Pyrolysis of Residual Biomass via Thermo-Catalytic Reforming – H2020 ToSynFuel

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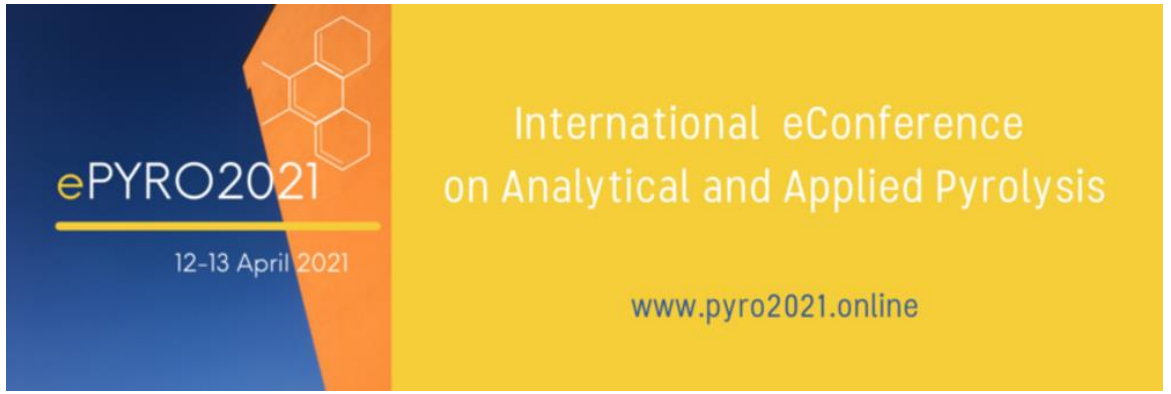

13. April 2021 ZOOM

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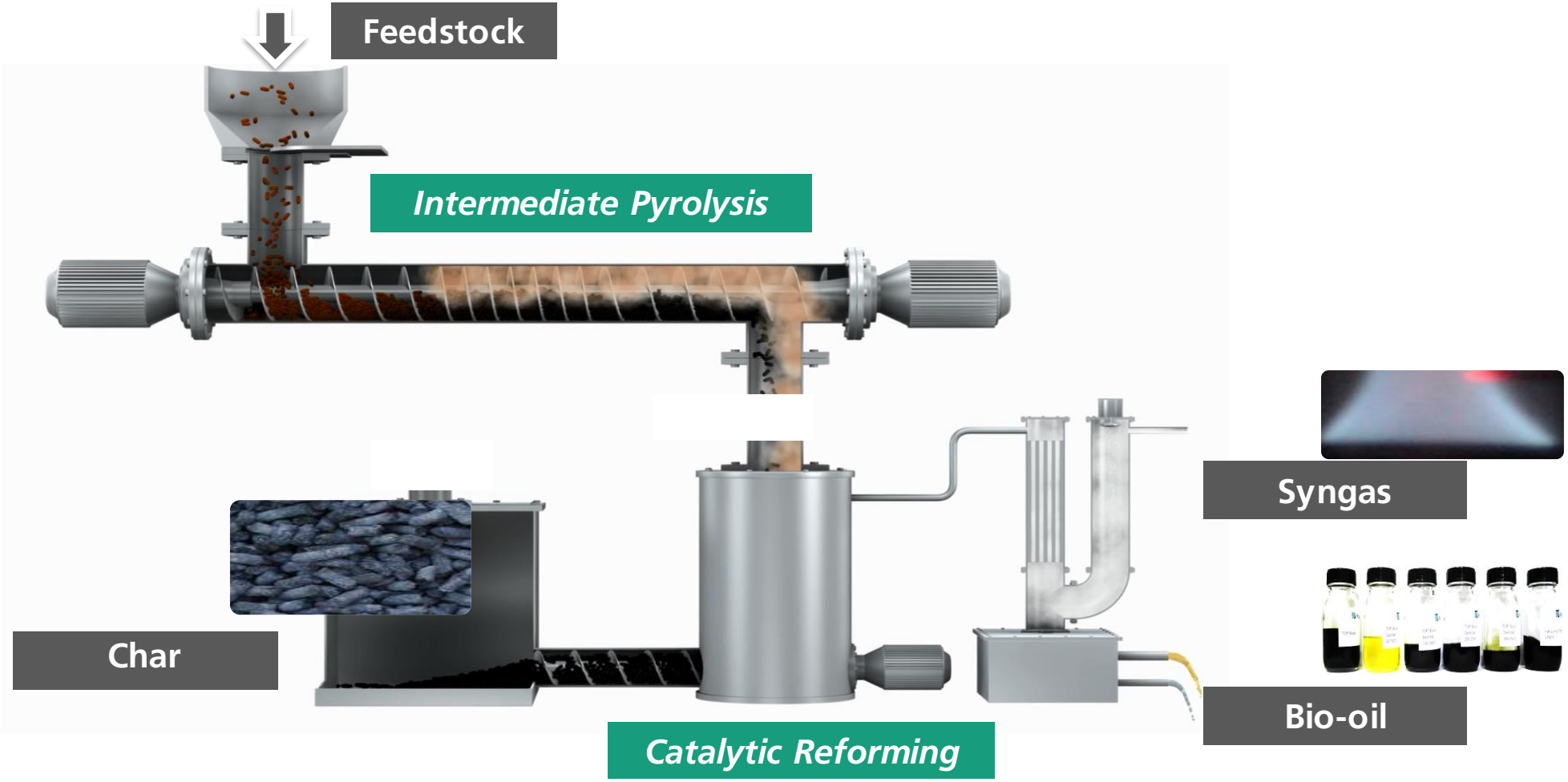
Conversion of sewage sludge

