

# Foresight applied to energy

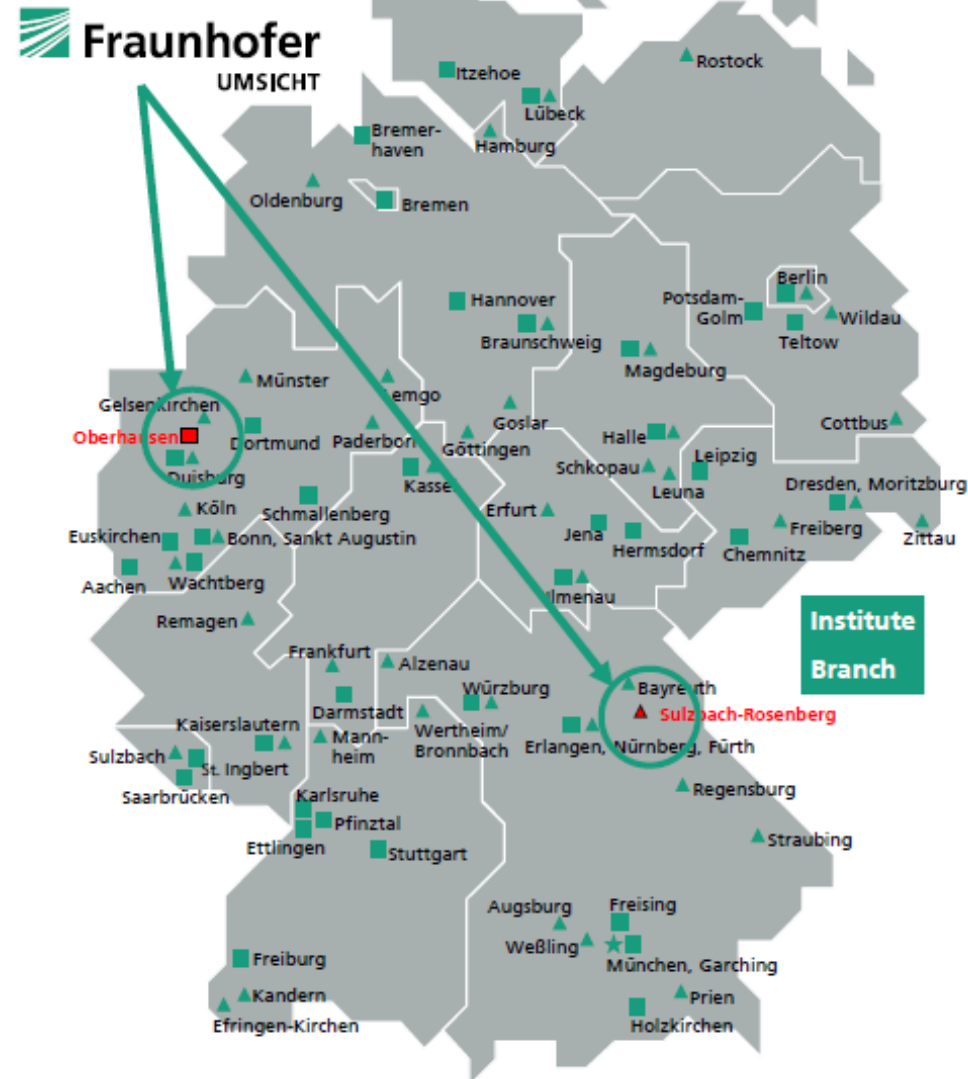
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## TO-SYN-FUEL

The Demonstration of Waste Biomass to  
Synthetic Fuels and Green Hydrogen

# The Fraunhofer-Gesellschaft

- 67 institutes and independent research facilities
- About 24 000 employees
- More than € 2 bn research funds
- Number 15 of German patent applicants<sup>1</sup>
- Spin-Offs are supported



<sup>1</sup> Source: Annual report 2014, Deutsches Patent- und Markenamt  
(Number 1: Robert Bosch GmbH, Number 2: Schaeffler Technologies GmbH & Co. KG 3: Siemens AG).

