpd size
- Development/ Identification of manufacturing processes for scale-up and numbering up
- Cost reduction by functional design of microstructured plates and decreased number of processing steps

IN-HOUSE MANUFACTURING

- Established an in-house production
- Improved the milling tool lifetime
- Optimization of milling program
- Optimization of finishing steps

REACTOR SCALE-UP

20.01.2021



FLEXCHX

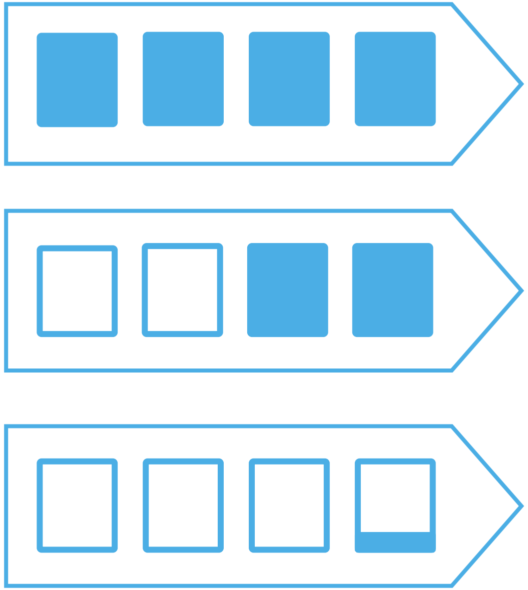
PROJECT OBJECTIVES

FLEXCHX

- Design of flexible FT-synthesis process to achieve maximal effectivity for summer season and heating
- Test key design issues affecting the flexibility and performance of the process
- Scale up of plant design and performance for industrial scale synthesis unit

MODULAR PLANT CONCEPT

LOAD FLEXIBILITY



* Conceptual visualization only, does not display actual reactor quantities

MODULARITY CONCEPT

Due to the modular design of the unit, partial loads could be realized. It is made up of several parallelized reactor modules. In case a load reduction/increase is desired, there are two options:

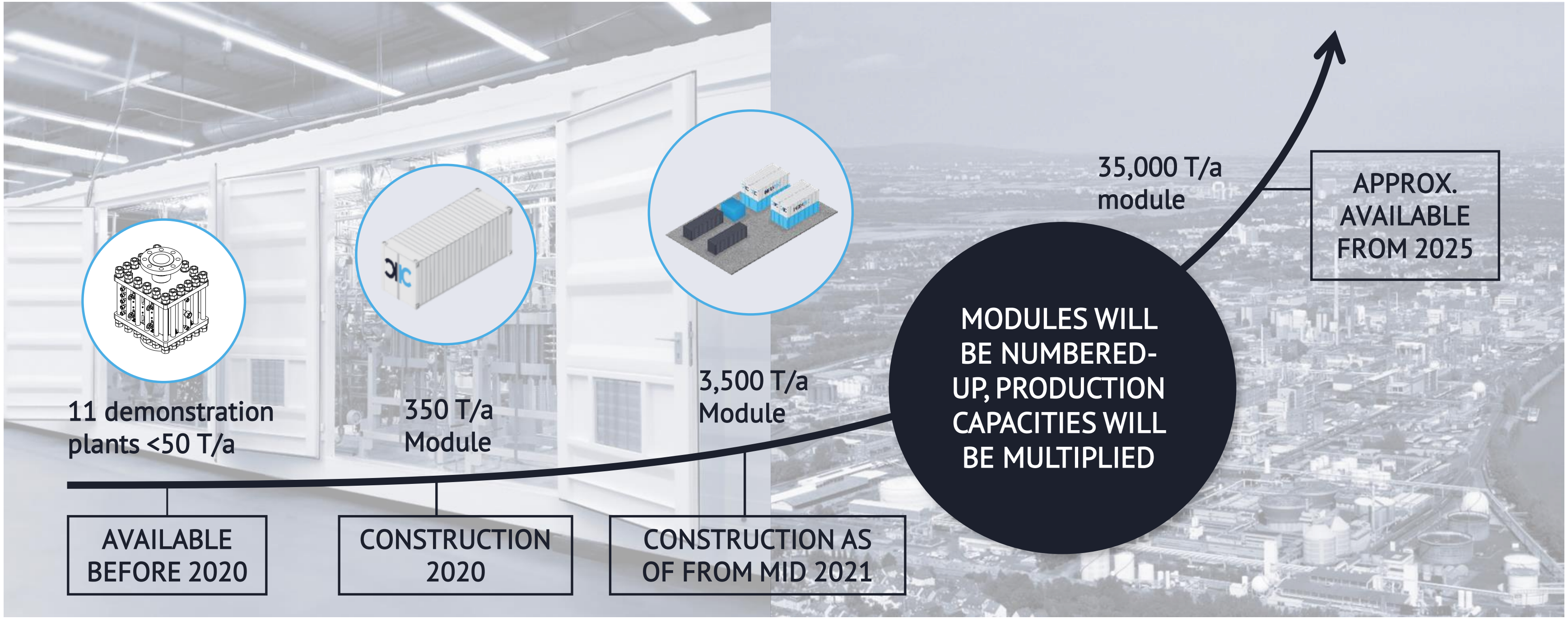
> Reducing/Increasing the load of one or more reactors or
> Startup/Shutdown of a number of individual reactors

Therefore, INERATECs modular technology aims at partial load operation within a range of 10 to 100% of nominal load.

PLANT SCALE UP

BY NUMBERING-UP

20.01.2021



Tim Boeltken
Managing Director

INERATEC GmbH

SUSTAINABLE, AFFORDABLE FUELS
& MATERIALS FOR EVERYONE

AWARDS

#SET100 CERTIFIED

DEUTSCHER GRÜNDER PREIS

LOTHAR SPÄTH AWARD | 2018
Für herausragende Innovationen in Wissenschaft & Wirtschaft

INNOVATIONSPREIS
DER DEUTSCHEN GASWIRTSCHAFT
2018

CLEAN TECH OPEN

ACKNOWLEDGEMENTS OF FUNDING

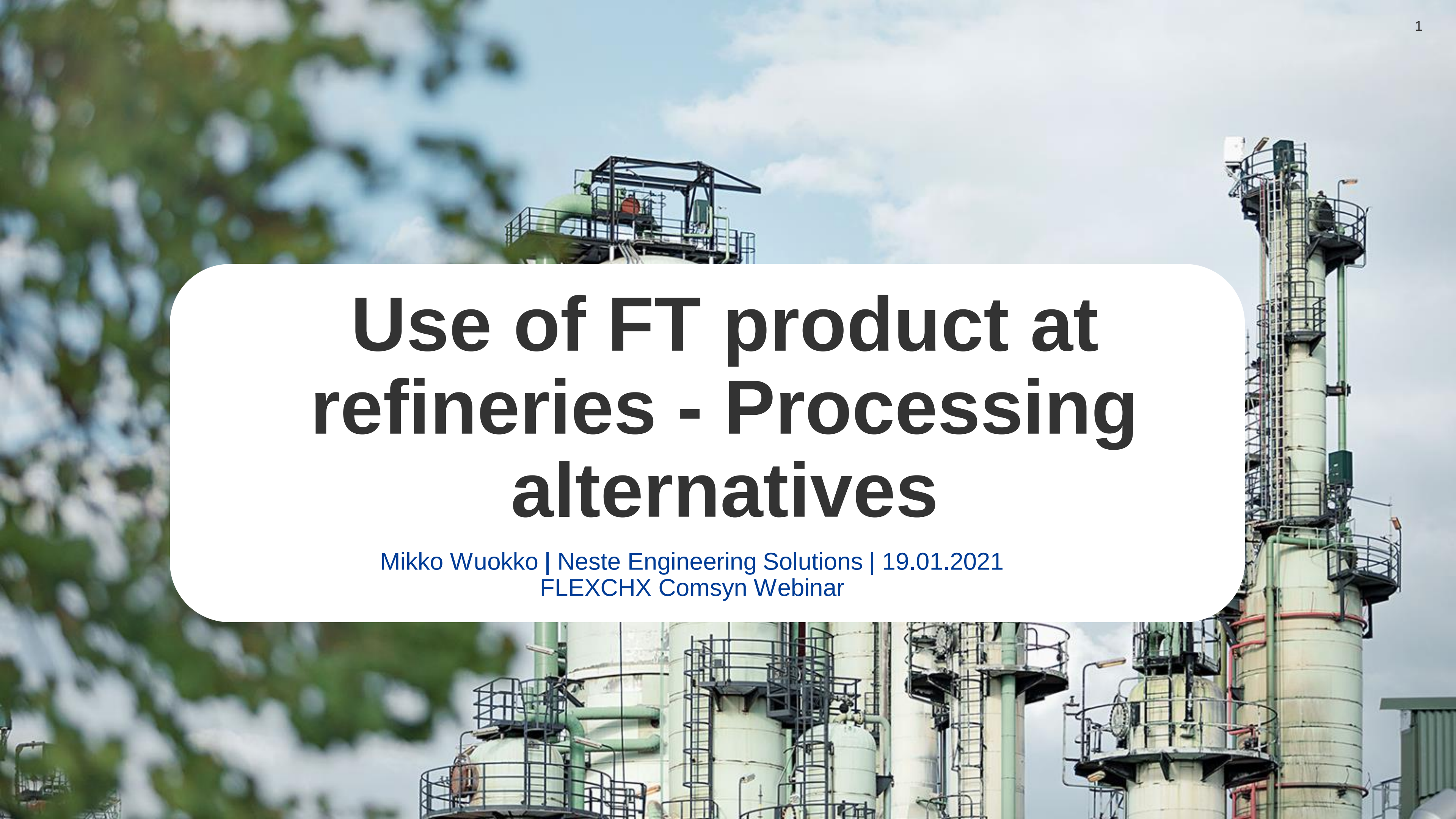
FLEXCHX

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

COMSYN

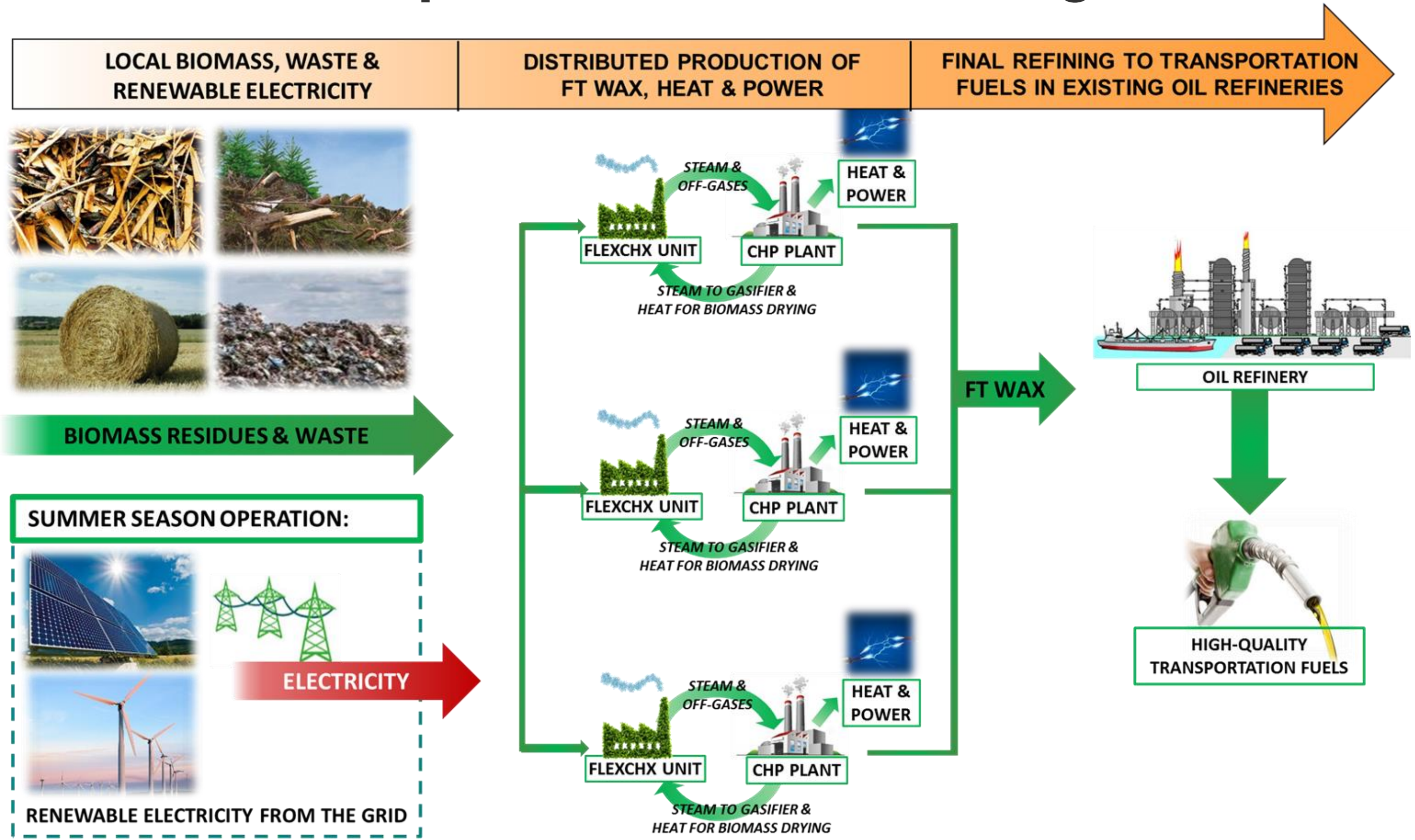
COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476



Use of FT product at refineries - Processing alternatives

Mikko Wuokko | Neste Engineering Solutions | 19.01.2021
FLEXCHX Comsyn Webinar

FLEXCHX concept - Centralized refining



Introduction

FLEXCHX units produce Fischer-Tropsch synthesis product, so-called **FT syncrude**

Eight different co-processing pathways for FLEXCHX syncrude were defined for seven product

The potential integration facilities were an **oil refinery, steam cracker and an HVO plant**

The **European product market** for interesting products also was defined, as well as a further look into a possible Finnish integration case

Preliminary **risk assessment** of refinery integration will be also concluded

Studied FLEXCHX FT syncrude co-processing product opportunities

Oil refinery
- Motor-gasoline
- Diesel
- Jet fuel

HVO plant
- Renewable diesel
- Renewable jet

Steam cracker
- Ethylene
- Propylene

Definition of FT syncrude

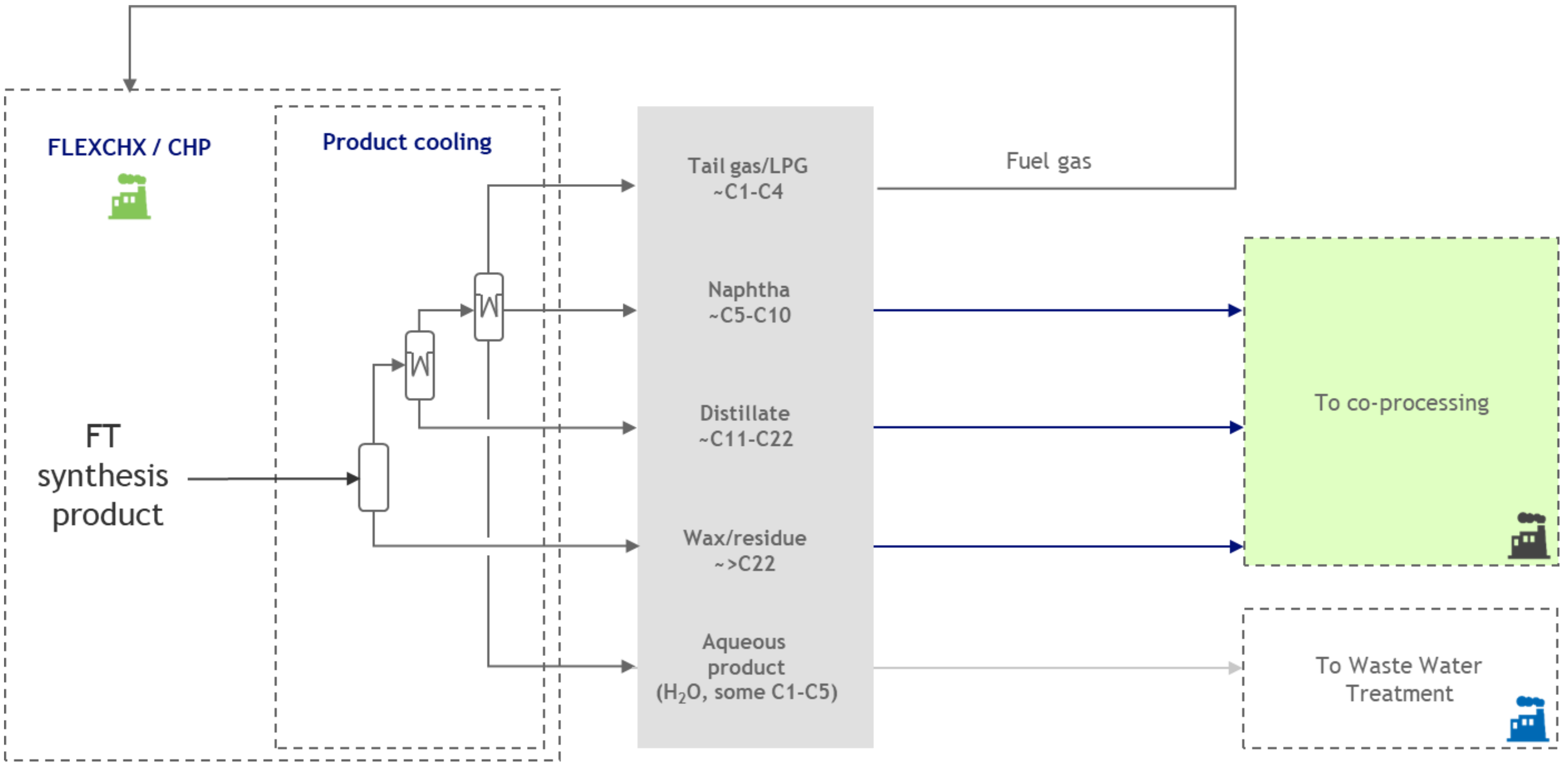
FLEXCHX syncrude composition was estimated in order to estimate suitability for different co-processing methods

Assumed composition was cobalt-based low-temperature Fischer-Tropsch syncrude derived from literature