The Thermo-Catalytic Reforming (TCR®) technology



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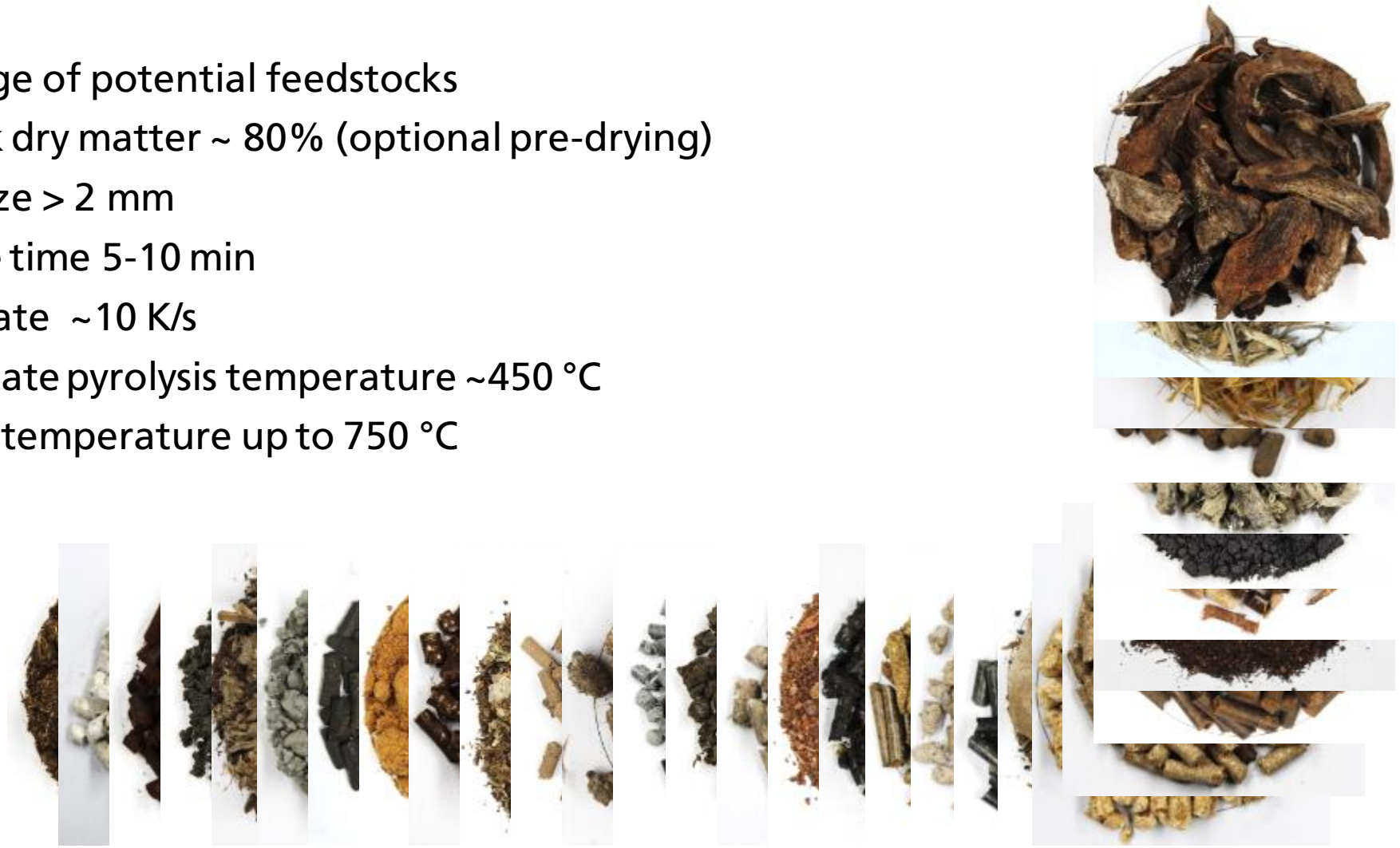
The Thermo-Catalytic Reforming technology

