Thermo-Catalytic Reforming (TCR®) in demonstration scale – Experiences from scale up

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30 May 2019

Lisboa

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Agenda

- Motivation
- TCR®-Technology
- Development: LabScale | PilotScale | IndustrialScale
- Conclusion

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Motivation

Biogenic residues

Green energy and green fuel from residues and waste

- Bringing the TCR® technology to market
- Utilization of biogenic and industrial residues (like digestate, sewage sludge, paper mill residue etc.)
- Green energy with high CO_2-reduction

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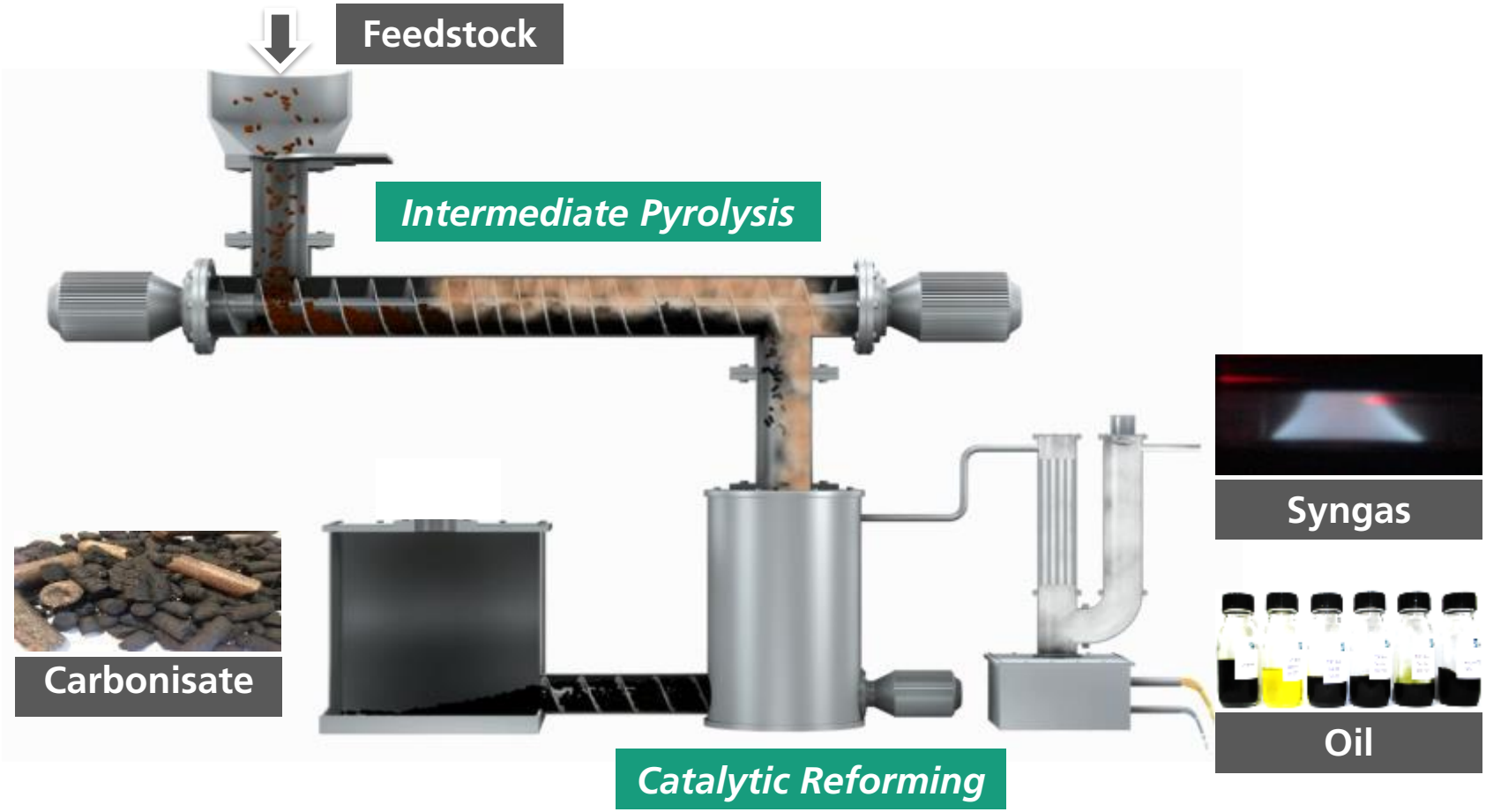
Thermo-Catalytic Reforming TCR®