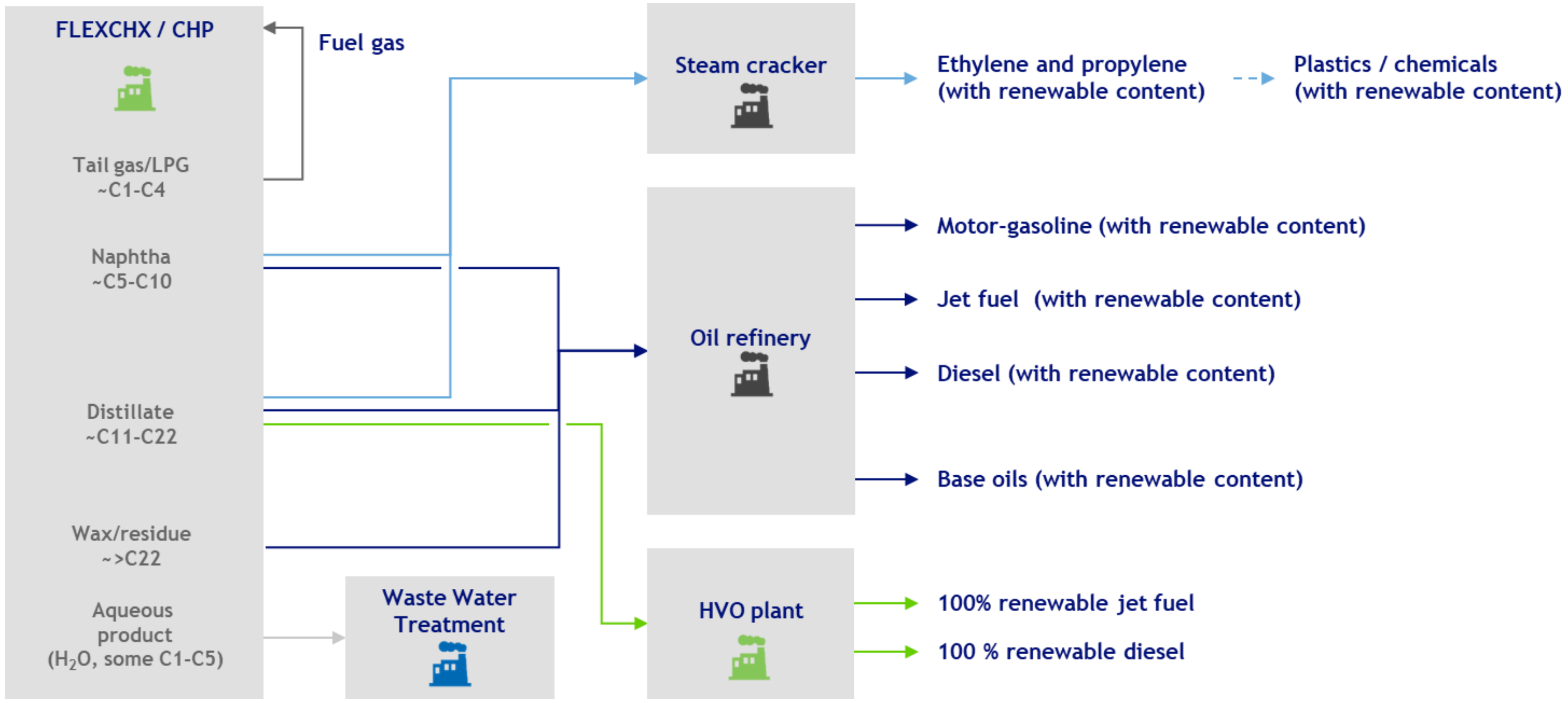
Product fraction	Carbon range	Share of product fraction (%)
Tail gas	C1-C2	7
LPG	C3-C4	5
Naphtha	C5-C10	20
Distillate	C11-C22	22
Wax	>C22	44
Aqueous product	C1-C5	2

FT syncrude is similar in composition and quality to fossil crude oil

FT syncrude fractionation scheme



Potential FLEXCHX syncrude integration pathways



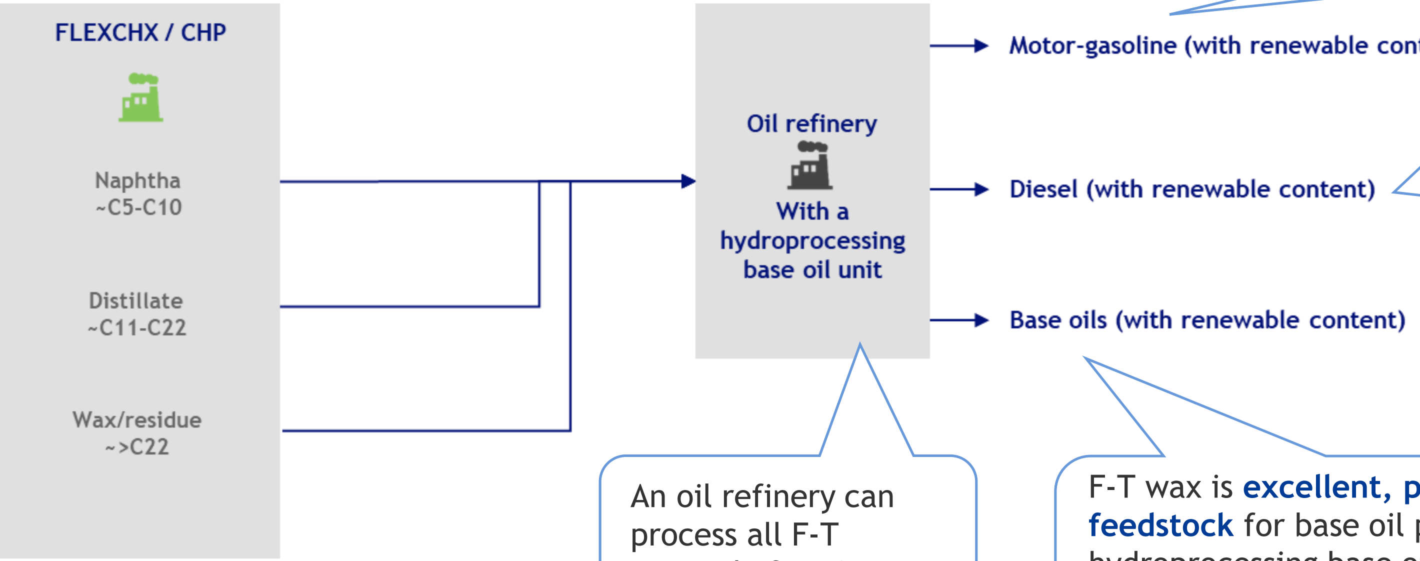
NESTE

FT syncrude co-processing suitability

FT fraction to be co-processed	Main product	Integration facility	Co-processing suitability	Investment needs	Technical attractiveness
FT naphtha	Motor gasoline	Oil refinery	No major technical limitations	No major investment needs	Good
FT distillate	Diesel	Oil refinery	**Possibly suitable for direct blending** **Cold flow properties a limiting factor**	**Isomerization required for high blends**	Good/ Adequate
FT distillate	Renewable diesel	HVO plant	No major technical limitations	No major investment needs expected	Good
FT distillate	Jet fuel	Oil refinery	**Expected poor cold flow properties** for product with existing refinery units	**Isomerization required for high blends**	Poor
FT distillate	Renewable jet fuel	HVO plant	No major technical limitations **Isomerization typically included in HVO plants**	No major investment needs expected	Good
FT wax	Base oils	Oil refinery	Hydroprocessing base oil unit required	No major investment needs expected	Good
FT wax	Transportation fuels	Oil refinery	No major technical limitations	No major investment needs expected	Good
FT naphtha and/or distillate	Ethylene and propylene	Steam cracker	**Olefins in feed can cause coking** **Pre-treatment possibly required**	**Possibly hydrotreatment required** as feed pre-treatment	Adequate/Poor

Integration case 1

Oil refinery with a hydroprocessing base oil unit



Gasoline production (catalytic reforming) is sensitive to heavy components □ **naphtha fraction quality needs to be considered**

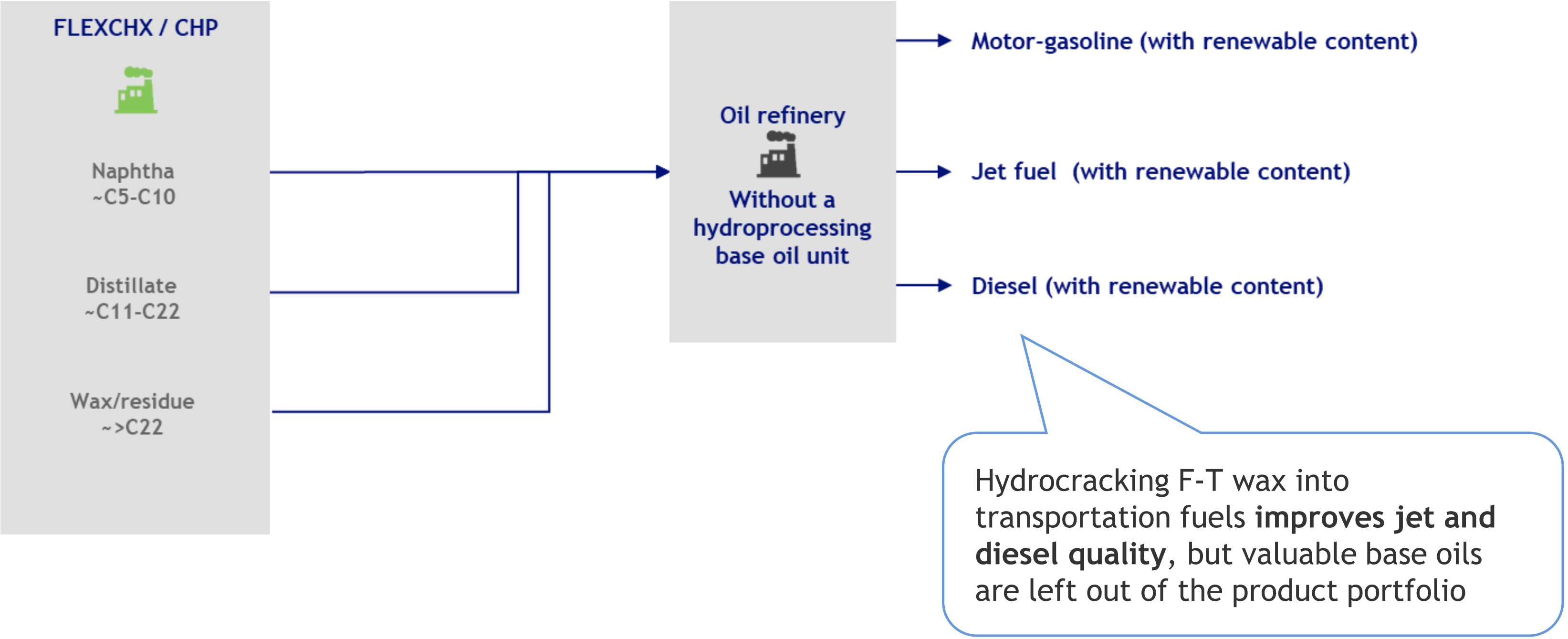
Blending distillate to diesel is an opportunity: by-passes hydroprocessing step, saves in production costs

An oil refinery can process all F-T syncrude fractions

F-T wax is **excellent, paraffinic feedstock** for base oil production in the hydroprocessing base oil unit □ base oil **end product quality could be improved** (better price)

Integration case 2

Oil refinery without a hydroprocessing base oil unit

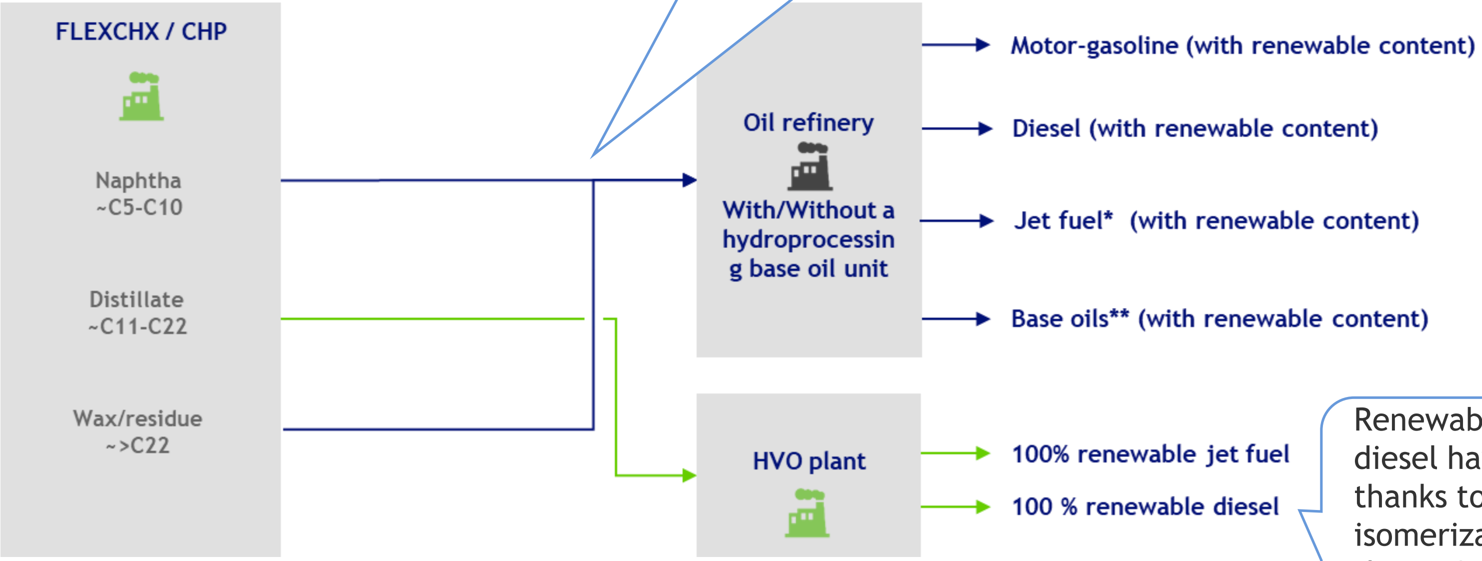


Integration case 3

HVO plant and oil refinery

An HVO plant **can only process the distillate**, other fractions need to be processed at an oil refinery

An ideal integration case is an HVO plant with an oil refinery at the same site



Renewable jet fuel and diesel have **better quality** thanks to the isomerization available at the HVO plant

*Produced in a refinery without a base oil unit
** Produced in a refinery with a base oil unit

Conclusions and next steps

A traditional oil refinery is likely well-suited for co-processing all the FT syncrude fractions, dedicated feeds could need modifications to assets

In order to reach most benefit from renewability, the FT syncrude naphtha could be processed at an HVO plant, but remaining fractions need to be processed elsewhere

Finland has potential for co-processing in existing renewable and traditional refining assets

A preliminary risk assessment will be performed to characterize technical risks in refinery integration

FLEXCHX project has received funding from the European Union’s Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

NESTE

USE OF FT PRODUCT IN OIL REFINERIES

COMSYN & FLEXCHX WEBINAR

date: 19/01/2021
name: Jan Jenčík, Jiří Hájek, Radek Černý, Aleš Vráblík
unit: Department of Development and Innovation