Process parameters

- Wide range of potential feedstocks
- Feedstock dry matter ~ 80% (optional pre-drying)
- Particle size > 2 mm
- Residence time 5-10 min
- Heating rate ~10 K/s
- Intermediate pyrolysis temperature ~450 °C
- Reformer temperature up to 750 °C



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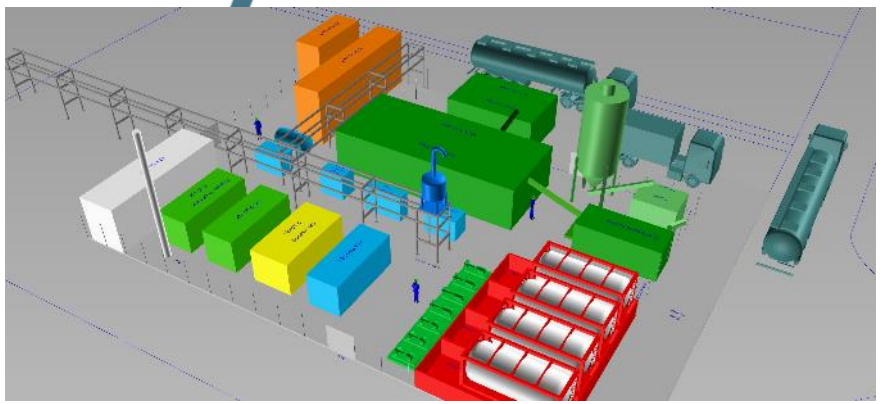
EU H2020 Project: TO-SYN-FUEL: Turning Sewage Sludge into Fuels and Hydrogen

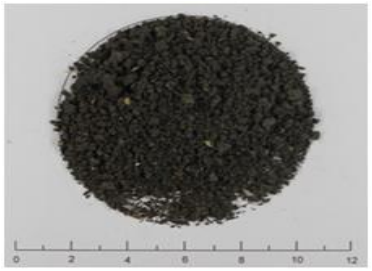


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grand agreement No 745749.

TO-SYN-FUEL

The Demonstration of Waste Biomass to Synthetic EN Conform Fuels and Green Hydrogen

- Contribute to the Renewable Energy Directive targets for renewable energy by validating waste feedstocks for the production of fuels
- Production of green hydrogen, diesel and gasoline equivalent liquid fuels from sewage sludge



- Showcase for future sustainable investment and economic growth across Europe
- Development of a business case, LCA and dissemination of results