A platform technology to use residues and to produce storable energy carriers



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Thermo-Catalytic Reforming TCR®

Exemplary analytics of products for sewage sludge

SEWAGE SLUDGE

C	26,2 m%
H	4,3 m%
N	3,7 m%
S	0,6 m%
O (Diff.)	27,3 m%
Ash	37,9 m%
H_2O	10,7 m%
LHV	12,2 MJ/kg

EDUCT

BIO-OIL

C	77,0 m%
H	7,08 m%
N	8,53 m%
S	1,02 m%
O (Diff.)	6,3 m%
TAN	4,45 mg KOH/g
LHV	33,8 MJ/kg

PRODUCTS

SYNGAS

H_2	39 v/v%
CO	10 v/v%
CO_2	22 v/v%
CH_4	8,7 ± 1 v/v%
C_xH_y	1,5 ± 1 v/v%
LHV	17,7 MJ/m³

CARBONISATE

C	23,8 m%
H	0,7 m%
N	1,9 m%
S	0,7 m%
O (Diff.)	1,2 m%
Ash	74,1 m%
LHV	9,0 MJ/kg

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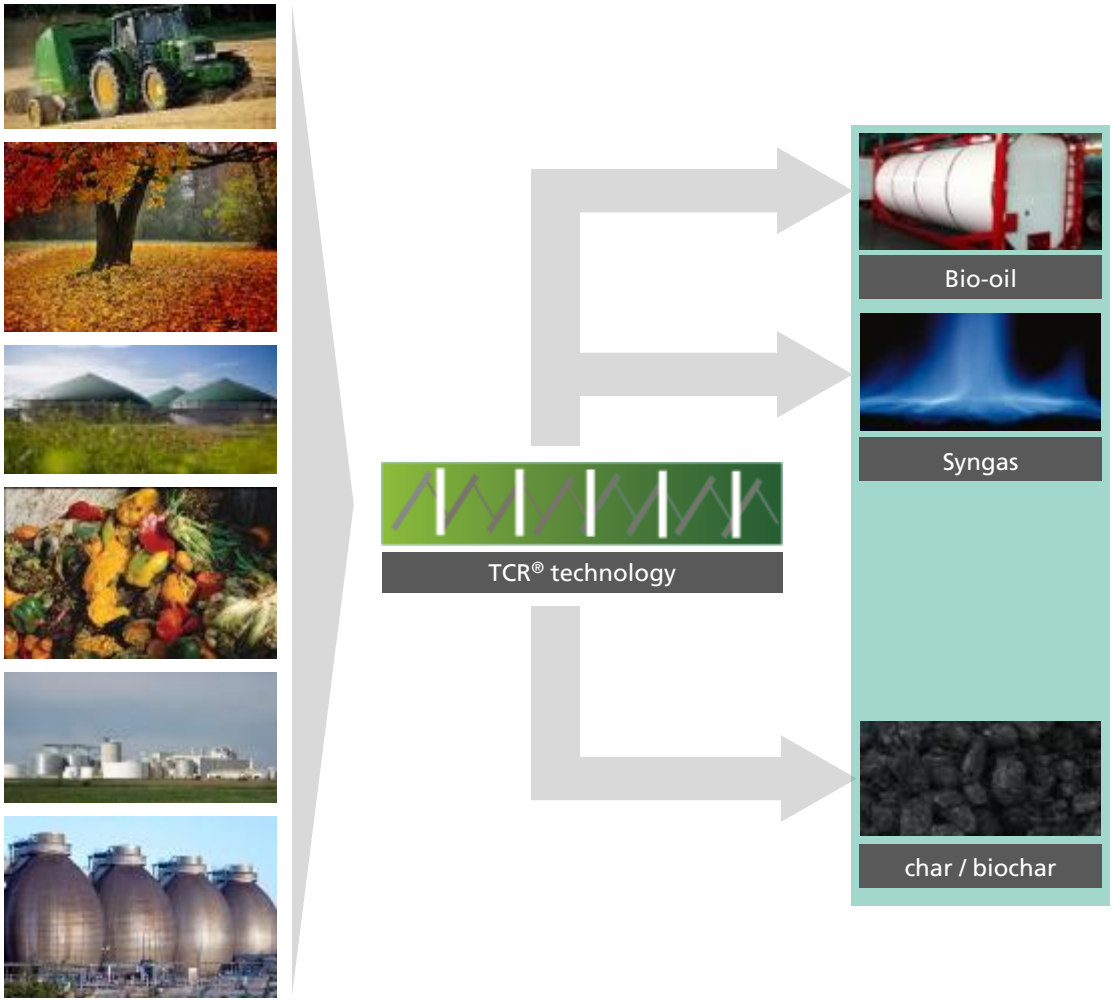
Thermo-Catalytic Reforming TCR®