ORLEN UniCRE

COMSYN

About ORLEN UniCRE

Current challenges to 2030

Reduction of carbon footprint

Alternative sources for energy and fuels

Reduction of waste

Further processing of by-products and waste products

Environmental and climate changes

Reduction of greenhouse gas emissions and ozone depleting substances

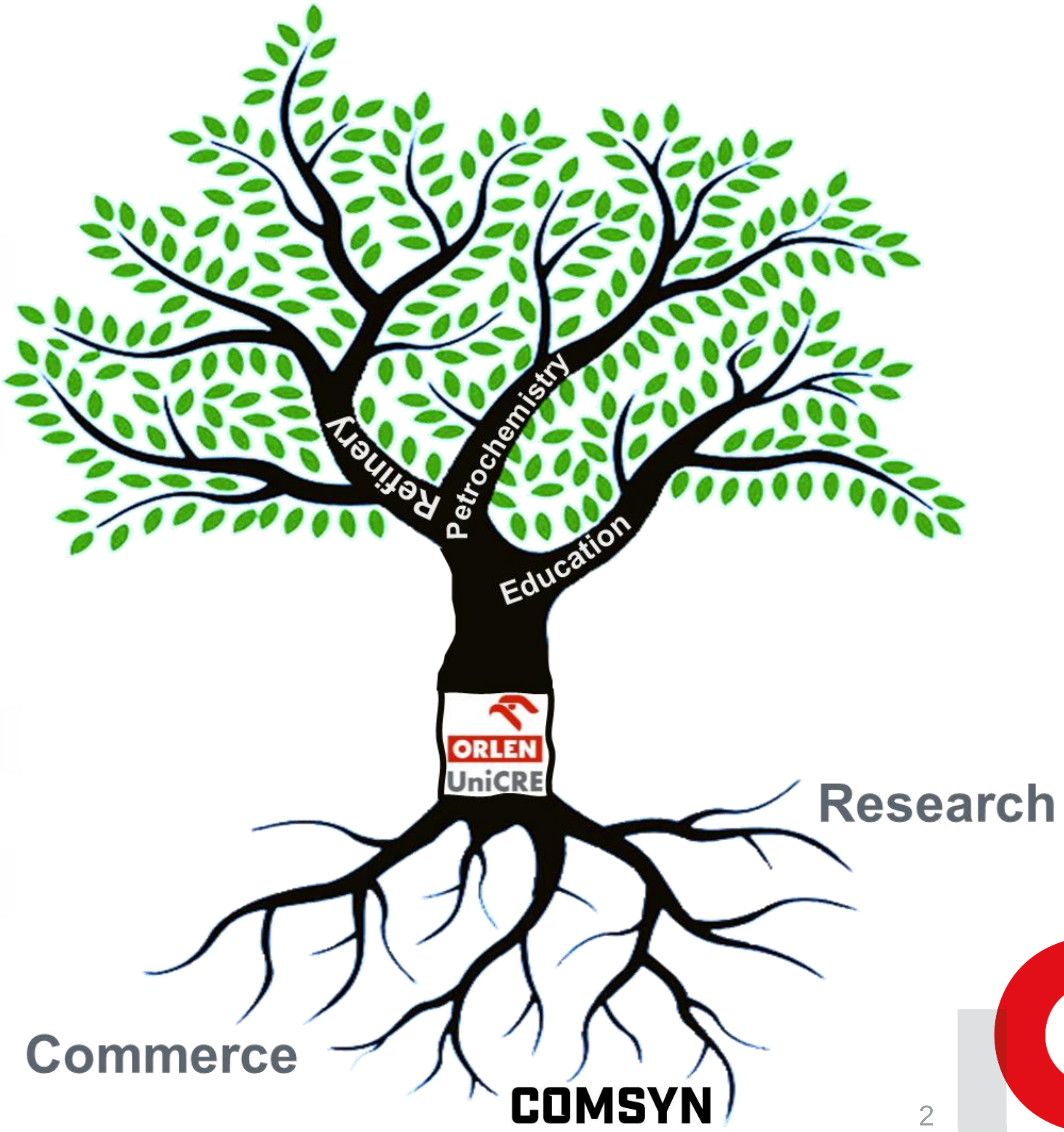
Health risks

Reducing emissions of harmful substances

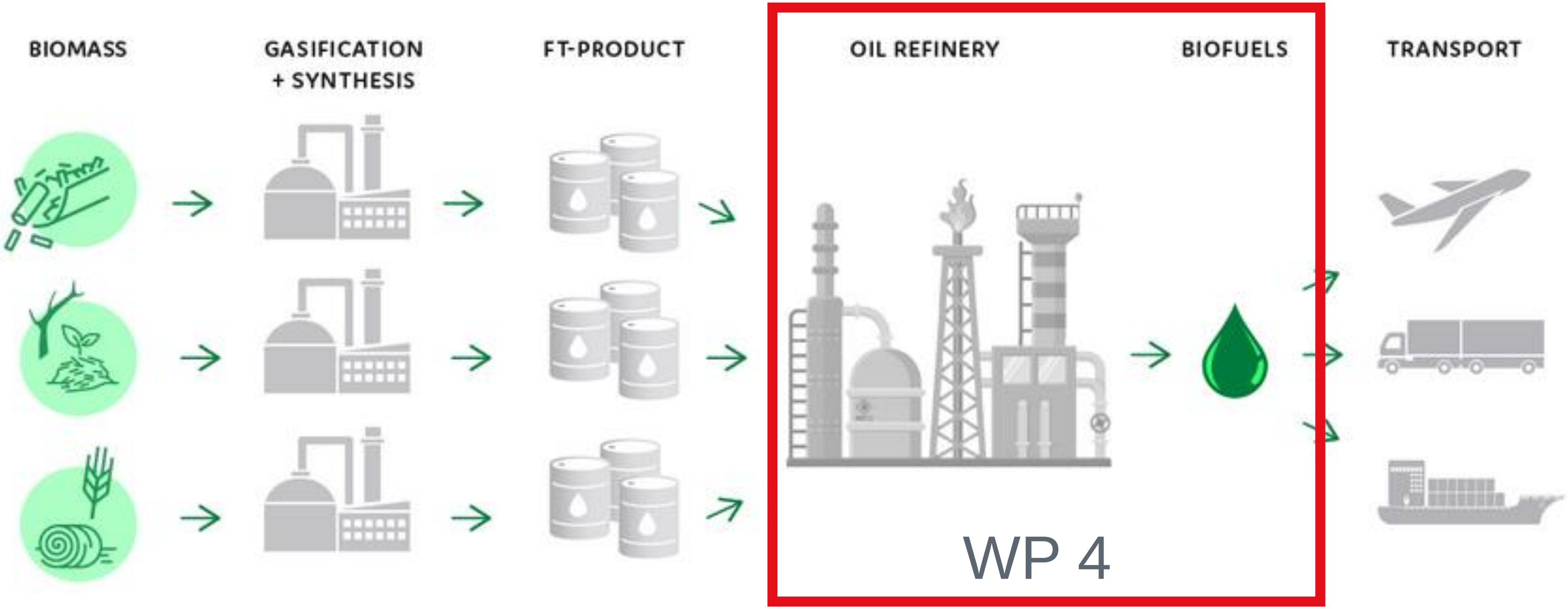
Shortage of skilled workers

Promotion of professional secondary and tertiary education

ORLEN UniCRE



COMSYN PROCESS CONCEPT



Main Targets of the COMSYN project

- Concept: decentralized primary conversion of biomass in 30 – 150 MW units.
- Target: reduction of biofuel production cost up to 35% compared to alternative routes → production cost for diesel lower than 0.80 €/l.
- GHG savings: 80 %
- Overall efficiency to FT biocrude + heat: 80%

COMSYN UPGRADING PROCESS - WP4

1) **CHARACTERISATION OF FT PRODUCTS AS A FEED FOR REFINERY**

2) **STAND-ALONE PROCESSING** - project results
   - Hydroisomerisation of FT diesel fraction

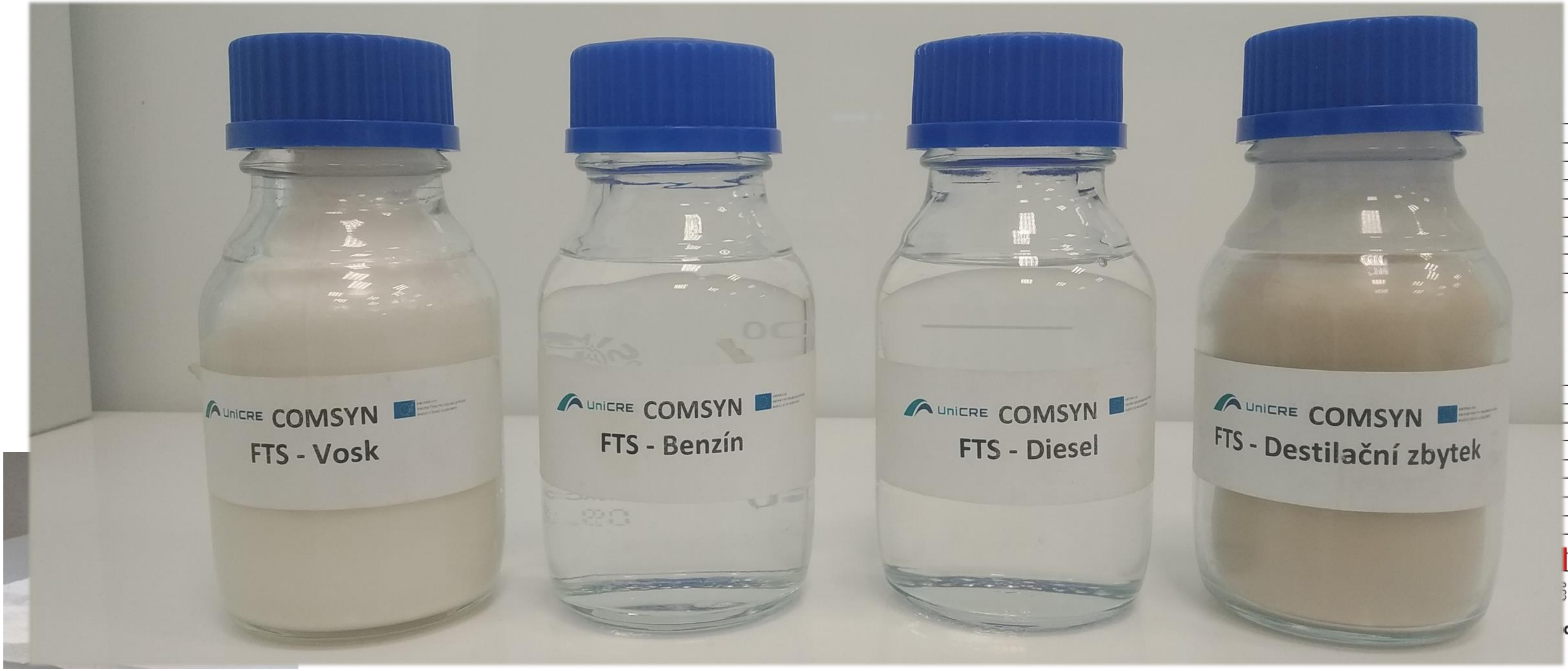
3) **CO-PROCESSING - project results**
   - Steam cracking
   - Hydrocracking

4) **POSSIBILITIES OF PROCESSING IN LITVÍNOV REFINERY (CZE)**

ORLEN UniCRE

COMSYN

CHARACTERISATION OF FT PRODUCTS AS A FEED FOR REFINERY

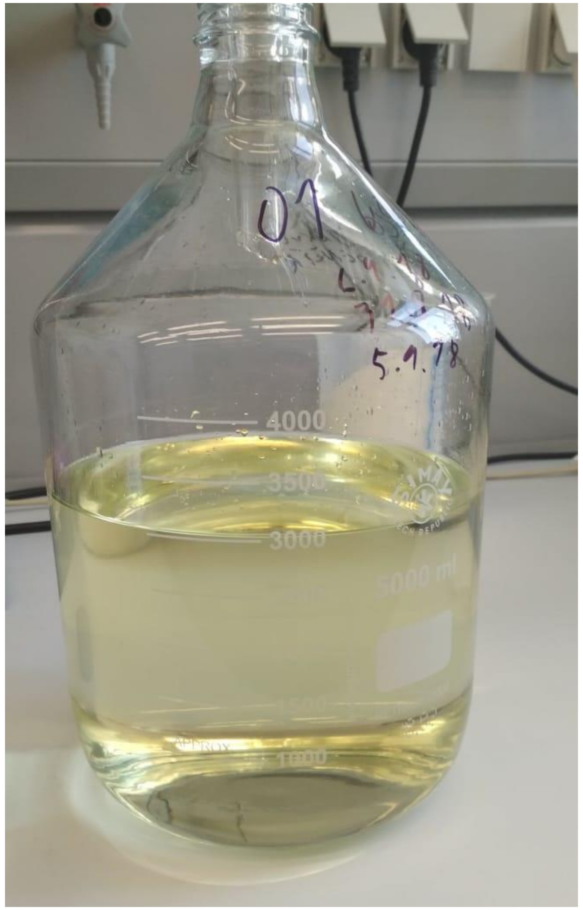


COMPARISON OF FT DIESEL FRACTION TO EN 590 AND EN 15940

		Diesel EN 590		Paraff. diesel EN 15940		FT diesel	
Parameter	unit	min.	max.	min.	max.	1st S.	2nd S.
Density at 15 °C	$kg.m^{-3}$	820	845	765	800	774.6	769.2
Kinematic viscosity at 40°C	$mm^2.s^{-1}$	2	4.5	2	4.5	2.3	2.1
Flash point	°C	>55	-	>55	-	93	84
CFPP, mild climate (grade A-F)*	°C	5	-20	5	-20	-6	-8
Cloud point	°C					-1.5	-1.7
Cetane index	-	46	-	65	-	86.7	82.8
Water content	$mg.kg^{-1}$	-	200	-	200	93.6	87.4
Sulphur content	$mg.kg^{-1}$	-	10	-	5	0.72	0.68

* 15.04. – 30.9. grade B (CFPP max. 0 °C)
01.10. – 15.11. grade D (CFPP max. -10°C)
16.11. – 28.02. grade F (CFPP max. -20 °C)
01.03. – 14.04. grade D (CFPP max. -10°C)

Hydroisomerisation step needed



Sample of FT diesel

COMSYN UPGRADING PROCESS - WP4

1) CHARACTERISATION OF FT PRODUCTS AS A FEED FOR REFINERY

2) **STAND-ALONE PROCESSING** - **project results**
   - Hydroisomerisation of FT diesel fraction

3) **CO-PROCESSING -** project results
   - Steam cracking
   - Hydrocracking

4) **POSSIBILITIES OF PROCESSING IN LITVÍNOV REFINERY (CZ)**

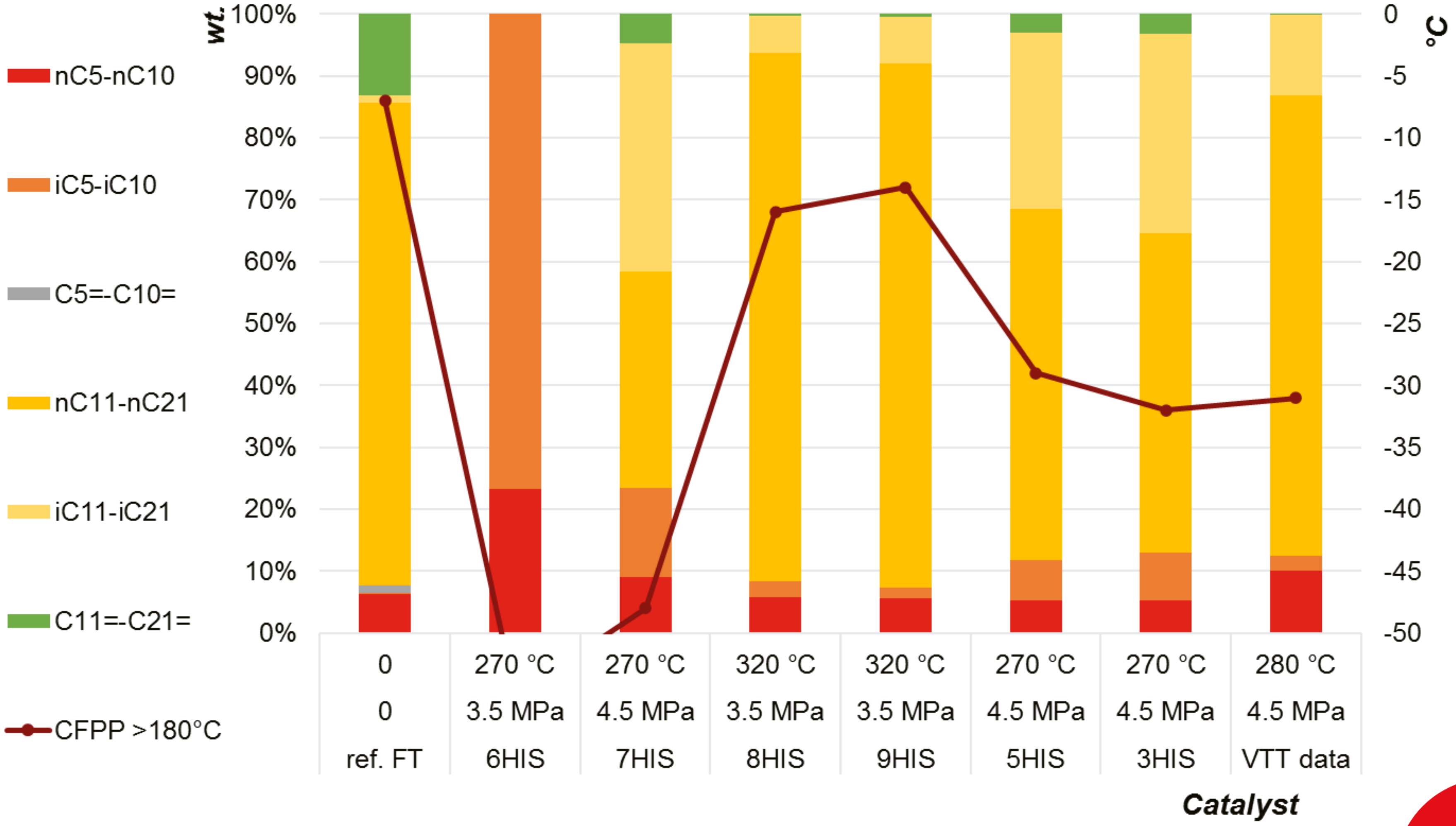
ORLEN UniCRE

COMSYN

RESULTS OF HYDROISOMERISATION EXPERIMENTS

Reactor setup

Catalyst samples



COMSYN UPGRADING PROCESS - WP4

1) **CHARACTERISATION OF FT PRODUCTS AS A FEED FOR REFINERY**

2) **STAND-ALONE PROCESSING** - project results
   - Hydroisomerisation of FT diesel fraction

3) **CO-PROCESSING - project results**
   - Steam cracking
   - Hydrocracking

4) **POSSIBILITIES OF PROCESSING IN LITVÍNOV REFINERY (CZ)**

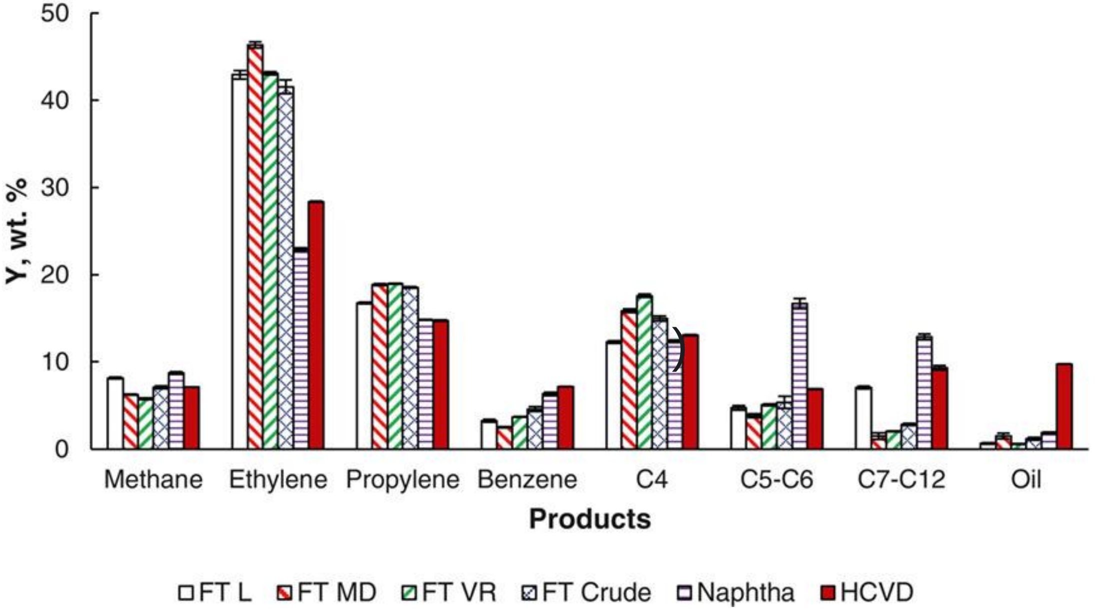
ORLEN UniCRE

COMSYN

RESULTS OF STEAM CRACKING EXPERIMENTS

Main pyrolysis products of pure feedstocks

Pyrolysis conditions: 815 °C, 65 NmL min^{-1}, 400 kPa



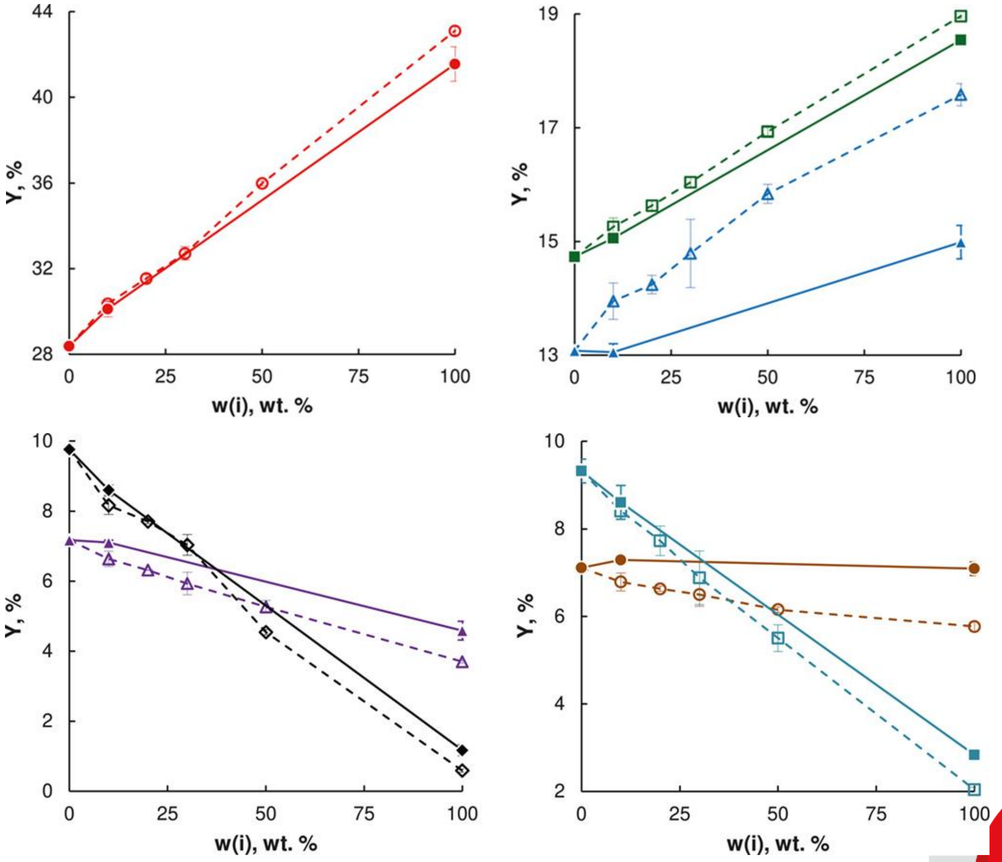
FT L – FT lights
FT MD – middle distillate
FT VR – vacuum residue
FT Cr – crude (Wax)
HCVD – hydrocracked vacuum distillate