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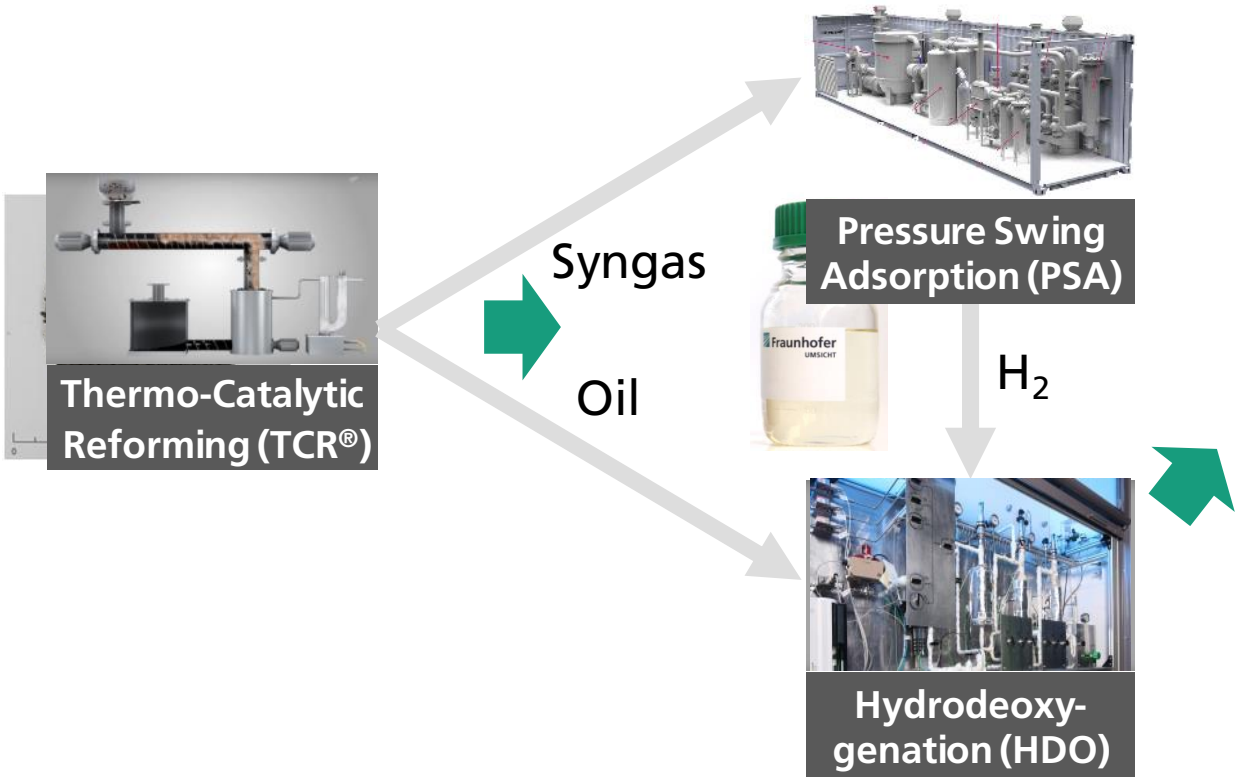
TO-SYN-FUEL
Core components



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Thermo-Catalytic Reforming TCR®

Bio-oil from sewage sludge

High quality, engine-ready

LHV: ≈34 MJ/kg

C	83.7 wt. %
H	9.0 wt. %
N	2.1 wt. %
S	0.9 wt. %
O (diff.)	3.7 wt. %
H_2O	0.6 wt. %
TAN	0.6 mg KOH/g
Ash	< 0.005 wt.%

- Thermal stable
- Low in O;S;N
- Low water content
- High heating value

→ Excellent Precursor for Hydrotreatment

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Thermo-Catalytic Reforming TCR®

Syngas from sewage sludge

Engine-ready gas

HHV:
≈14-18 MJ/m³

H_2	38 ± 3 v/v%
CO	8 ± 2 v/v%
CO_2	30 ± 3 v/v%
CH_4	14 ± 2 v/v%
C_xH_y	3 ± 1 v/v%