# Facts and Data about Fraunhofer UMSICHT

## Sites Oberhausen and Sulzbach-Rosenberg

Head of Fraunhofer UMSICHT Oberhausen: Prof. Dr.-Ing. Eckhard Weidner  
Head of Institute Branch Sulzbach-Rosenberg: Prof. Dr. Andreas Hornung

|                                             |                        |
|---------------------------------------------|------------------------|
| ■ Foundation                                | 1990                   |
| ■ Budget 2015                               | € 39,1 m               |
| ■ Staff*                                    | 489                    |
| ■ Spin-off enterprises*                     | 12                     |
| ■ Institute branch<br>in Sulzbach-Rosenberg | integrated 1 July 2012 |

Site Oberhausen

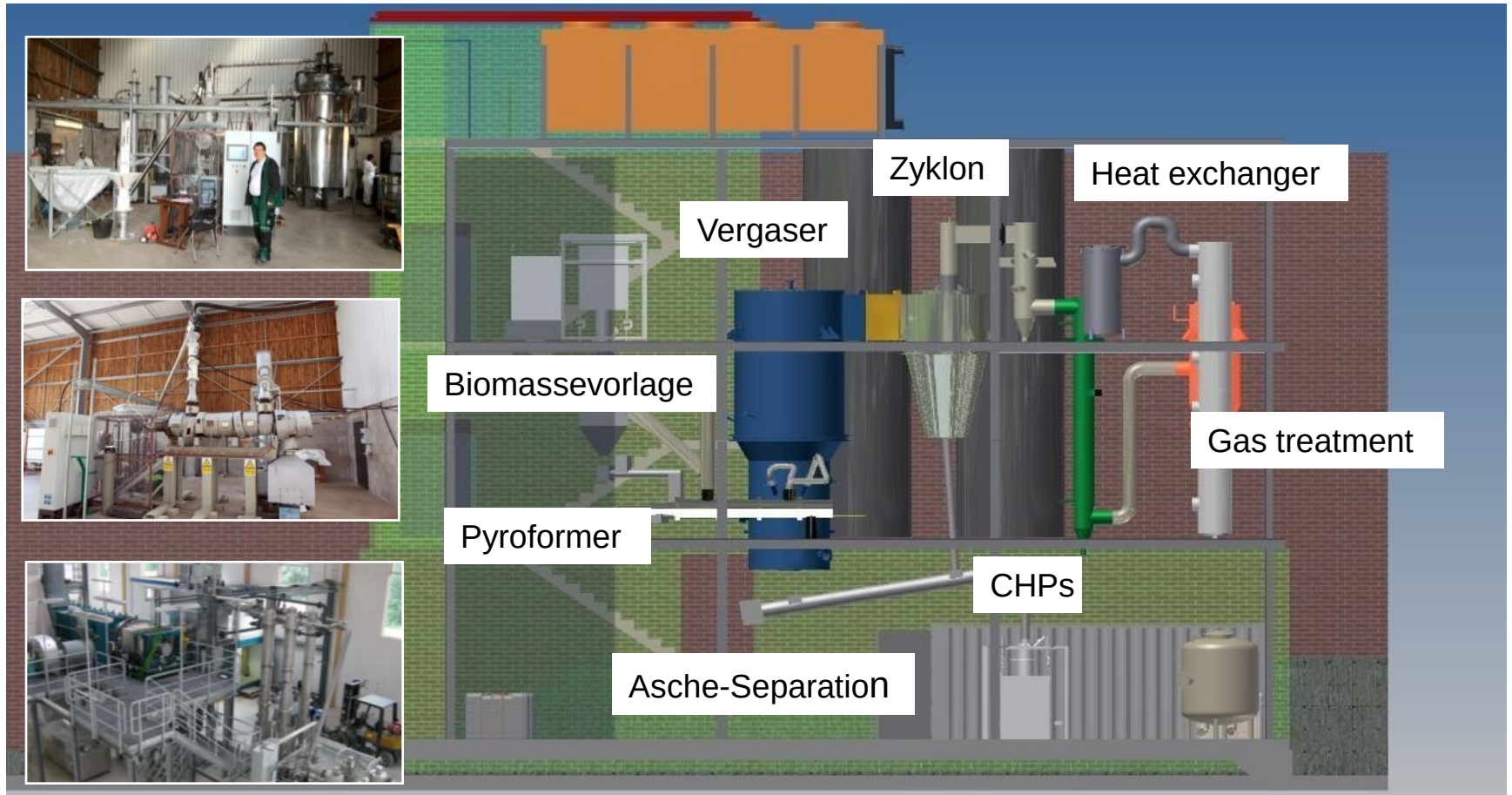


Site Sulzbach-Rosenberg



\*As per 12-31-2015

# Installation of the unit at Aston University in EBRI Birmingham - Haloclean 400 KW<sub>el</sub>



# Haloclean - technical pilot demonstration







Systan Technologies