Pyrolysis products of co-processing

Addition of FT Cr (▲ ♦●■) and FT VR (Δ◊○□) of 0, 10, 20, 30, 50 and 100 wt.% in the HCVD feedstock

○• ethylene
□▪ propylene
Δ▲ C4 fraction

Δ▲ benzene
◊♦ oil
○• methane
□▪ C7–C12

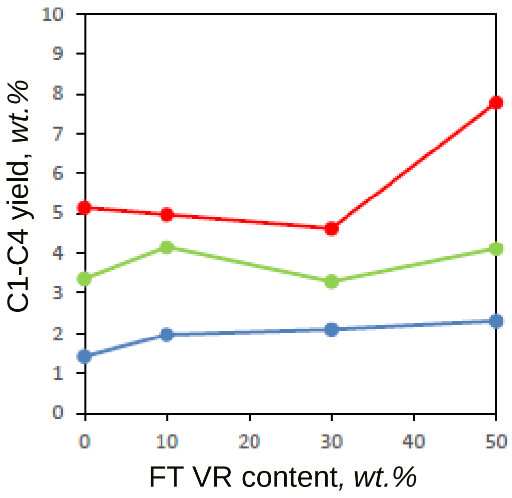


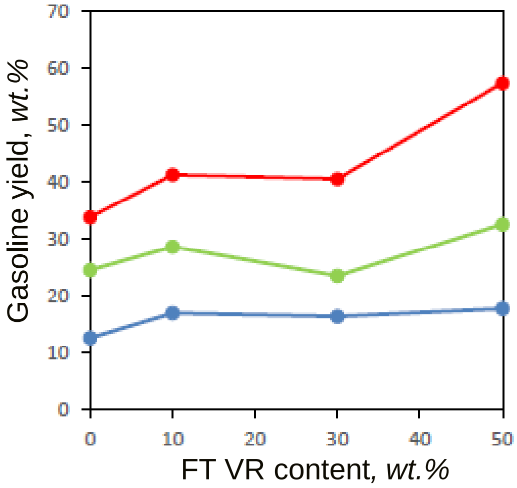
RESULTS OF HYDROCRACKING EXPERIMENTS

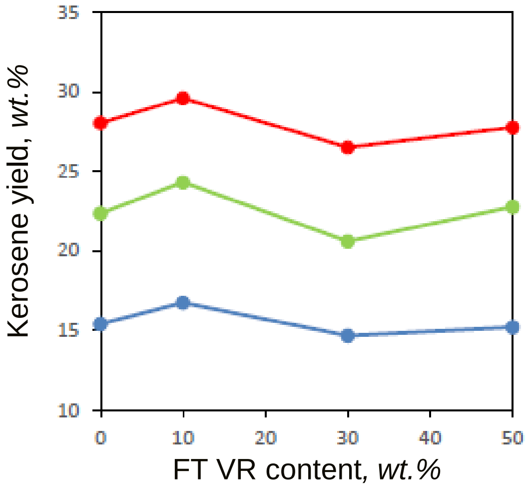
Hydrocracking of pure FT VR and co-processing

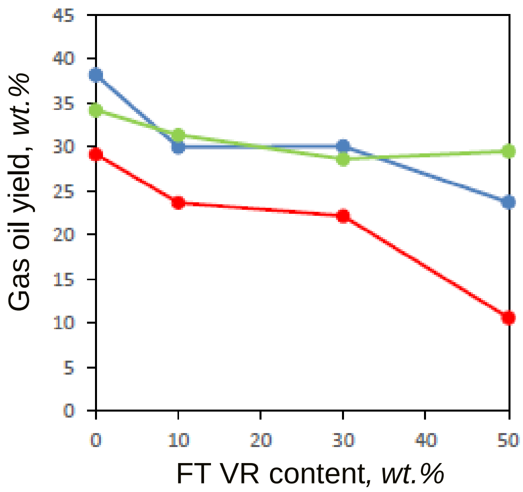
Addition of FT Vacuum Residue (FT VR) 0, 10, 20, 30, 50 and 100 wt.% in the Vacuum Distillate (VD) feedstock

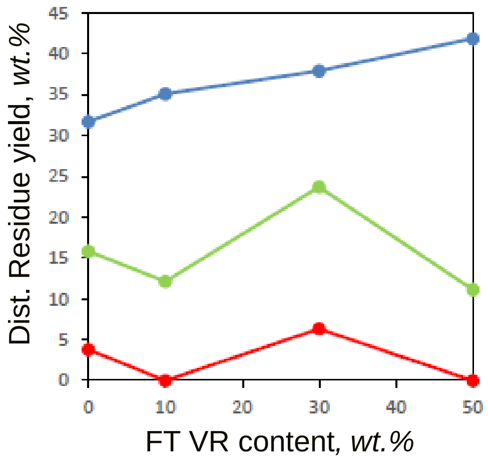
Hydrocracking experiments were performed at conditions: pressure of 16 MPa and reaction temp.: 390, 400 and 410 °C



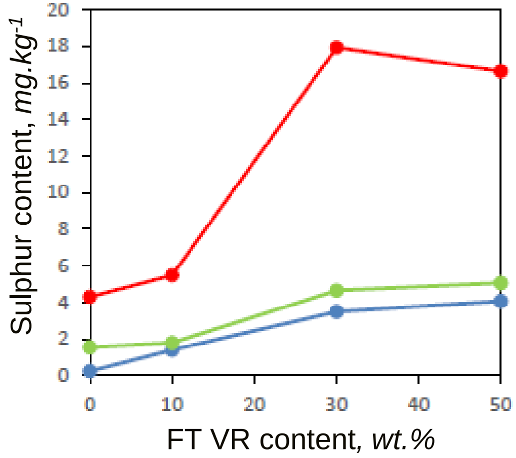








Gasoline yield *C5 –150 °C*
Kerosene yield *150–230 °C*
Gas oil yield *230–360 °C*
Dist. residue *> 360 °C*



COMSYN UPGRADING PROCESS - WP4

1) **CHARACTERISATION OF FT PRODUCTS AS A FEED FOR REFINERY**

2) **STAND-ALONE PROCESSING** - project results
   - Hydroisomerisation of FT diesel fraction

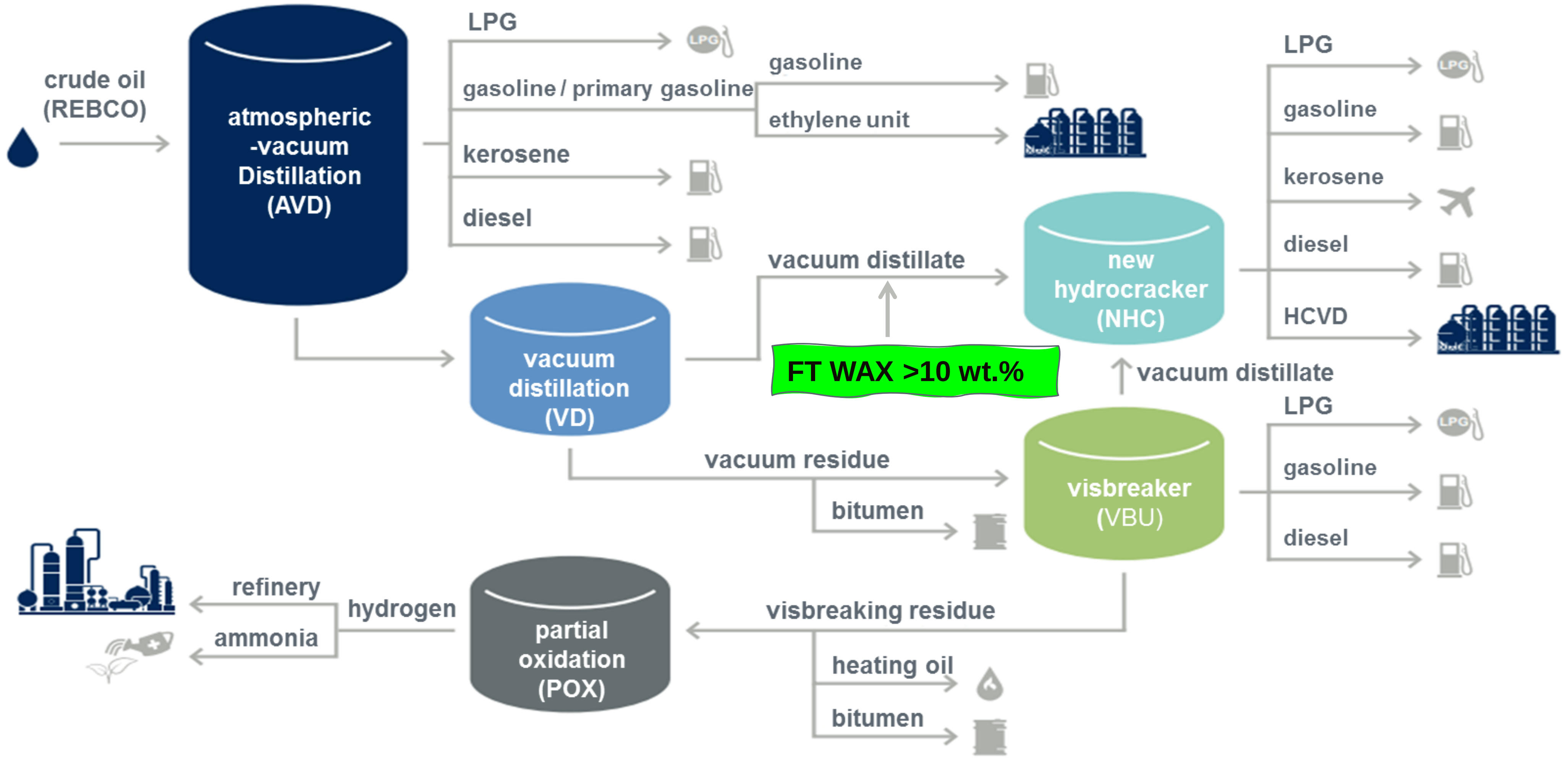
3) **CO-PROCESSING -** project results
   - Steam cracking
   - Hydrocracking

4) **POSSIBILITIES OF PROCESSING IN LITVÍNOV REFINERY (CZ)**

ORLEN UniCRE

COMSYN

POSSIBILITIES OF PROCESSING IN LITVÍNOV REFINERY (CZ)



CONCLUSIONS

- Reduction of crude oil consumption.
- GHG savings via processing of renewable materials.

- COMSYN final FT diesel meets European standards for automotive fuels = drop-in fuel.
- Addition of FT products into fossil feed will not impair the quality of fuels.

- Addition of FT products showed a positive influence on the conversion of the fraction boiling above 400 °C to lighter fractions consequently causing higher production of basic plastics (already with recycled biomaterial).

- Processing and co-processing of waste materials in the existing refineries will help to preserve an employment in regions currently dependent on crude oil refining.

ACKNOWLEDGEMENT

COMSYN

VTT Technical Research Centre of Finland	VTT
INERATEC, Germany	INERATEC
ORLEN UniCRE, Czech Republic	ORLEN UniCRE
GKN Sinter Metals Filters, Germany	GKN SINTER METALS
DLR, German Aerospace Center, Germany	DLR
Wood, Italy	wood.
AFRY, Finland	AFRY ÅF PÖYRY

CONSORTIUM

- Industry: UniCRE, Wood, GKN, AFRY
- SMEs: Ineratec
- Research organizations: VTT, DLR, UniCRE

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 727476.

THANK YOU FOR YOUR ATTENTION

wood.

Techno-Economic Studies for COMSYN process

Vincenzo Tota, Arianna Osio

20th January, 2021

Main Agenda

- Introduction to Wood
- Overview of Comsyn concept
- Validation of the concept at industrial scale
- Basis of Techno-Economic assessment
- Rewiew of Heat integration concept
- Results of preliminary techno-economic assessment
- Next steps

wood.

Introduction to Wood

wood.

Full services provider

Consulting

- Economic analyses
- Acquisition studies
- Feasibility assessments
- Market research, segmentation and pricing analyses
- Environmental and permitting
- Due diligence marketing and customer reviews
- Supply/demand analyses
- New technology evaluations

Engineering

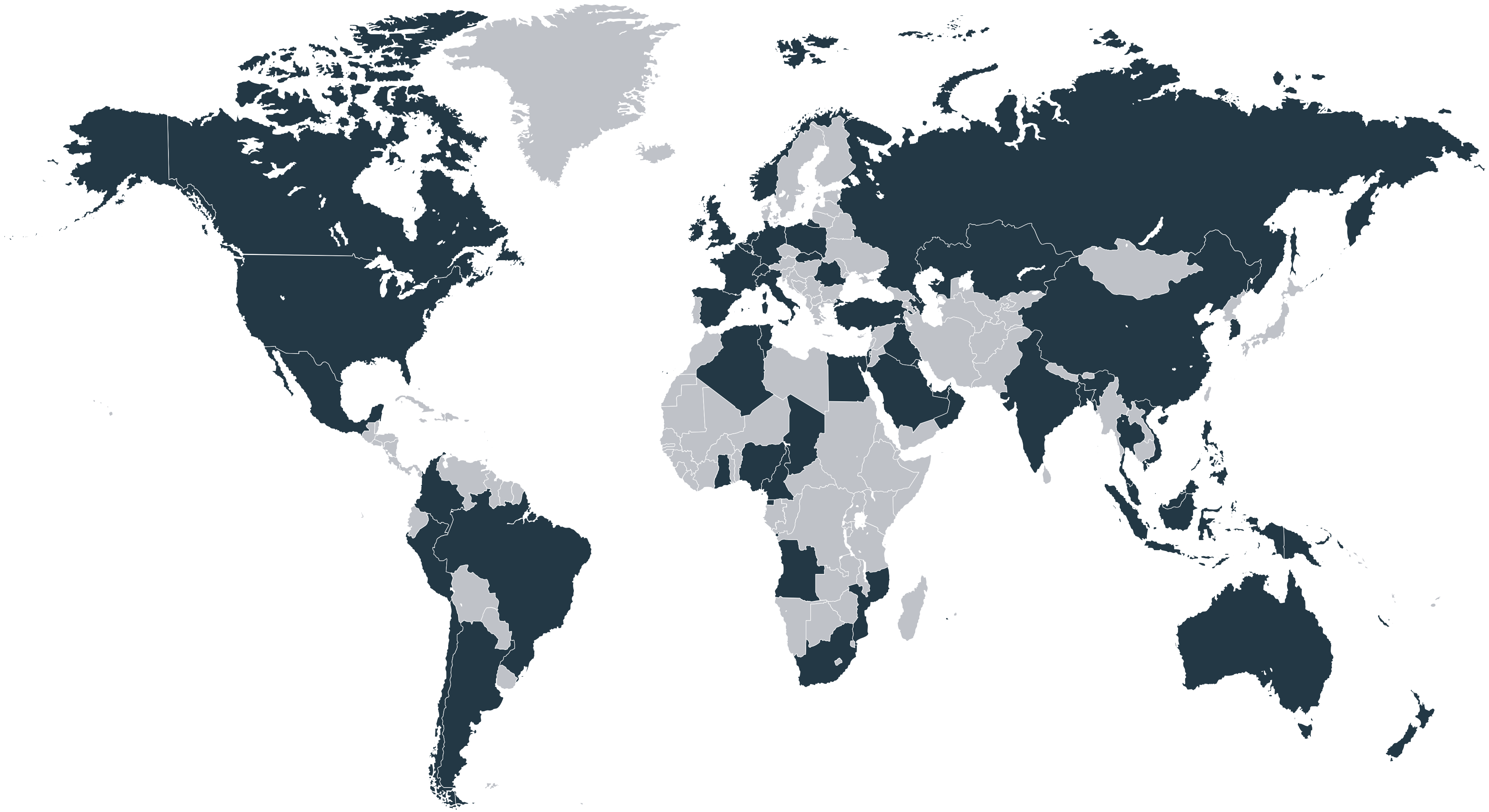
- Planning
- Engineering all disciplines
- Design
- Project support
- Supply chain management
- Commissioning & start-up
- Process simulation and modeling

Project Delivery

- Planning and support
- Cost management
- Risk management
- Procurement
- Vendor surveillance
- EPC
- General contractor
- Construction management
- Integrated safety program

wood.