High Hydrogen Content Essential for Hydrogen Separation by PSA

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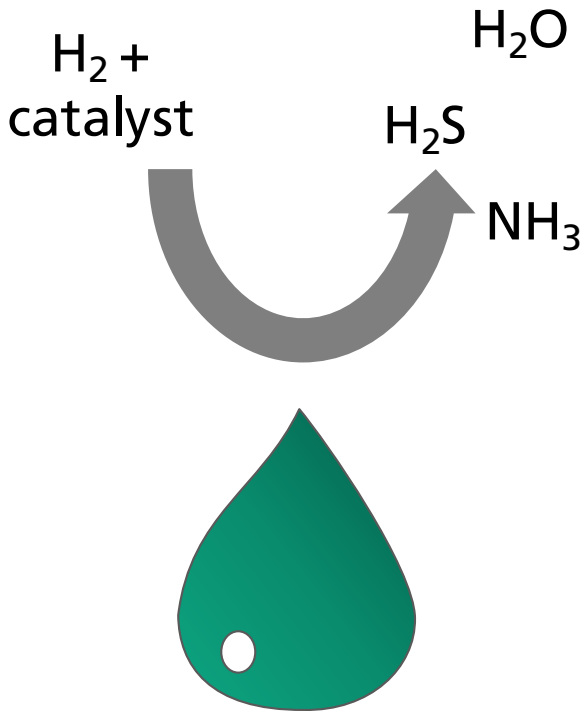
Upgrading of TCR® bio-oil for renewable fuels

Hydrotreating of TCR® bio-oil

TCR® bio-oil



260-400 °C up to 200 bar

thermal stability required!

Hydrotreated TCR® bio-oil (HBO)

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Upgrading of TCR® bio-oil for renewable fuels

Hydrotreating of TCR® oil

TCR® BIO-OIL

C	83.7 wt%
H	9.0 wt%
N	2.1 wt%
S	0.9 wt%
O (diff.)	3.7 wt%
H_2O	0.6 wt%
Ash	< 0.005 wt%

LHV	34.0 MJ/kg
TAN	0.6 mg KOH/g
Viscosity	4.4 mm²/s
Density	1014.4 kg/m³

HYDROTREATING

HYDROTREATED TCR® BIO-OIL (HBO)

C	86.2 wt%
H	13.0 wt%
N^x	0.5 - 0.0 wt%
S^x	< 0.01 wt%
O^x (diff.)	0.7 - 0.0 wt%
H_2O	0.003 wt%
Ash	< 0.005 wt%

LHV	42.25 MJ/kg
TAN	< 0.1 mg KOH/g
Viscosity	0.97 mm²/s
Density	815 kg/m³
Flash point	< - 20 °C
Yield	83 wt%

^{x}: Depending on P, T

Neumann, J.; Jäger, N.; Apfelbacher, A.; Daschner, R.; Binder, S.; Hornung: Biomass and Bioenergy, 2016