Various applications – Bio-oil



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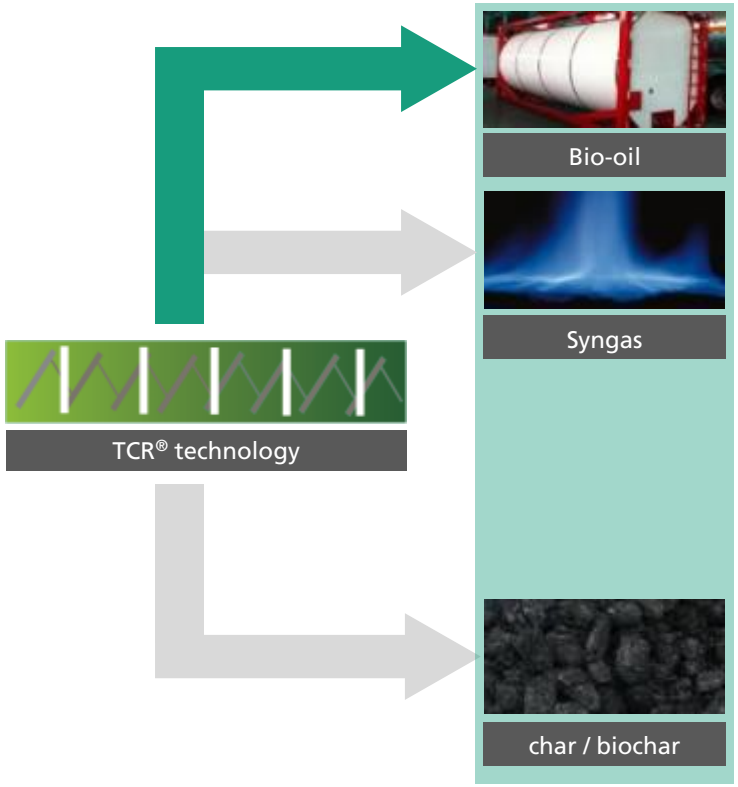
Thermo-Catalytic Reforming TCR®

Various applications – Bio-oil



Unique quality

- Low acid number
- High calorific value
- Miscible with common fuels
- Thermal stability
- Low Viscosity