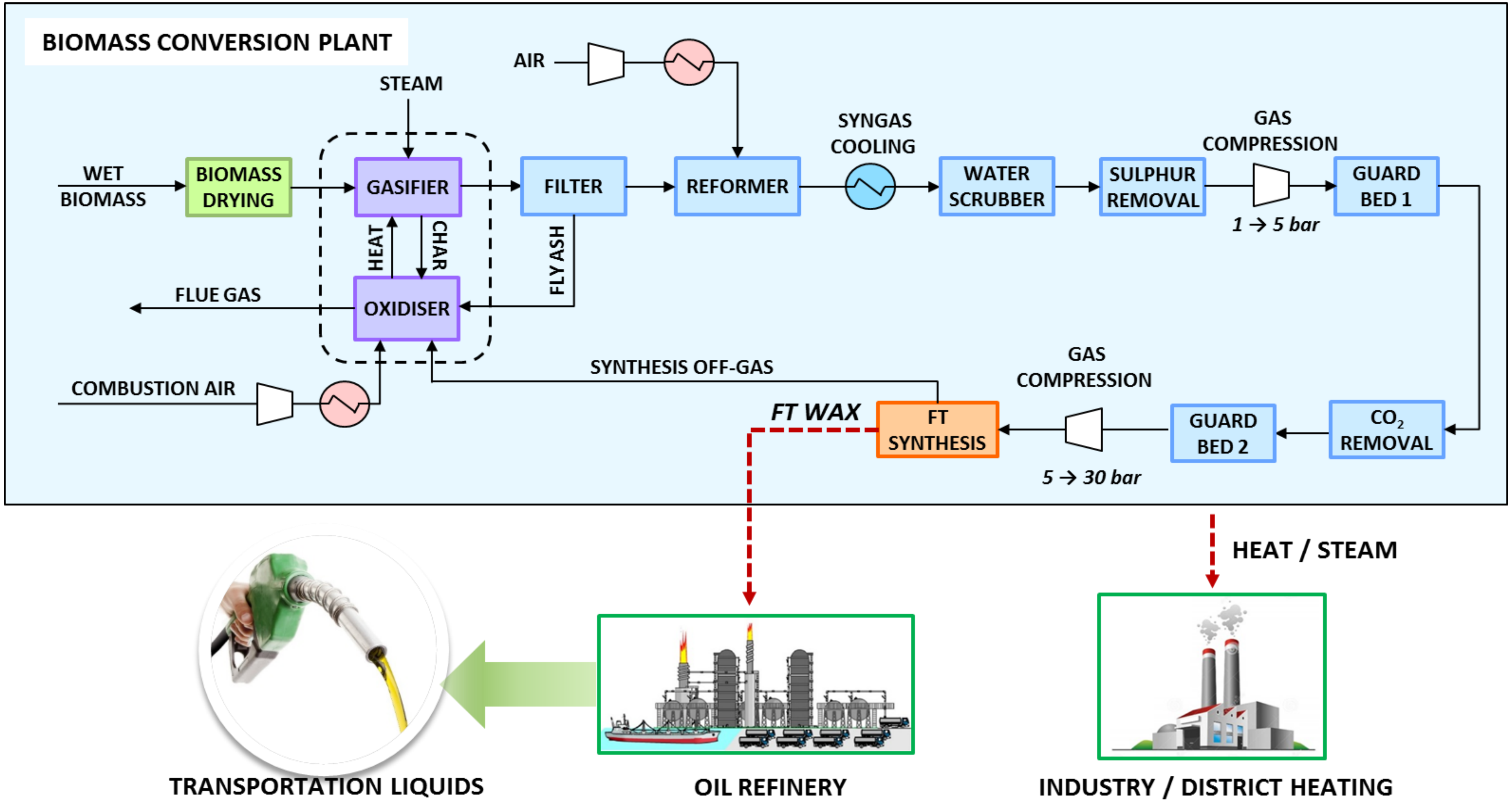
Our global footprint



Overview of COMSYN plant concept

wood.

COMSYN plant concept



wood.

Concept validation at industrial scale

Validation at industrial scale

Full Process Engineering Design Package

- Process Flow Diagrams
- Heat &Mass Balance
- Equipment list:
  - Main dimensions / sizing parameters
  - Material Of Construction
- Equipment Datasheets
- Control operating philosophy
- CAPEX and OPEX estimate

wood.

Main basis & assumptions

Main basis & assumptions

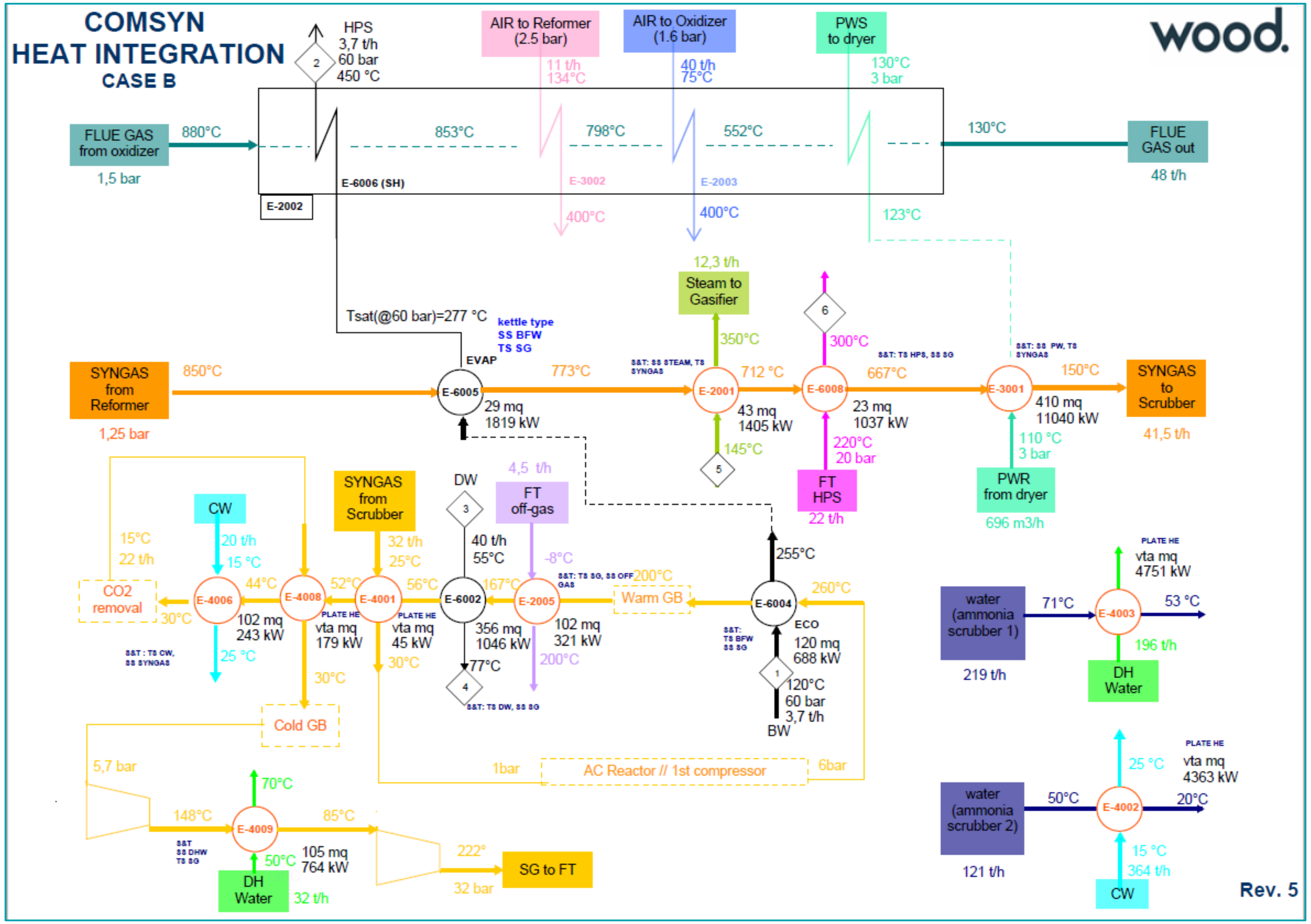
- Feedstock: forest residue
- Plant capacity: 100 MWt as feedstock thermal input, i.e approx. 31 kta of biocrude production
- Excess heat used for:
  - District Heating supply
  - Internal Power generation for plant own needs
- Configuration cases:
  - Case 1 : No CO_2 removal
  - Case 2 : Partial CO_2 removal (approx. 80%)
- Plant life: 20 years
- Target IRR for calculation of production cost: 12%
- Plant onstream factor: 94%

Heat Integration Review

Heat Integration Review

Heat integration in COMSYN is crucial for energy optimization:

- Heat rejection from FT reactions
- Heat recovery form Syngas Cooling and Oxidizer Flue Gas
- FT offgas re-use
- DH production and Steam Integration with Power Plant



wood.

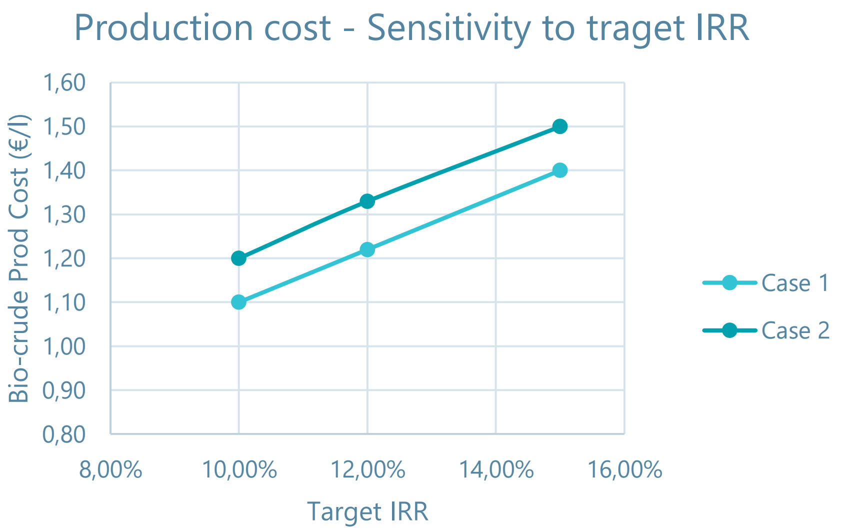
Main results & conclusions

Main Results

- Case 2, compared to Case 1:
  - Higher CAPEX (reduction in FT is overcome by the increase in the syngas treatment)
  - Higher OPEX (effects of optimized FT operation are overcome by O&M cost increase in the other units)
- Sensitivities to:
  - Financial Leverage
  - Target IRR

Results Summary

	Case 1 No CO2 capture		Case 2 80% CO2 Capture	
CAPEX (M€)	186.0		199.0	
O&M Cost (M€/y)	22.32		23.37	
Financial Leverage	*None*	*50%*	*None*	*50%*
Bio-crude Prod. Cost (€/l)	1.22	1.06	1.33	1.15

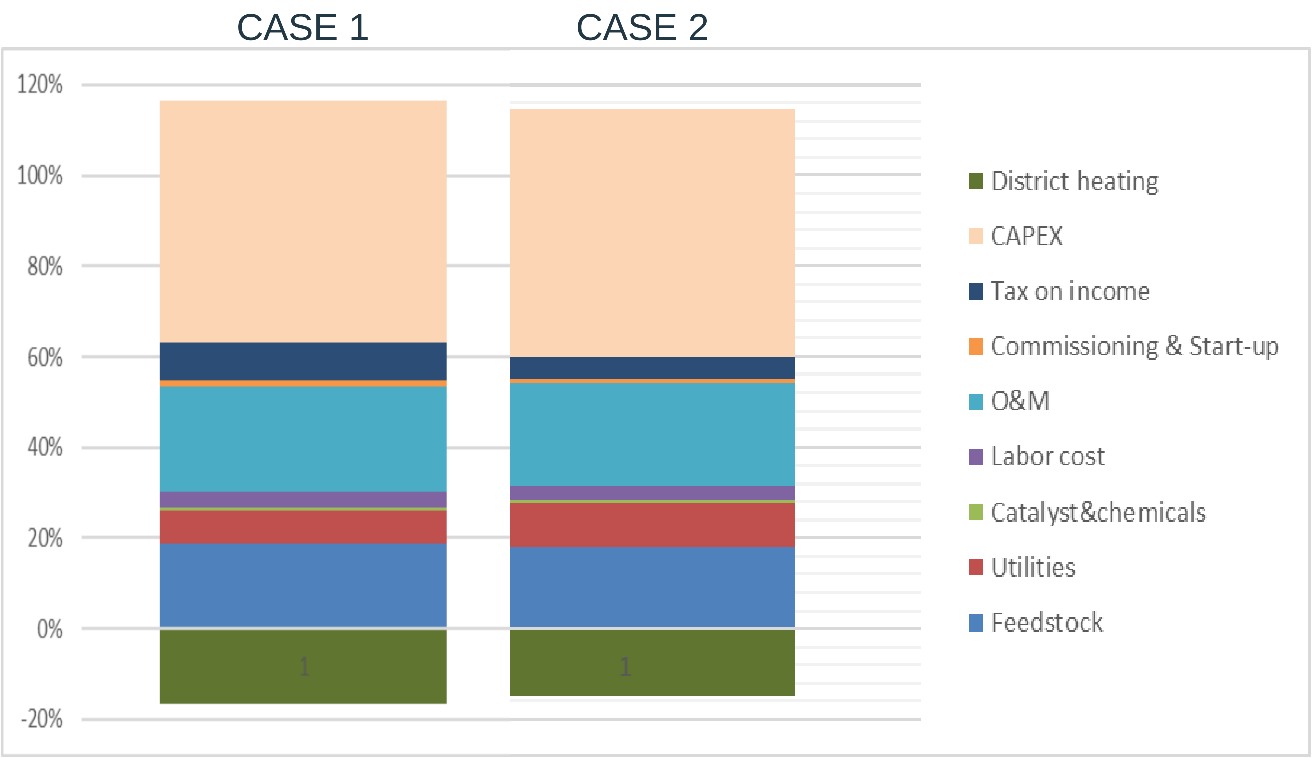


wood.

Main Results

Production Cost breakdown:

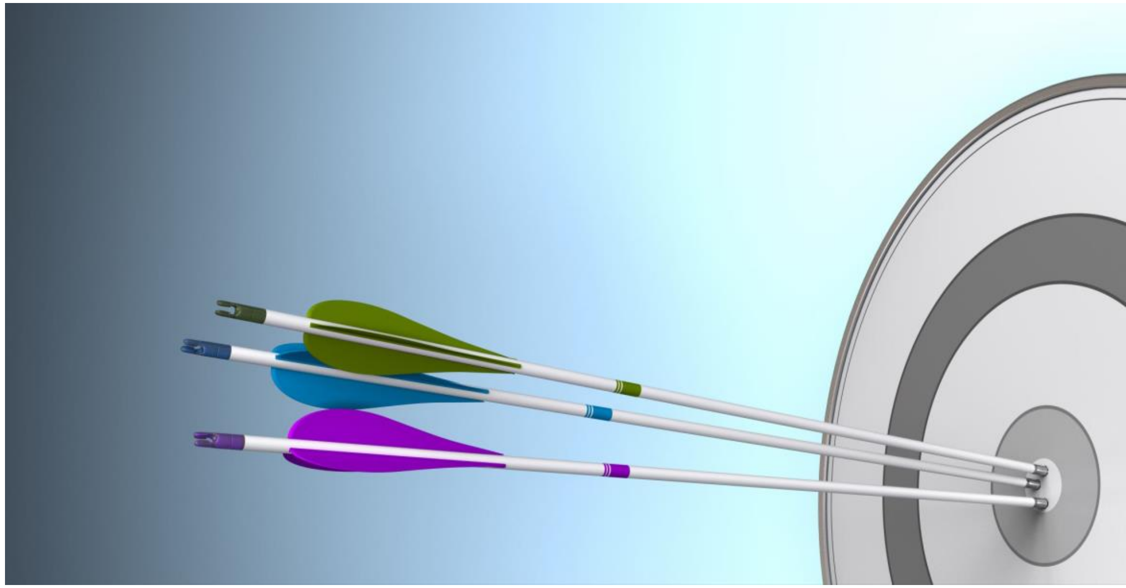
- Case 1 and Case 2 show the same behaviour
- Highest contribution by:
  - CAPEX
  - O&M (other than feedstock)
  - feedstock



Conclusions

Preliminary results show that:

- The estimated bio-crude production cost is promising but still higher than the initial project target (bio-fuel @ 0.8 €/l)
- The CO_2 capture does not appear to be beneficial for the overall techno-economic perfomance



More in-depth analysis will be carried out in the next months (study of business cases)

wood.

Next steps for COMSYN

Next steps – Business Study Cases

Northern Europe case:

- Feedstock: forest residue (e.g. bark)
- Plant size: 150-200 MWt (feedstock)
- DH generation
- Steam Integration with pulp mill / sawmill
- Possible sale of excess offgas to lime kilns

Central Europe case:

- Feedstock: agricultural residue (e.g. straw)
- Plant size: 150-200 MWt (feedstock)
- DH generation
- Steam Integration with industries (paper mill / chemical plant)

Thank you!
Any questions?

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 727476.

Techno-economic studies for the FLEXCHX process

Ralph-Uwe Dietrich,
Felix Habermeyer, Julia Weyand, Simon Maier
DLR e.V.