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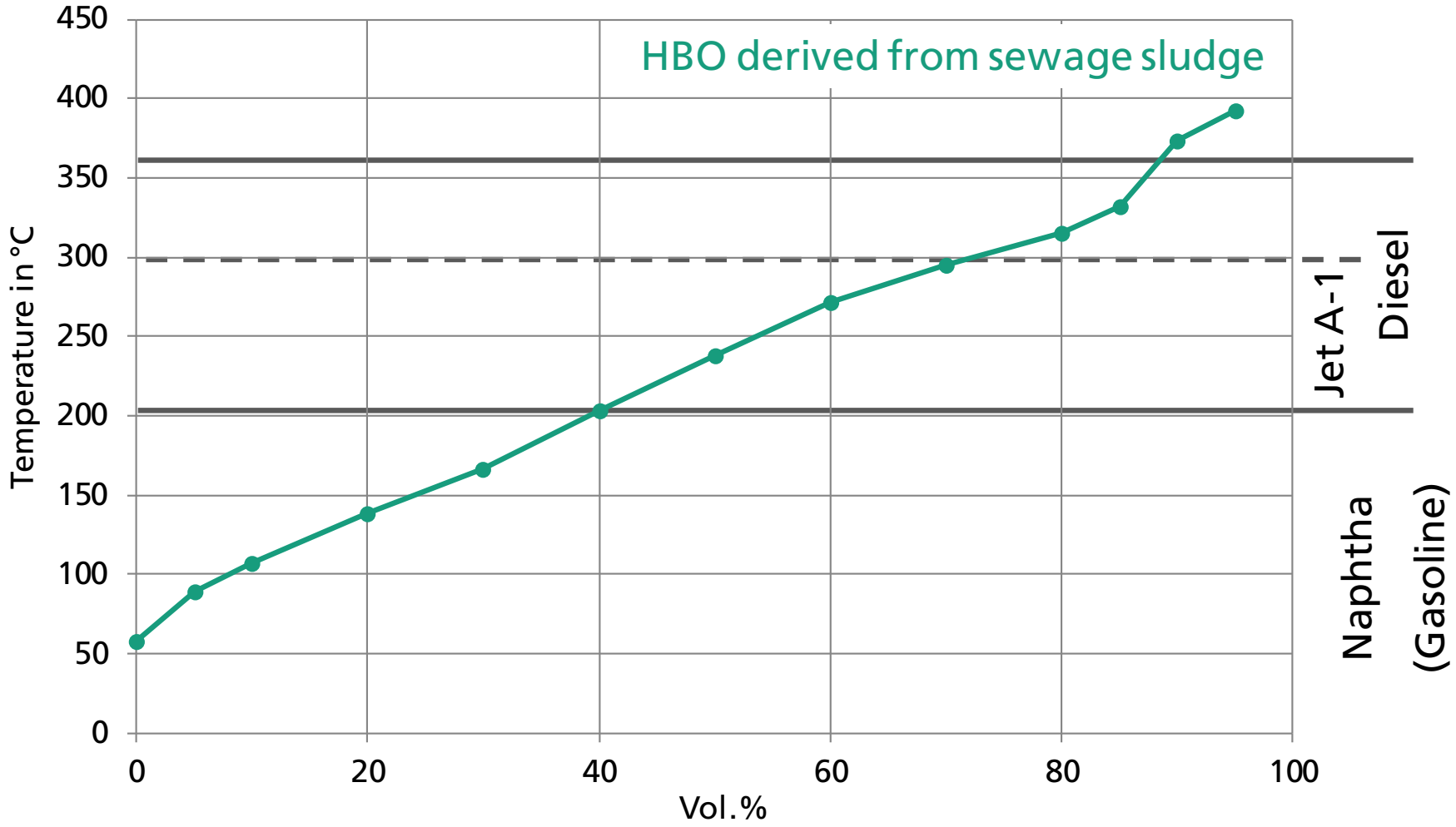
Refining of TCR® bio-oil for renewable fuels

Distillation of hydrotreated TCR® bio-oil



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Refining of TCR® bio-oil for renewable fuels

Renewable TCR® naphtha from sewage sludge

Gasoline standard EN 228				
min	max	Property	Unit	HDO TCR® naphtha
720	775	Density	kg/m³	✓
-	5	Evaporation residue	mg/100ml	✓
-	35	Aromates	% (V/V)	✓
-	18	Olefines	% (V/V)	✓
-	1	Benzol	% (V/V)	✓ 1.5*
-	10	Sulfur	mg/kg	✓
-	5	Lead	mg/l	✓
-	2	Manganese	mg/l	✓
-	2,7	Oxygen	% (m/m)	✓
20	50	E70	% (V/V)	✓ **
46	71	E100	% (V/V)	✓
75	-	E150	% (V/V)	✓
-	210	End of Boiling Point	°C	✓
-	2	Distillation residue	% (V/V)	✓
45	90	Vapour pressure DVPE	kPa	✓ **

* Achievable by an adjustment of the hydrotreating

** Lack of light boilers due to laboratory distillation without cryocooler

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Refining of TCR® bio-oil for renewable fuels

Renewable TCR® diesel from sewage sludge

Diesel standard EN 590 min	Diesel standard EN 590 max	Property	Unit	HDO TCR® diesel	
51	-	Cetane Number		✓	
46	-	Cetane Index		✓	
820	845	Density at 15 °C	kg/m³	✓	
-	8	PAH	% (m/m)	✓	
-	10	Sulfur	mg/kg	✓	15 *
55	-	Flash point	°C	✓	
-	0,01	Ash content	% (m/m)	✓	
-	200	Water content	mg/kg	✓	
Class 1	Class 1	Copper strip corrosion (3 hours at 50 °C)	Class	✓	
-	460	Lubricity at 60 °C	µm	✓	
2	4,5	Viscosity at 40 °C	mm^2/s	✓	
-20 (Winter)	0 (Summer)	CFPP	°C	✓	
-	< 65	Volume at 250 °C	%V/V	✓	
85	-	Volume at 350 °C	%V/V	✓	
-	360	95 %(V/V) recovered at	°C	✓	