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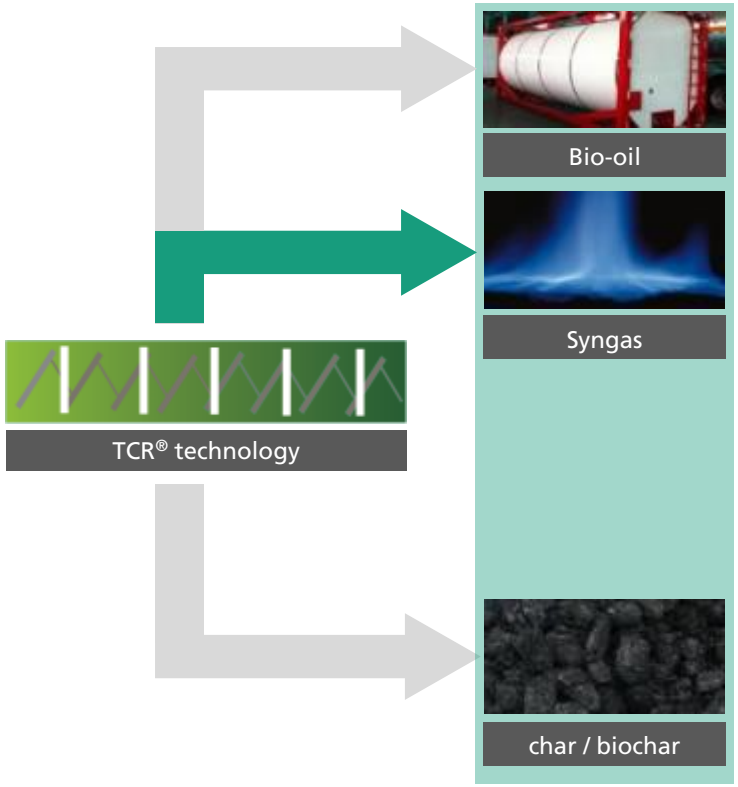
Thermo-Catalytic Reforming TCR®

Various applications – Syngas



Engine-ready gas

- Tar and dust free syngas
- Direct suitable for engines
- High hydrogen content
- Free of aromatic-compounds

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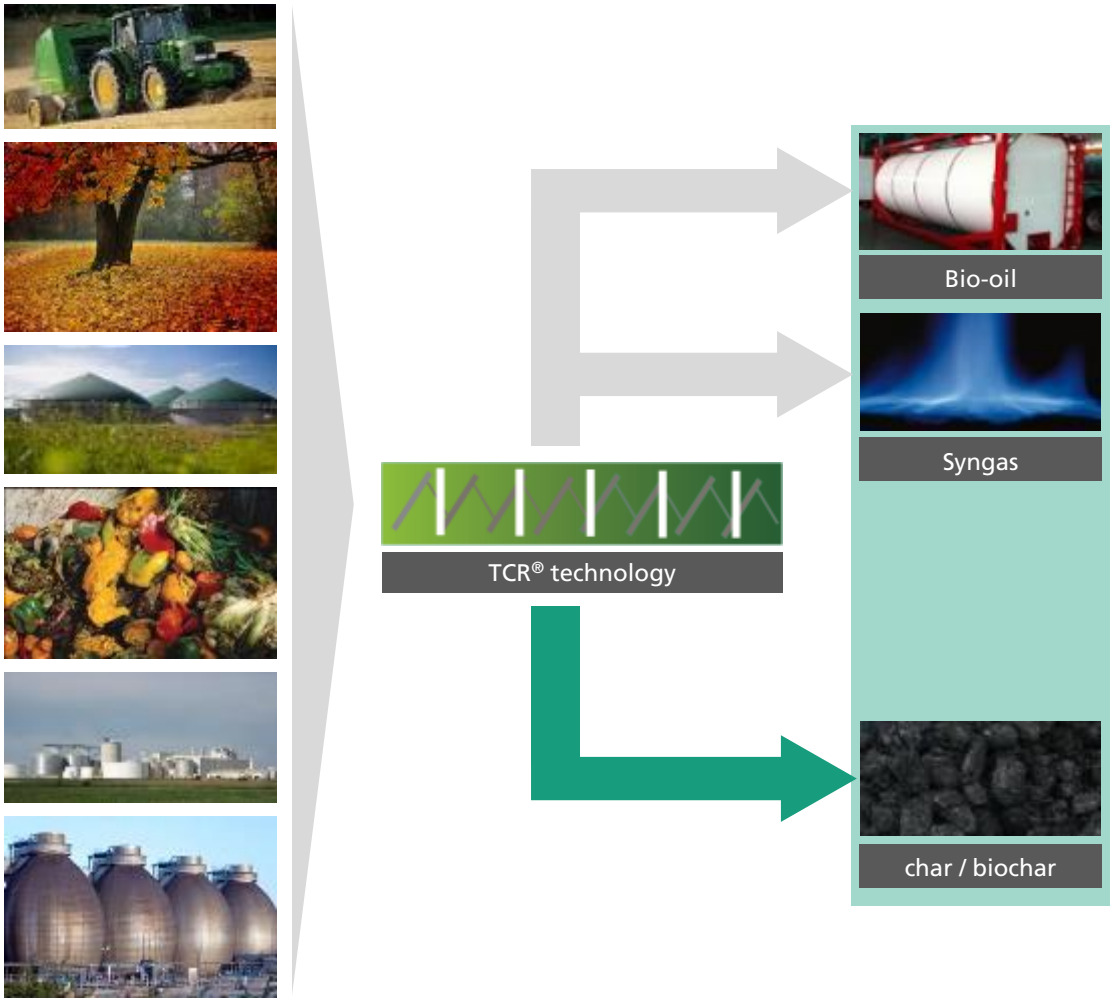
Thermo-Catalytic Reforming TCR®