19 Jan 2021

DLR

Outline

A. Motivation & Project Idea

B. Techno-economic analysis

C. Life cycle assessment

D. Conclusion & Outlook

Outline

A. Motivation & Project Idea

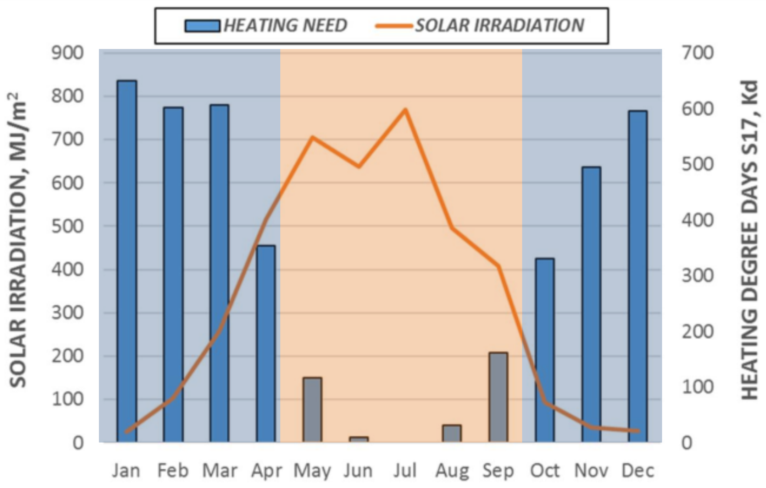
B. Techno-economic analysis

C. Life cycle assessment

D. Conclusion & Outlook

FlexCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

The FLEXCHX process response to energy market alteration

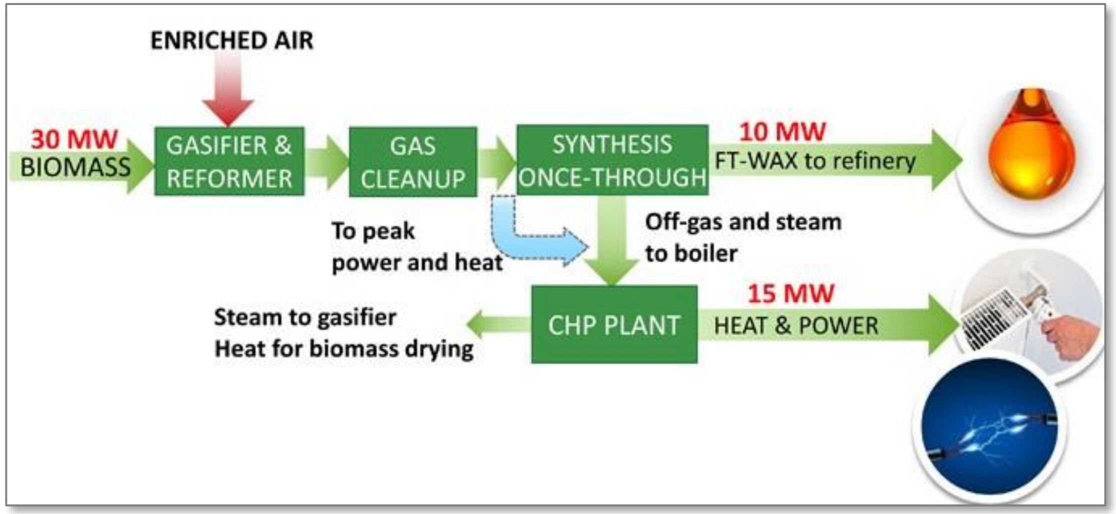


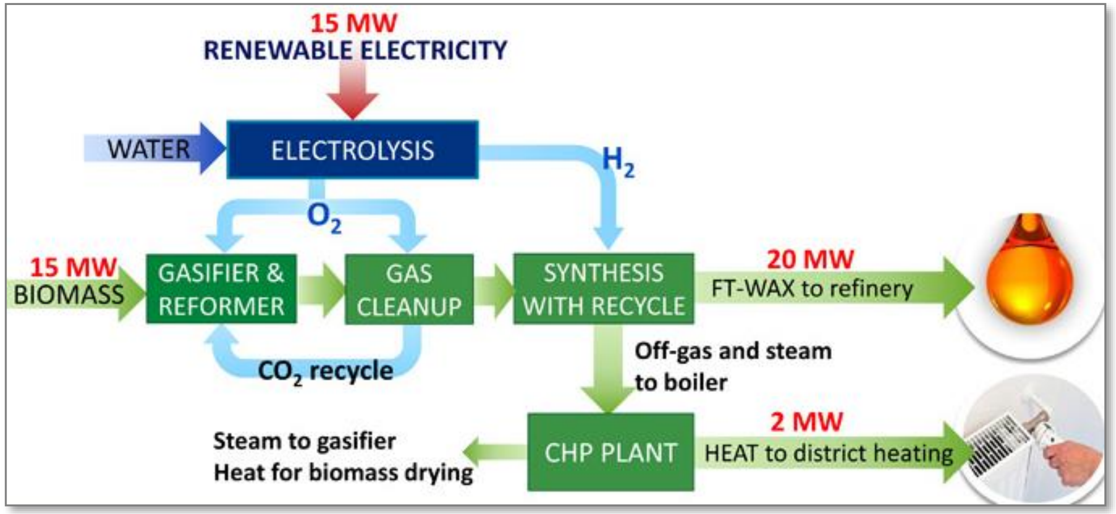
Winter Mode[1]

High district heating demand & lack of renewable electricity

Summer Mode [1]

Low district heating demand & readily available renewable electricity





[1] FLEXCHX project proposal

Outline

A. Motivation & Project Idea

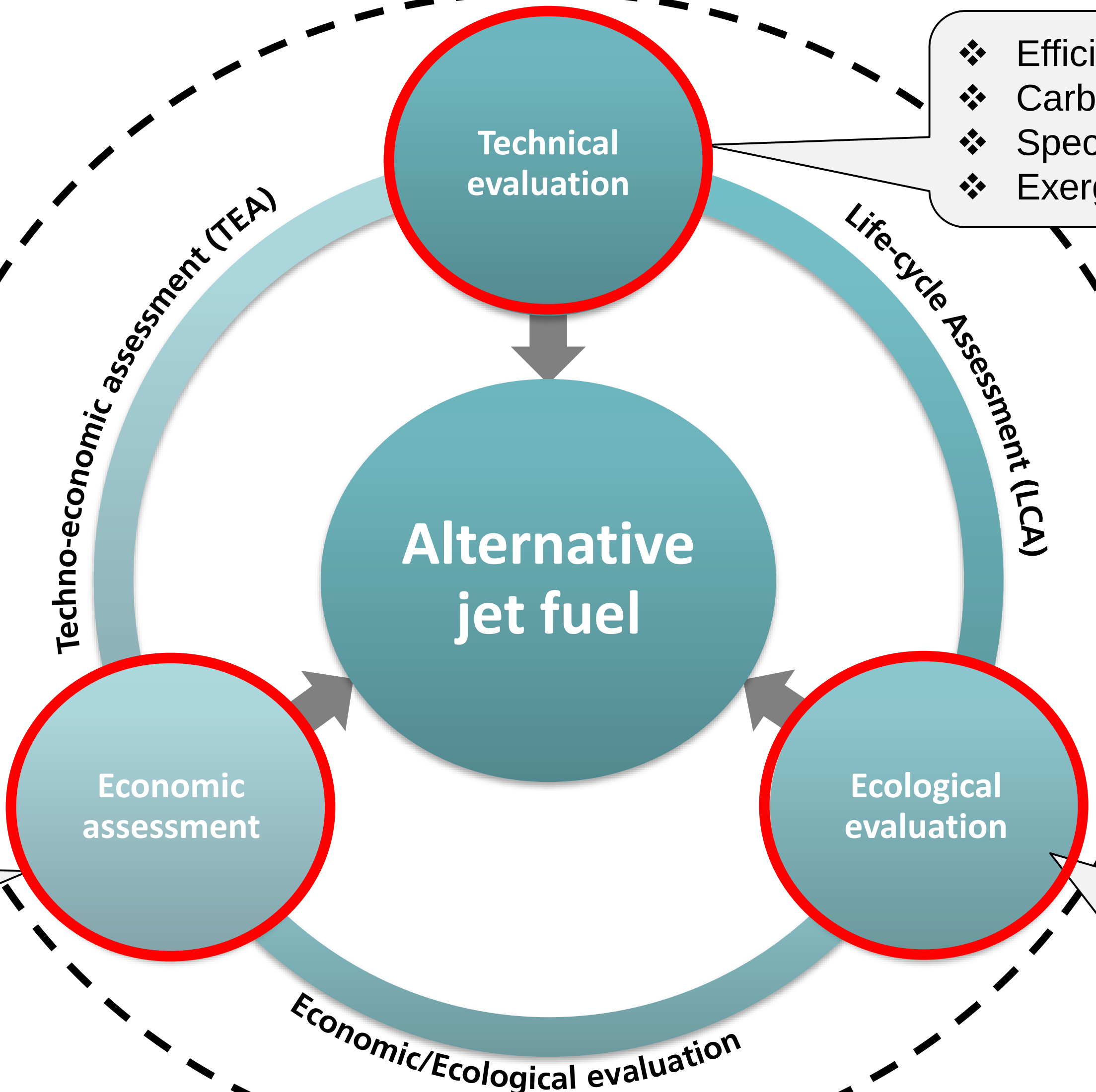
B. Techno-economic analysis

C. Life cycle assessment

D. Conclusion & Outlook

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Techno-Economic and ecological assessment (TEEA)



- Efficiencies (X-to-Liquid, Overall)
- Carbon conversion
- Specific feedstock demand
- Exergy analysis

DLR-evaluation and optimization tool

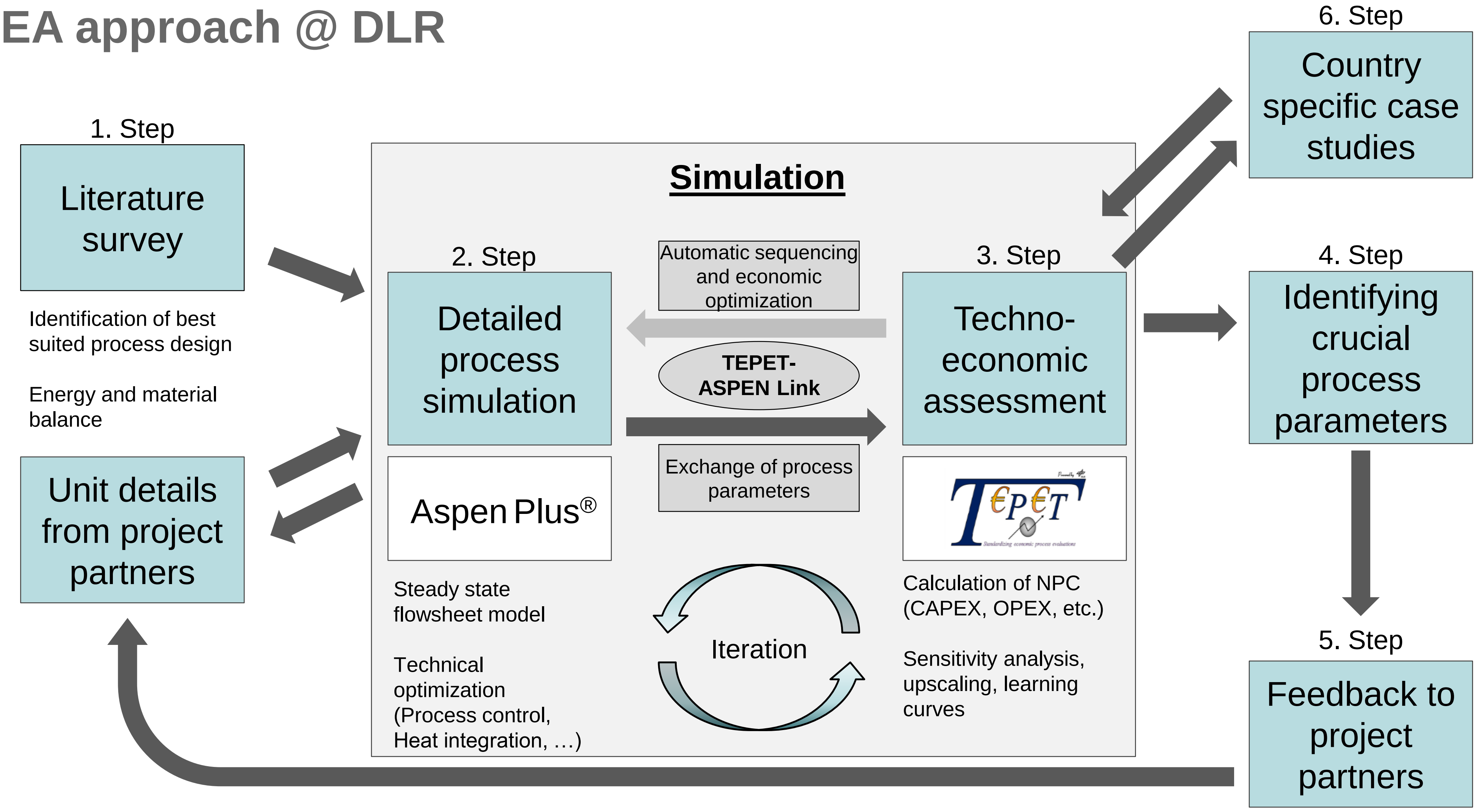
TEPET — Standardizing economic process evaluations

- CAPEX, OPEX, NPC
- Sensitivity analysis
- Identification of most economic feasible process design

- Environmental impacts
- Identification of ecological preferable process designs

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

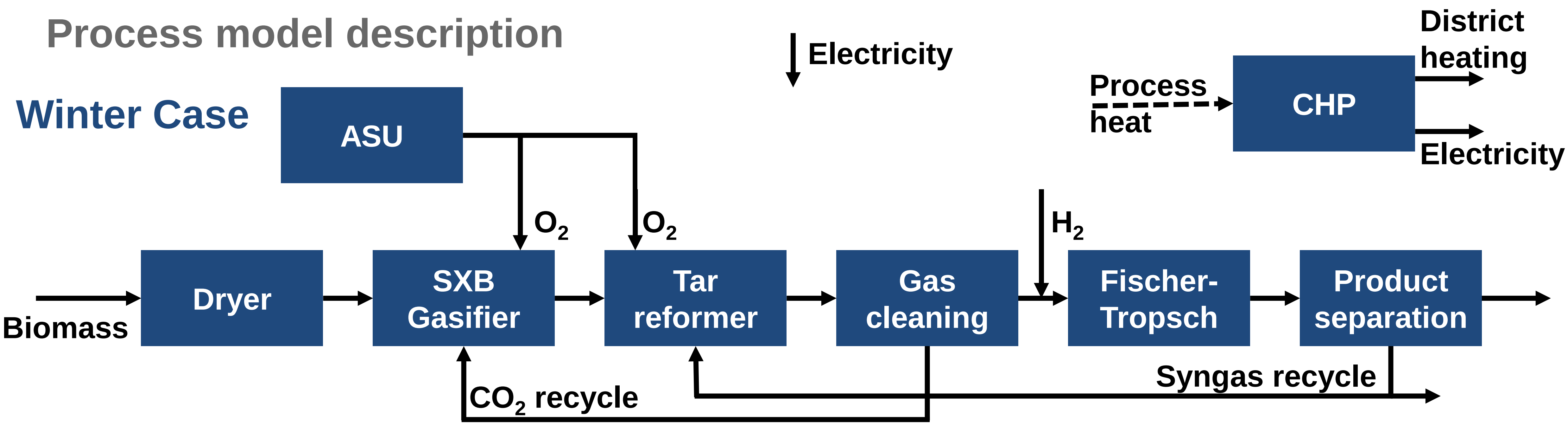
TEA approach @ DLR



FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Process model description

Winter Case



Key modelling assumptions:

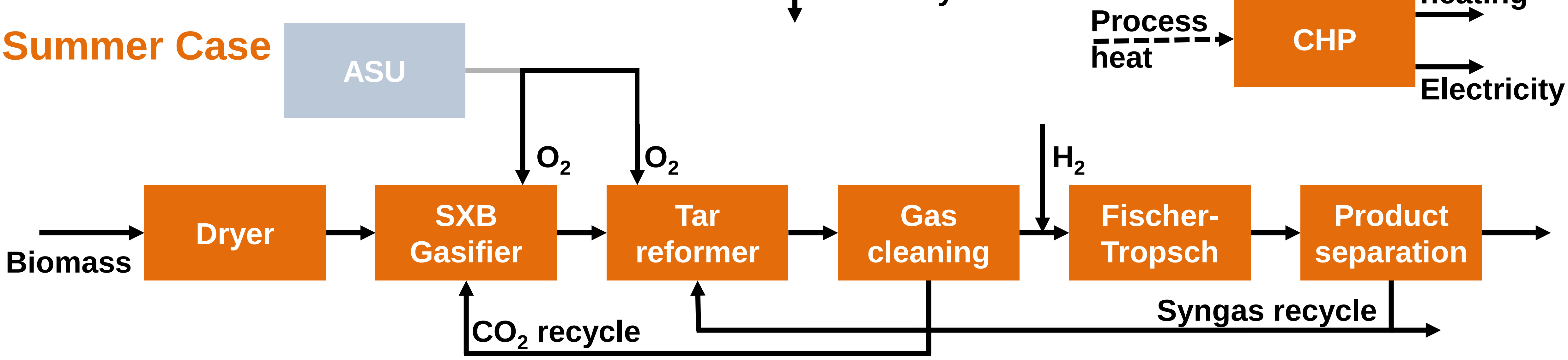
- Model for novel SXB gasifier developed by **VTT**
- FT model developed with **INERATEC** [1] microreactor performance data @ 80 % CO conversion
- 80 % methane conversion in reformer based on novel **Johnson Mattheys** catalyst performance
- PEM electrolyzer assuming 75 $\%_{LHV}$ efficiency [2]

[1] Hamelinck, C. N., Faaij, A. P., den Uil, H., & Boerrigter, H. (2004). Production of FT transportation fuels from biomass; technical options, process analysis and optimisation, and development potential. *Energy*, *29*(11), 1743-1771.
[2] Buttler, A., & Spliethoff, H. (2018). Current status of water electrolysis for energy storage, grid balancing and sector coupling via power-to-gas and power-to-liquids: A review. *Renewable and Sustainable Energy Reviews*, *82*, 2440-2454.

DLR

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Process model description



Key modelling assumptions:

- Model for novel SXB gasifier developed by **VTT**
- FT model developed with **INERATEC** [1] microreactor performance data @ 80 % CO conversion
- 80 % methane conversion in reformer based on novel **Johnson Mattheys** catalyst performance
- PEM electrolyzer assuming 75 $\%_{LHV}$ efficiency [2]

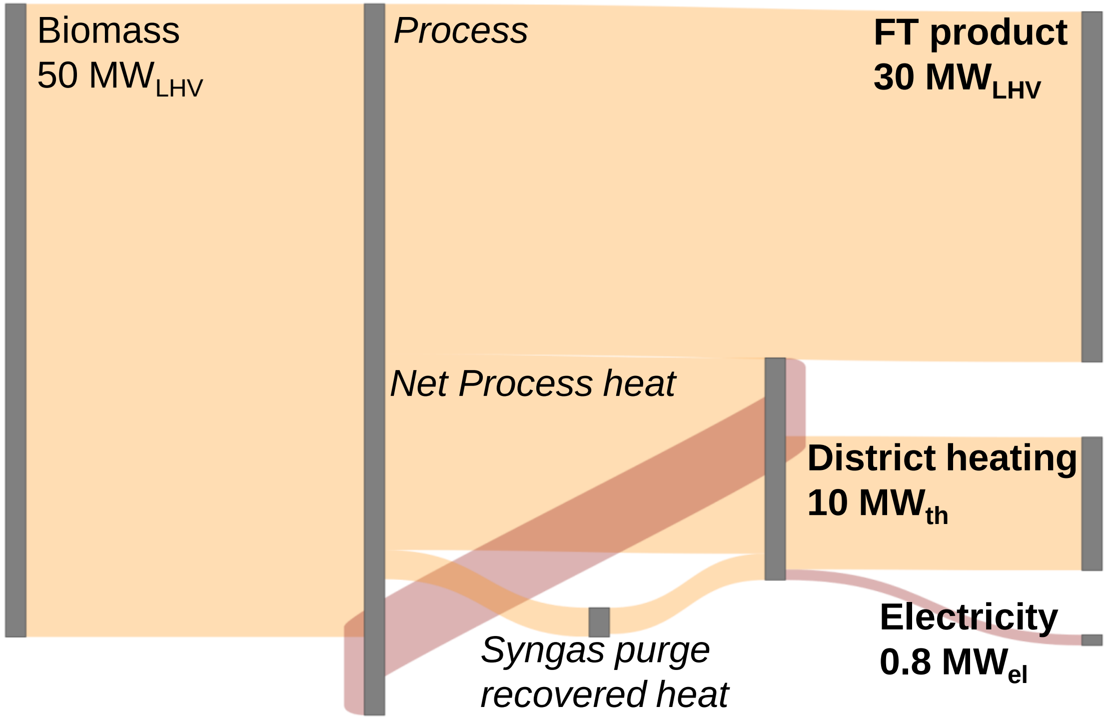
[1] Hamelinck, C. N., Faaij, A. P., den Uil, H., & Boerrigter, H. (2004). Production of FT transportation fuels from biomass; technical options, process analysis and optimisation, and development potential. *Energy*, *29*(11), 1743-1771.