* Achievable by an adjustment of the hydrotreating

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Thermo-Catalytic Reforming TCR®

Carbonisate from sewage sludge

Very low H and O content

HHV:
≈10.5 MJ/kg

C	33.5 wt.%
H	0.1 wt.%
N	3.5 wt.%
S	0.7 wt. %
O (diff.)	<2 wt. %
H_20	<1 wt. %
Ash	62 wt. %

Ash: P, Na, K, Mg, ...

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Thermo-Catalytic Reforming TCR®

Phosphorous recovery from TCR-char

Gasification of char:

- Additional H_2 : Overall process produces more H_2 than required for HDO
- Recovery of Phosphorous out of gasification ash better
- Additional energy for process heat.
- Gasification of TCR char is technically tar free

TCR char and gasifier ash

Updraft gasifier at UMSICHT (cheap, no tar)

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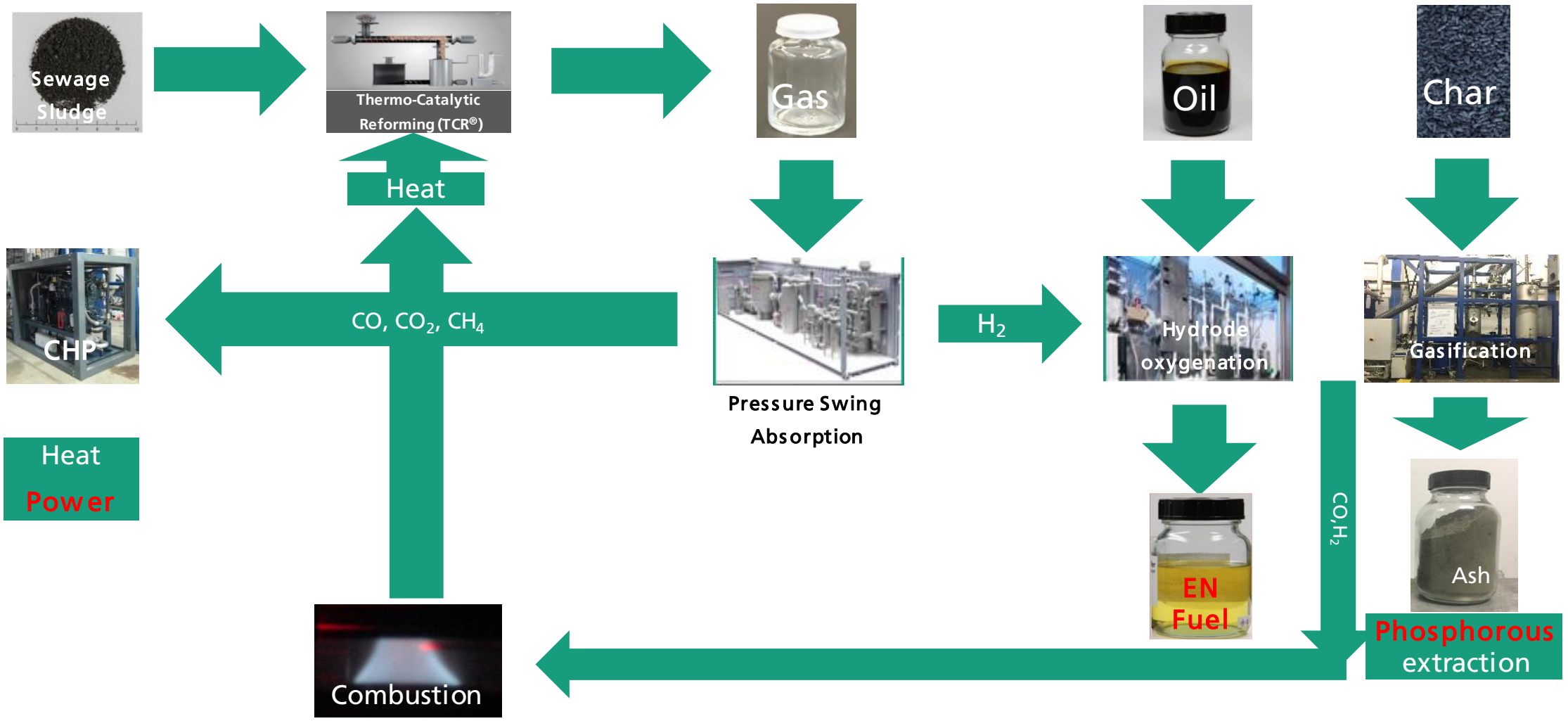
TO-SYN-FUEL:
In a nutshell