Various applications – Char



Anthrazitic-like, storable biochar

- Very low H and O content
- High calorific value
- High soil stability
- Significant ash content

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Thermo-Catalytic Reforming TCR®

Level of development: 2013

TCR2

Lab unit

Operational capacity: 2 kg/h

Heat Source: electrical

Purpose: initial feasability testing of materials

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Thermo-Catalytic Reforming TCR®

Level of development: 2014

TCR2
Lab unit

Scale Up x15

TCR30
Pilot unit
Operational capacity: 30 kg/h
Heat Source: electrical
Purpose: long duration and CHP testing

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Thermo-Catalytic Reforming TCR®

Level of development: 2017

TCR300

Demonstration

Operational capacity: 300 kg/h

Heat Source: flue gas

Purpose: scale-up, sludge treatment

Scale Up x10

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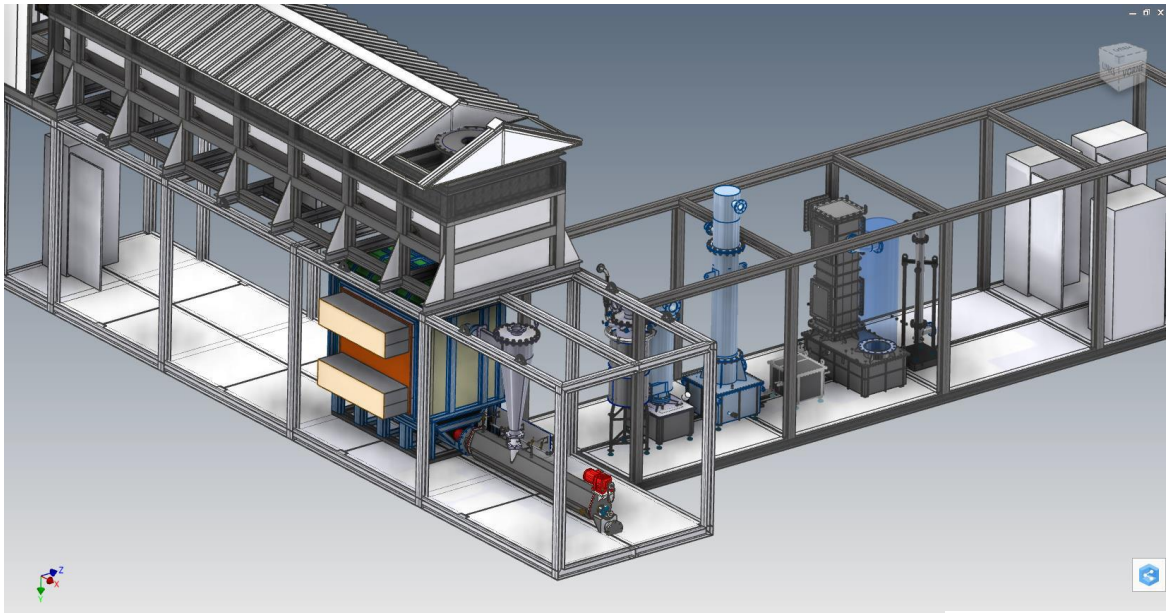
Thermo-Catalytic Reforming TCR®