[2] Buttler, A., & Spliethoff, H. (2018). Current status of water electrolysis for energy storage, grid balancing and sector coupling via power-to-gas and power-to-liquids: A review. *Renewable and Sustainable Energy Reviews*, *82*, 2440-2454.

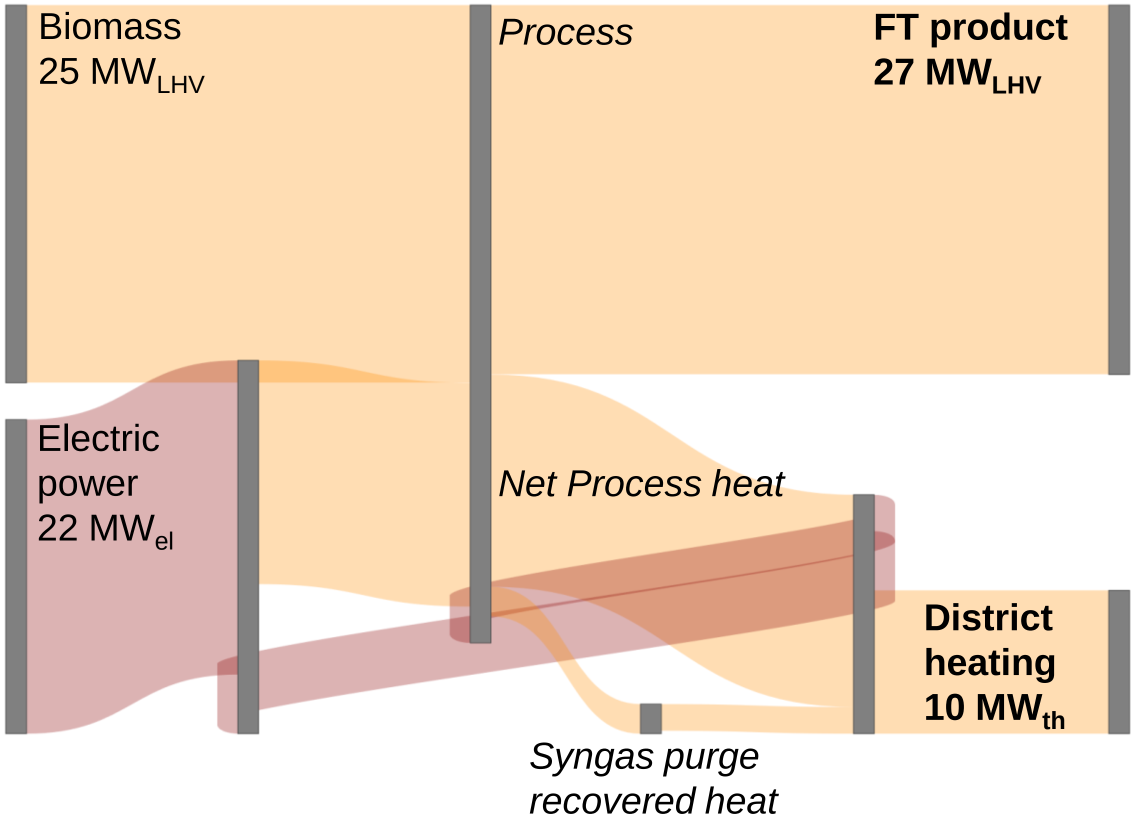
FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Simulation results: Energy efficiency

Winter Mode



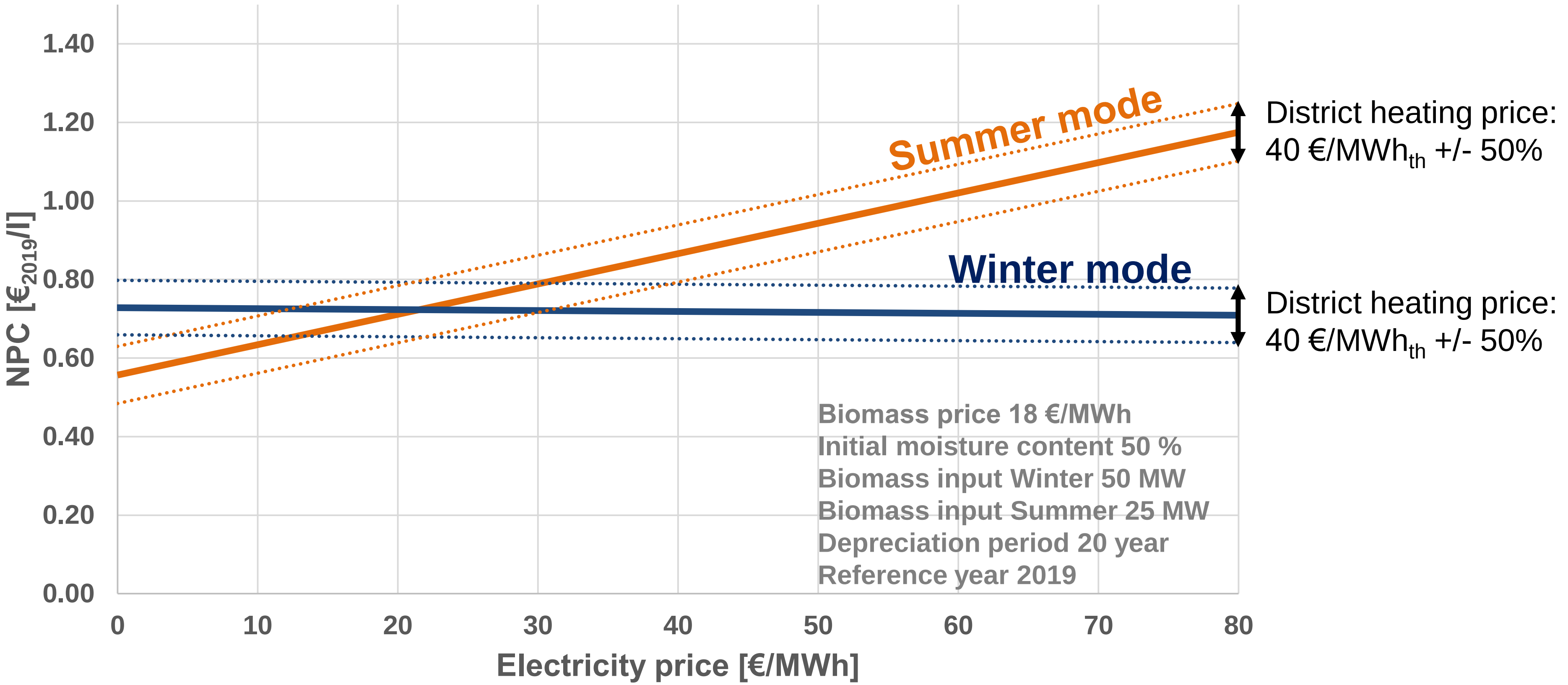
Summer Mode



→ **Fuel efficiency: ca. 60 % in Winter mode and ca. 57 % in Summer mode**

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Economic analysis glimpse for 50 MW_{LHV} biomass input FLEXCHX plant



→ **Summer mode has an economic edge at electricity costs of < 20 €/MWh_e**

Outline

A. Motivation & Project Idea

B. Techno-economic analysis

C. Life cycle assessment

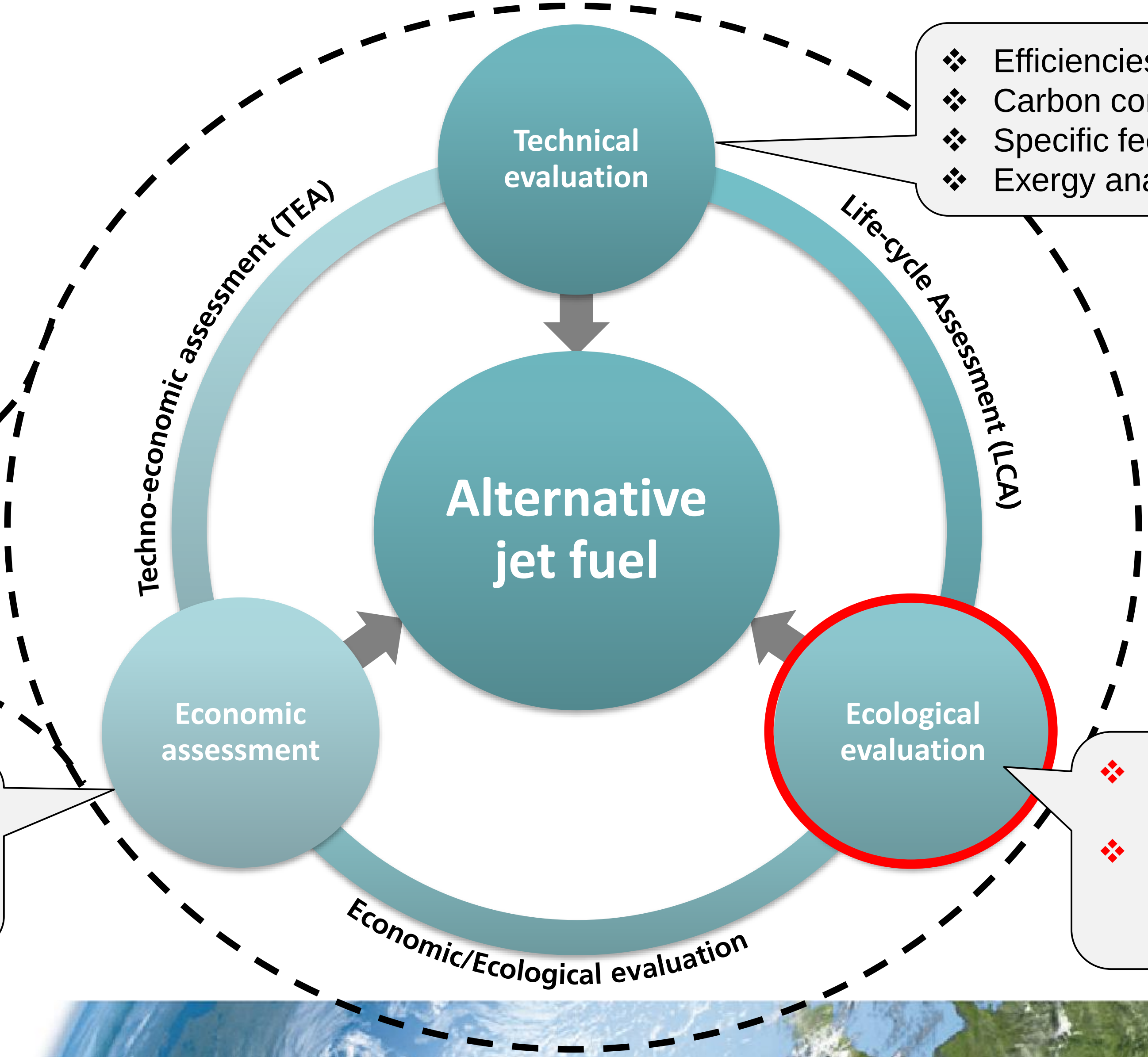
D. Conclusion & Outlook

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Techno-Economic and ecological assessment (TEEA)

- Efficiencies (X-to-Liquid, Overall)
- Carbon conversion
- Specific feedstock demand
- Exergy analysis

DLR-evaluation and optimization tool

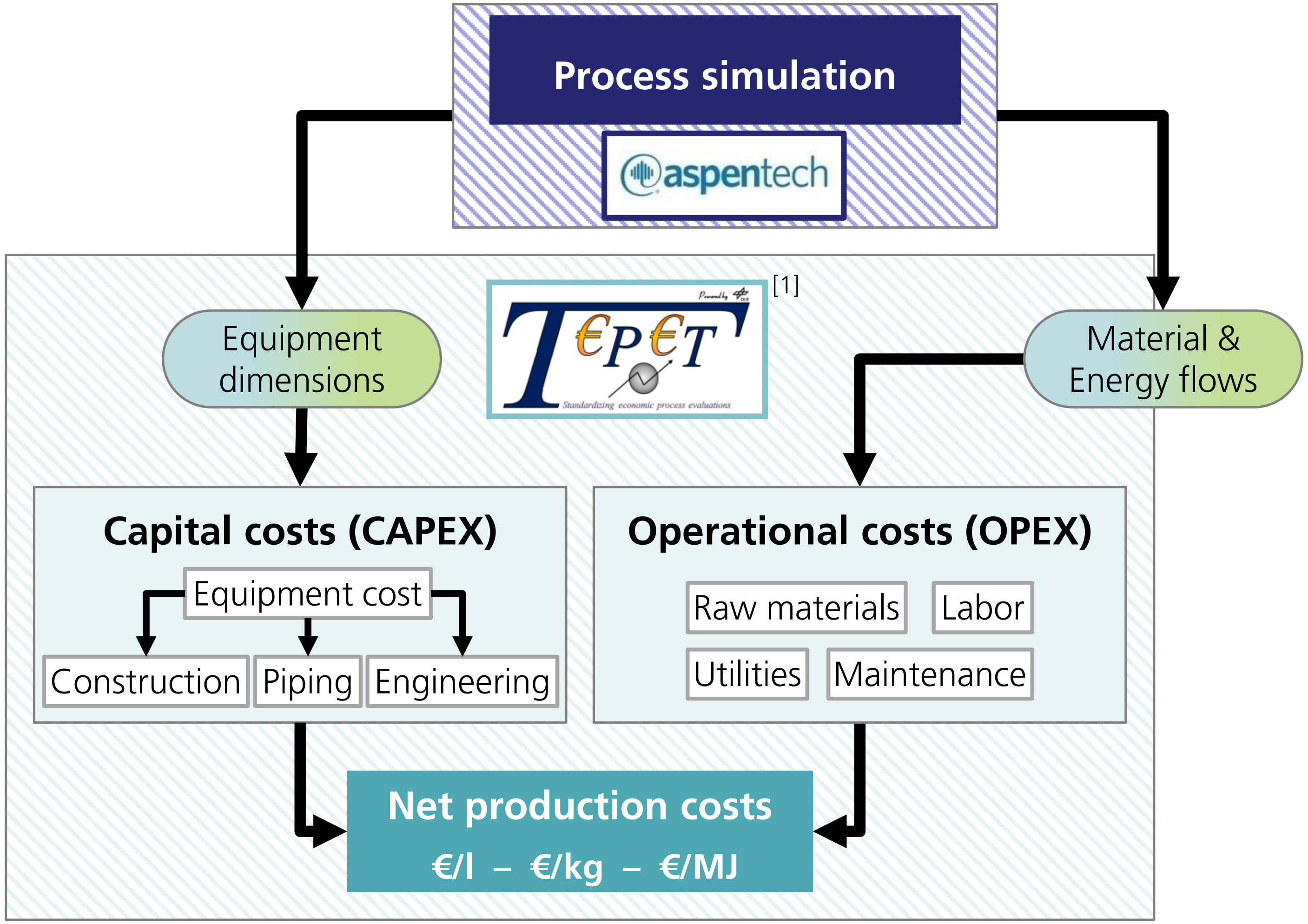


- CAPEX, OPEX, NPC
- Sensitivity analysis
- Identification of most economic feasible process design

- **Environmental impacts**
- **Identification of ecological preferable process designs**

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

LCA – Optimized integration in existing assessment system



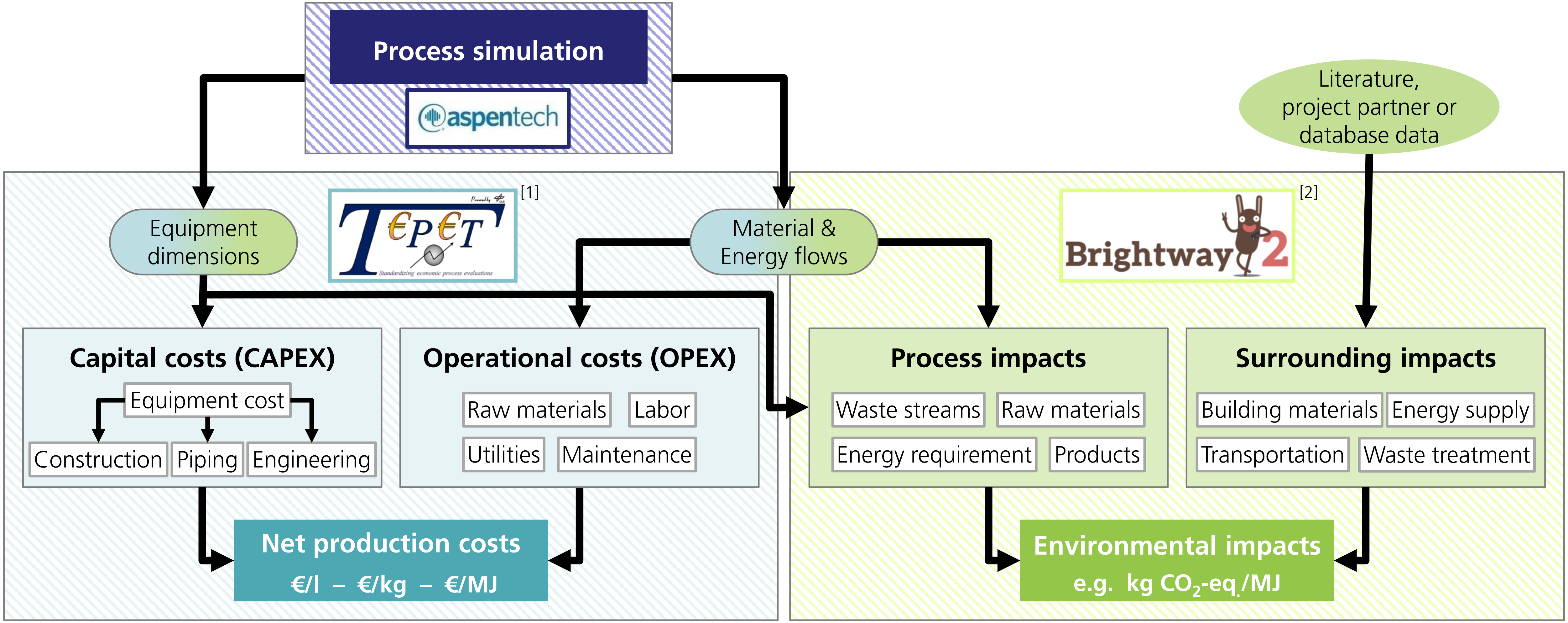
- Adapted from **best-practice chem. eng. methodology**
- Meets AACE class 3-4, Accuracy: **+/- 30 %**
- **Year specific** using annual CEPCI Index
- Automated interface for **seamless integration**
- Easy sensitivity studies for **every** parameter
- Learning curves, economy of scale, …