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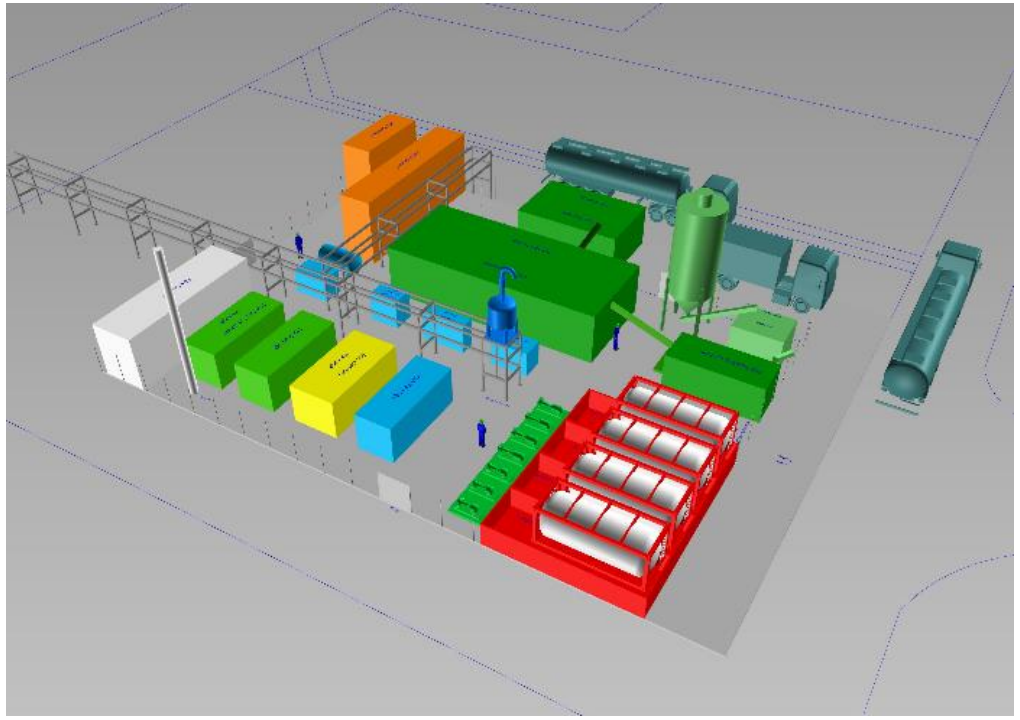
TO-SYN-FUEL
Next steps

- Construction phase — Q1/2018
- Commissioning phase — Q1/2020 –Q2/2021
- Demonstration phase — Q2/2021-2022
  - 5000 h of operation
  - 500 kg/h of sewage sludge
  - 200 t of HDO liquid fuels



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Conclusion

- Successful utilization of sewage sludge
  - Production of renewable fuels
- High product qualities
  - TCR® bio-oil as renewable crude oil
  - TCR® gas rich in hydrogen
  - TCR® char for gasification
- TCR® bio-oil highlights
  - Thermally stable (atmospheric distillation)
  - Directly suitable for hydrotreating
  - Renewable gasoline and diesel
  - Drop-in biofuel for petroleum refineries

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Pyrolysis of Residual Biomass via Thermo-Catalytic Reforming – Experimental Investigation of Sewage Sludge

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