Level of development – today

Scale Up x2



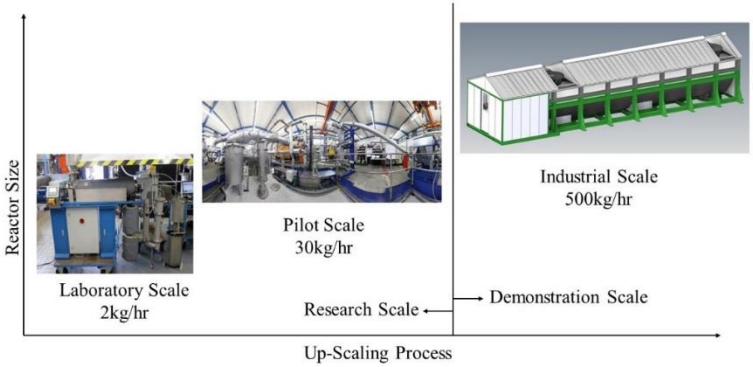
TCR500

Long-term demonstrator

Operational capacity: 500 kg/h

Heat Source: flue gas

Purpose: pre-commercial demonstrator



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TCR-Technology
High potential for biogenic wastes

- High potential of feedstocks
- Decentral application, Smaler plants can be applied: 3.000…25.000 $Mg*a^{-1}$
- Short logistic chains
- Nutrients can be recycled by biochar chain
- > 70 different feedstocks tested so far

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Facts and results on upscale

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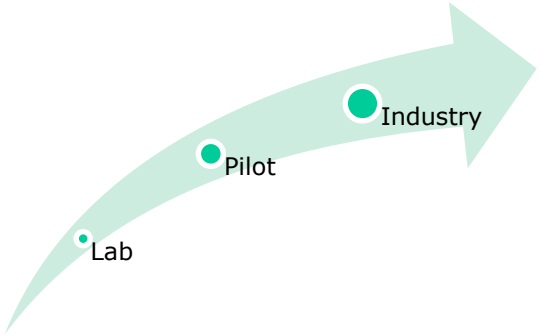
Up-Scaling of the TCR® Technology

Comparison of main parameters

	TCR2	TCR30	TCR300
Volume:			
Reactor	0,0053 m³	0,0540 m³	1,5 m3
Reformer	0,0071 m³	0,0475 m³	0,97 m3
Residence time reactor	7 min	10 min	10 min
Capacity	2 kg/h	30 kg/h	300 kg/h



Experiences and lessons learnd on the way:

- teething problems occurred mainly in auxiliary equipment and have been solved
- functionality approved
- various test campaigns on sewage sludge successful
- continuous and stable operation