[1] Albrecht et al. (2016) - A standardized methodology for the techno-economic evaluation of alternative fuels – A case study, Fuel, 194: 511-526
[2] Mutel (2017) - Brightway: An open source framework for Life Cycle Assessment, Journal of Open Source Software, 2(12): 236

DLR

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

LCA – Optimized integration in existing assessment system



[1] Albrecht et al. (2016) - A standardized methodology for the techno-economic evaluation of alternative fuels – A case study, Fuel, 194: 511-526
[2] Mutel (2017) - Brightway: An open source framework for Life Cycle Assessment, Journal of Open Source Software, 2(12): 236

DLR

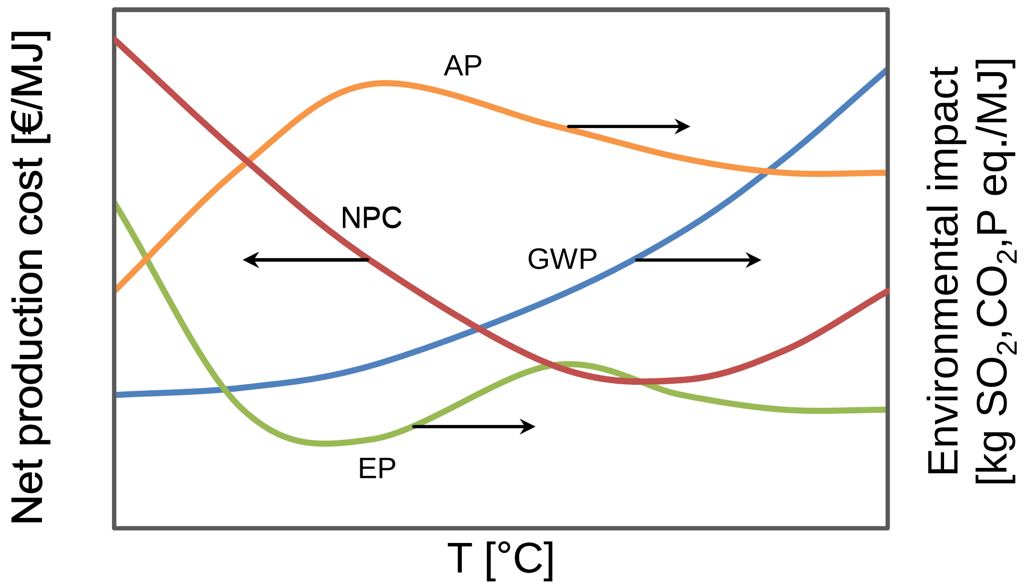
FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

Process simulation based LCA

- Environmental impact of FLEXCHX biofuel?
- Does the environmental assessment change the outlook on winter vs. summer mode?
- What is the environmentally optimized process configuration?

➢ Answers through process simulation based LCA

AP – Terrestrial acidification potential (SO_2 eq.)
GWP – Global warming potential (CO_2 eq.)
EP – Freshwater eutrophication potential (P eq.)



Schematic view of the net production cost (NPC) and environmental impacts in dependency to a particular process parameter (e.g. gasifier, reformer temperature etc.)

Outline

A. Motivation & Project Idea

B. Techno-economic analysis

C. Life cycle assessment

D. Conclusion & Outlook

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919.

National Case studies for Finland, Lithuania and Germany

Country specific market conditions: Labor cost, district heating/power market, biomass price & availability

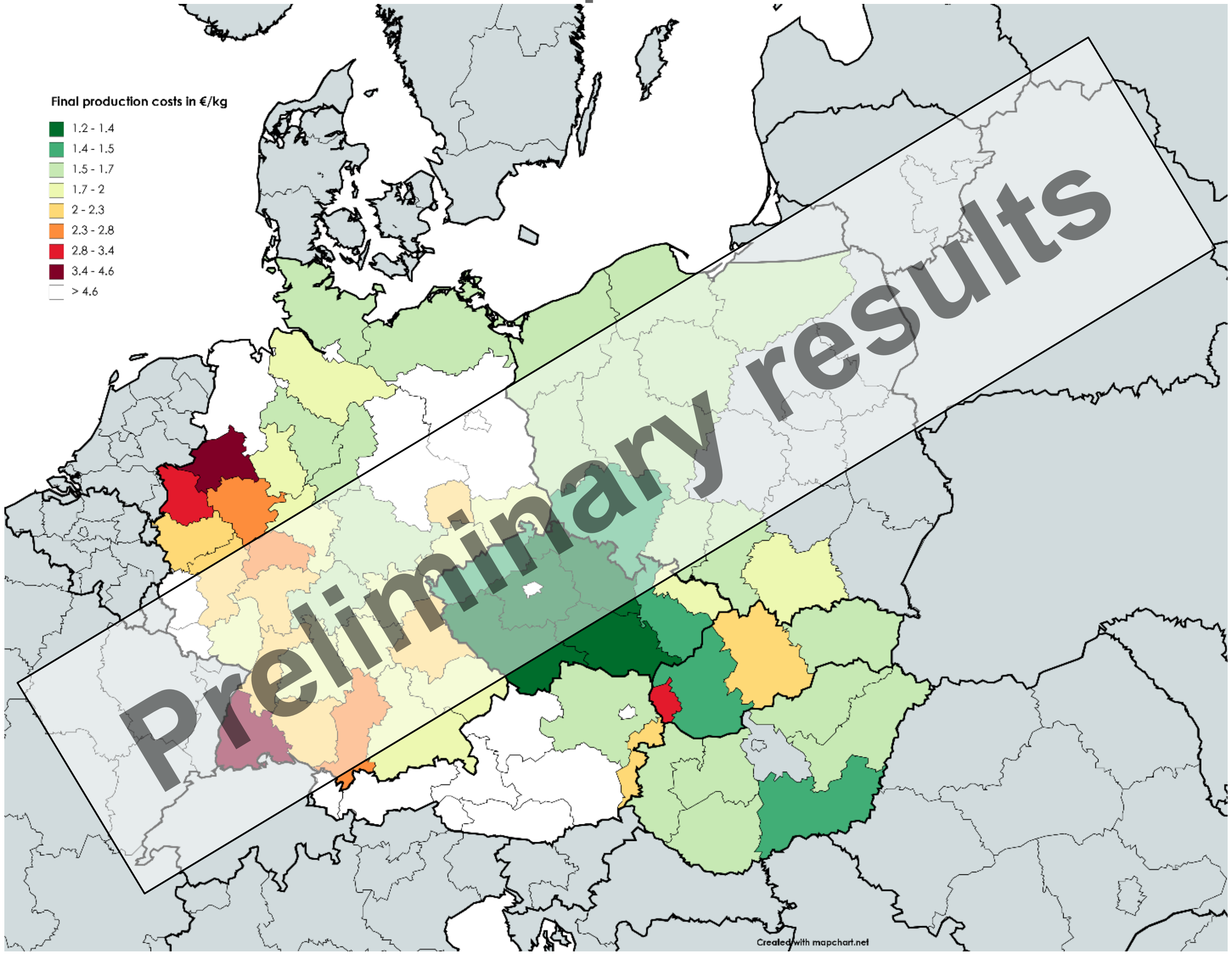
National economic feasibility studies

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

Roadmap for Central-European business case: Example COMSYN

Final production costs

- Assumptions:
  - Straw as biomass feedstock
  - Product refining at Litvinov ORLEN UniPetrol refinery
  - 20 years of plant life time
  - 10 % interest rate
  - 8260 h/a operation
  - 10 workers per shift



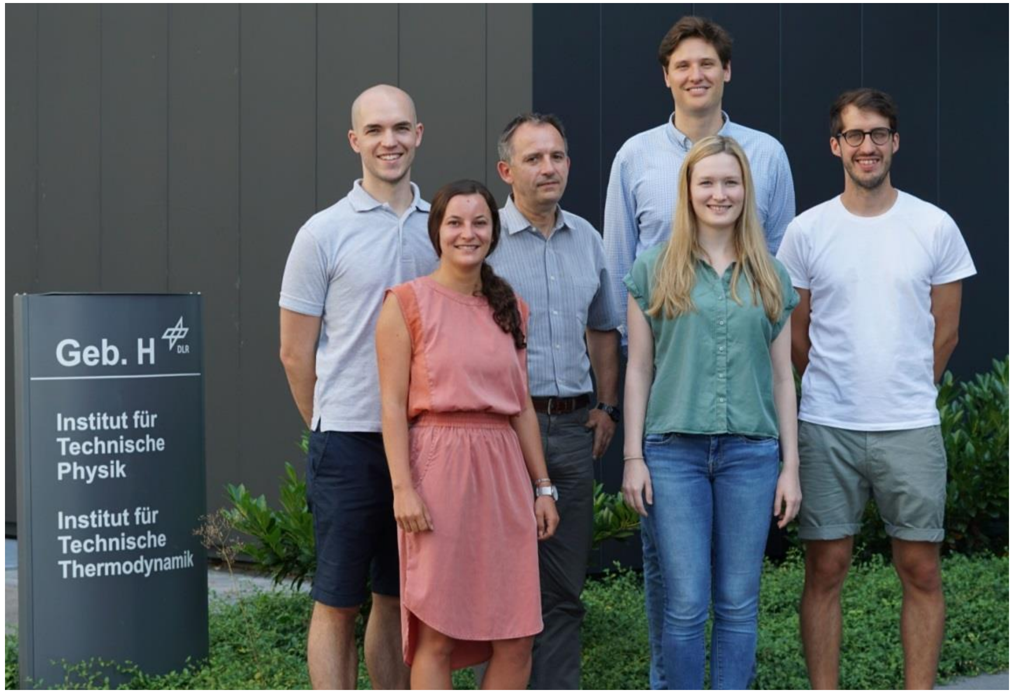
Conclusion and outlook

- The **techno-economic analysis tool TEPET** enables an automated cost+performance evaluation of multiple process configurations and operating regimes
  - Successfully applied in multiple projects
  - Standard TEA tool in the national research initiative Energiewende im Verkehr [1]
- FLEXCHX process model incorporates **unit models based on project partner's experimental data**
  - Fuel efficiency: ≈ **57 % in** Summer (25 MW) and Winter ≈ **60 %** in Winter (50 MW)
  - 50 MW plant: Summer operation mode attractive @ renewable electricity price **< 20 €/MWh**
- **TEPET tool** was extended for **automated process simulation based life cycle assessment**
- Flexible input data for **individual national case studies** provided

Outlook:

- **National case studies** for **Finland** (Helen), **Lithuania** (LEI) and **Germany** (DLR)
- **Techno-economic analysis publication**
- **LCA results publication** planned

[1] https://www.dlr.de/vf/desktopdefault.aspx/tabid-2974/1445_read-52897



THANK YOU FOR YOUR ATTENTION

German Aerospace Center (DLR)
Institute of Engineering Thermodynamics
Research Area Techno Economic Assessment

ralph-uwe.dietrich@dlr.de
http://www.dlr.de/tt/en

DLR

Compact Gasification and Synthesis for Flexible Production of Transport Fuels and Heat

Concluding Remarks

Esa Kurkela, VTT

EU 28 (EU27+UK) - energy in transport

- **Biofuels are needed in all 2050 EU scenarios**
- **First generation biofuels and HVO can not fulfill the need**
- In CIRC and 1.5 LIFE ~ 50 Mtoe
- In P2X scenario ~ 30 Mtoe
- Present use in EU:
  - traffic biofuels ~17 Mtoe/a
  - total bioenergy ~ 100 Mtoe

- 150 MW gasification BTL plant
  - 1 plant: 60 ktoe
  - **200 plants: 12 Mtoe**

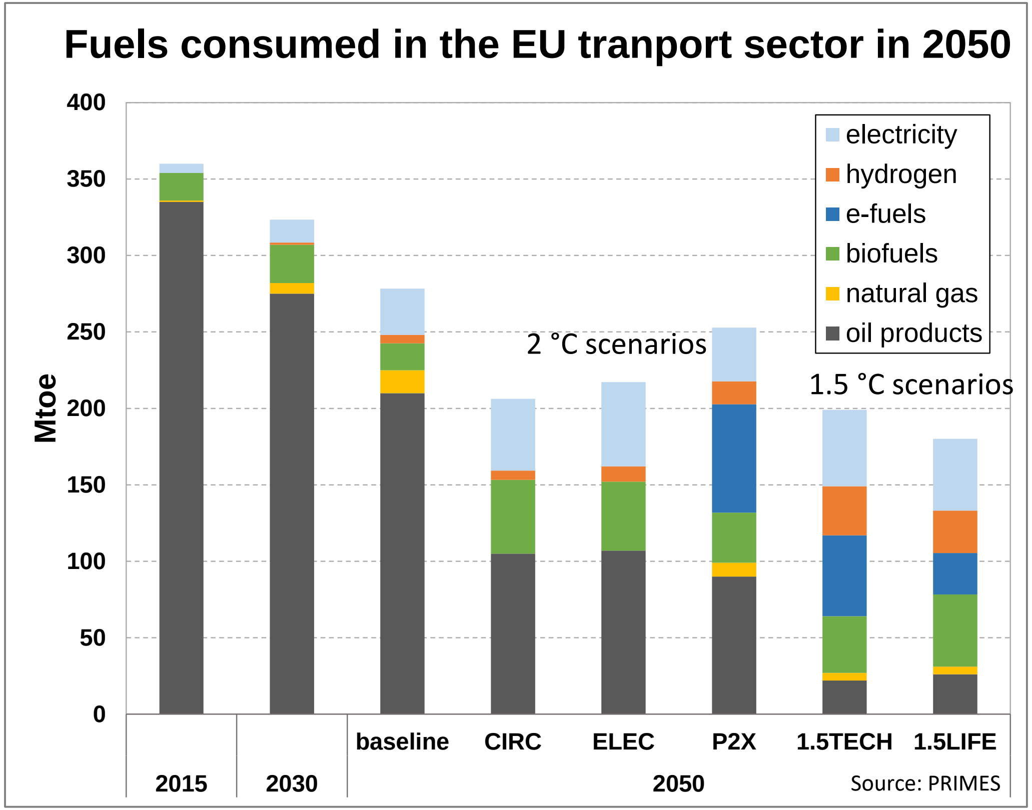
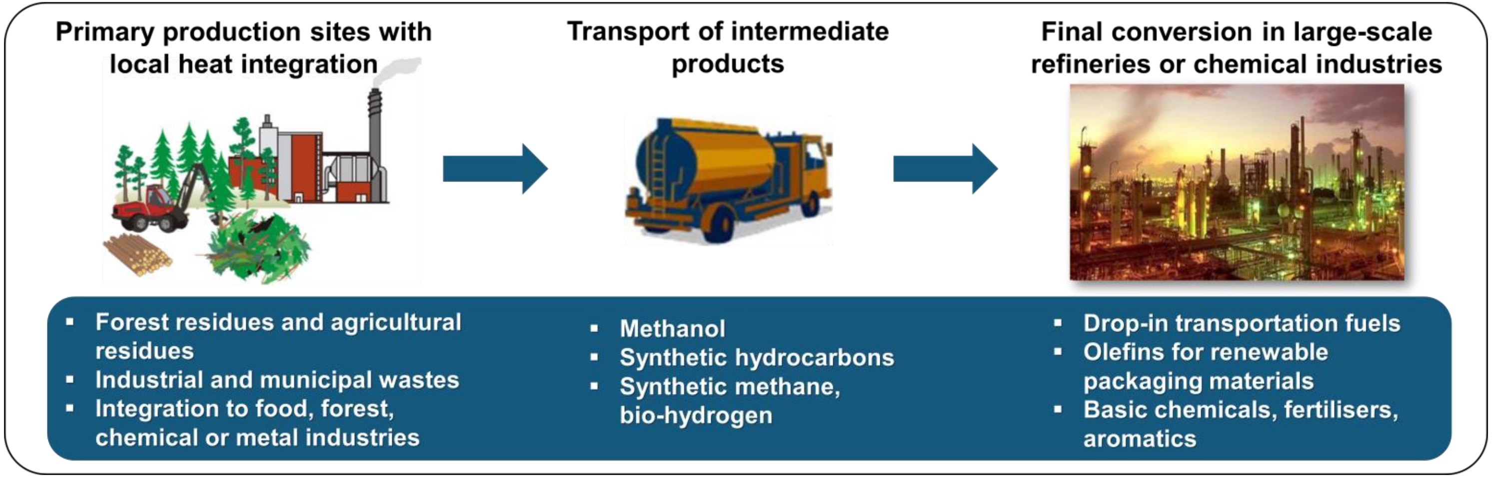


Figure made according to "EC 28.11.2018, In-depth analysis in support of the Commission Communication COM(2018) 773"

Two gasification technologies have been developed to TRL5 enabling double integration in synthetic fuels production
- looking for partners to realize technology demonstration



PRIMARY CONVERSION

- Distributed production of FT sync rude at small-to-medium scale gasification/synthesis units located **close to biomass resources**
- **Integrated to local district heating networks or heat-consuming industries** (> 75-80 % overall eff.)

FINAL CONVERSION

- **Final refining** of FT products into drop-in transportation liquids takes place in **existing oil refineries**
- **Advantages:** benefits from economies of scale, product portfolio can be tailored according to market demand

Thank you for attending our webinar!

Now we have time to answer to a few of your questions presented in the chat!

These projects have received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919 FLEXCHX and No 727476 COMSYN.

https://www.comsynproject.eu/
http://www.flexchx.eu/index.htm

Lapland, Finland