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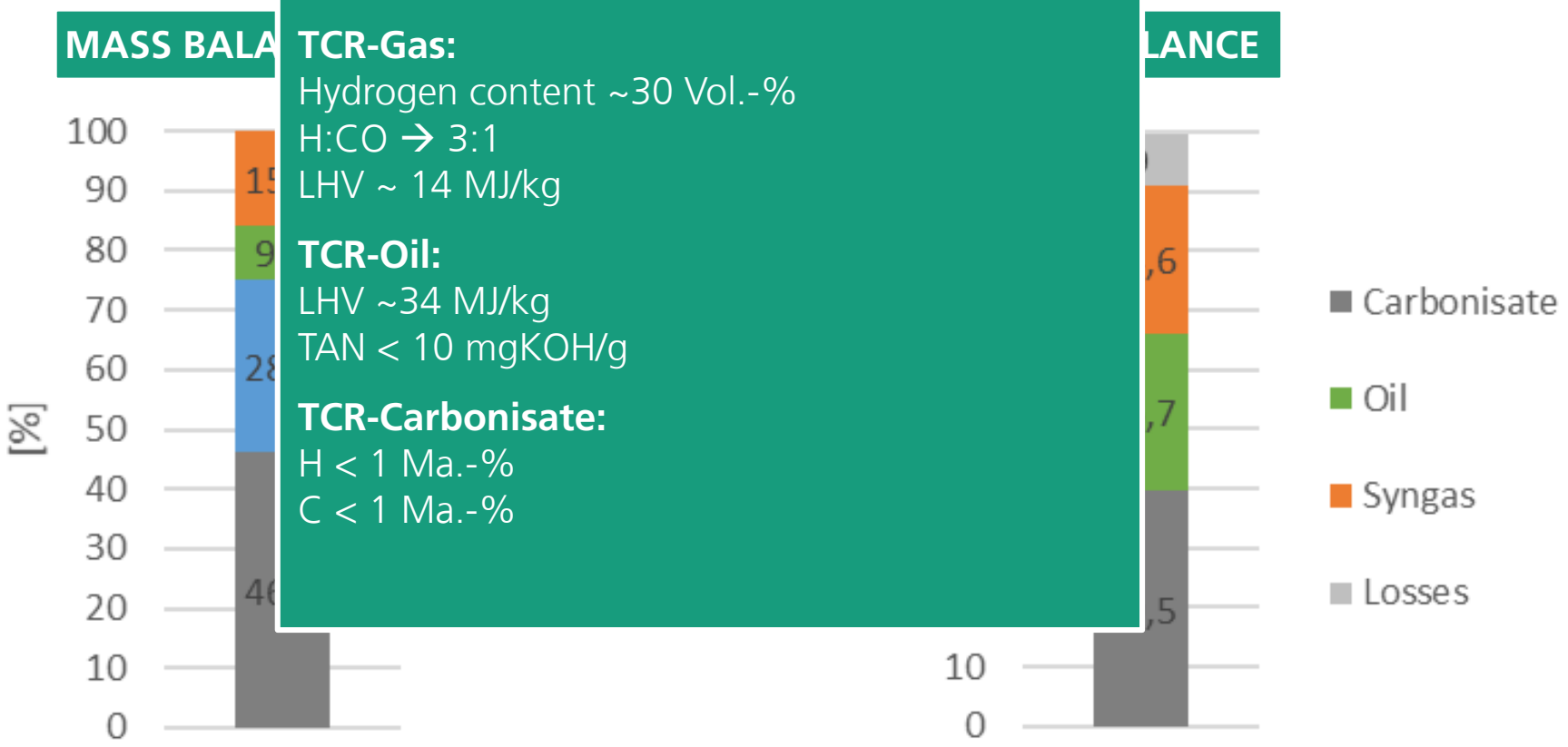
Up-Scaling of the TCR® Technology

Energy and mass balance for sewage sludge



Results from TCR300-trials – highlights

TCR-Gas:
Hydrogen content ~30 Vol.-%
H:CO → 3:1
LHV ~ 14 MJ/kg

TCR-Oil:
LHV ~34 MJ/kg
TAN < 10 mgKOH/g

TCR-Carbonisate:
H < 1 Ma.-%
C < 1 Ma.-%

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Product application
Hydrodeoxygenation (HDO)

BIO-OIL

C	79.6 wt%
H	9.9 wt%
N	7.0 wt%
S	0.5 wt%
O (diff.)	2.9 wt%
H_2O	1.3 wt%
Ash	< 0.005 wt%

LHV	34.3 MJ/kg
TAN	2.7 mg KOH/g

HYDROTREATING

HYDROTREATED BIO-OIL (HBO)

C	86.1 wt%
H	14.6 wt%
N	< 0.55 wt%
S	< 0.03 wt%
O (diff.)	< 0.1 wt%
H_2O	0.03 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%

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Product application

Pre-commercial demonstrator within ToSynFuel-project

Former rally world champion **Walter Röhrl** at ground breaking ceremony

Visit „ToSynFuel“ at the exhibition

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Conclusion

- **Up scale of TCR® from lab scale to pre-commercial scale**
  - Core components approved (TCR300)
  - Upscale from TCR2 – TCR30 – TCR300
    → delivers analog results and qualities & quantities
  - Auxiliary equipment: teething problem solved
  - Lessons learned for long-term demonstrator within ToSynFuel (TCR500)

- **Generation of several 1,000 l of bio crude with TCR300**
  - Upgrade to standard fuel approved (HDO)

- **Goal: TCR-Crude oil as drop-In fuel in refineries**

- **Next step: commercial application**

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Thermo-Catalytic Reforming (TCR®) process in commercial scale – scale up from pilot to industrial scale

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Centre for Energy Storage

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