sustainable effluents  
www.systan.co.uk

BOC  
13.2kg  
E233

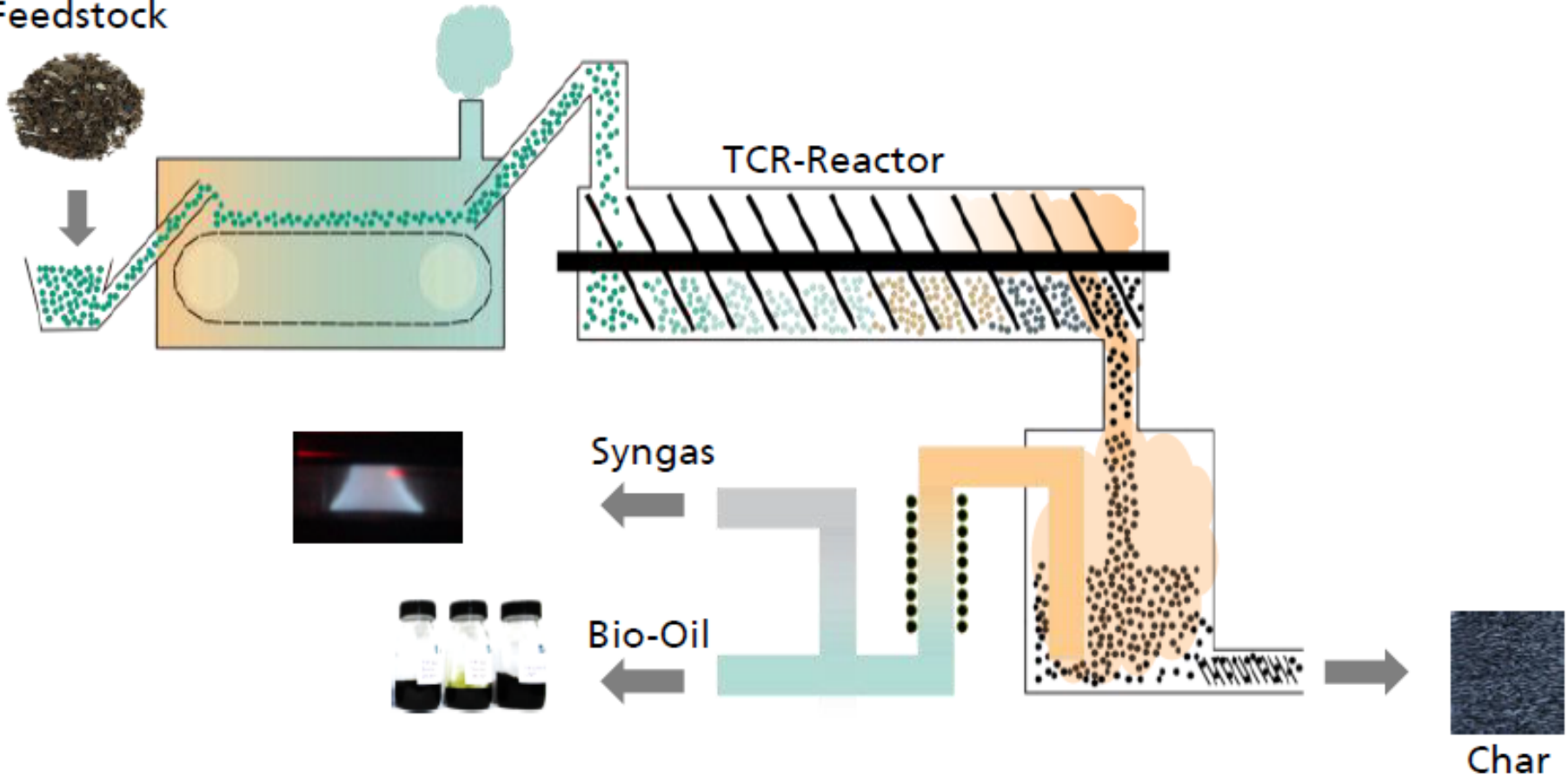
# Project Overview - Motivation

- Greater use of renewable energy to stop climate change
- EC: 10% target of energy used in transport from renewable sources
- First generation biofuels are environmentally and socially unsustainable - leading to higher food prices
- Need to bring to market advanced biofuels using lignocellulosic biomass (non-food competing)
- Existing conversion routes to produce advanced liquid biofuels, whilst scientifically credible, have not been widely successful at commercial scale
- Biochemical processes such as fermentation are slow and poorly suited to second-generation (mixed composition, lower cellulose content) feedstocks
- Thermochemical processes such as gasification and pyrolysis are more flexible with regard to feedstocks, but cannot be cost competitive unless carried out in large centralized facilities

# Project Overview

## *System Approach*

Feedstock

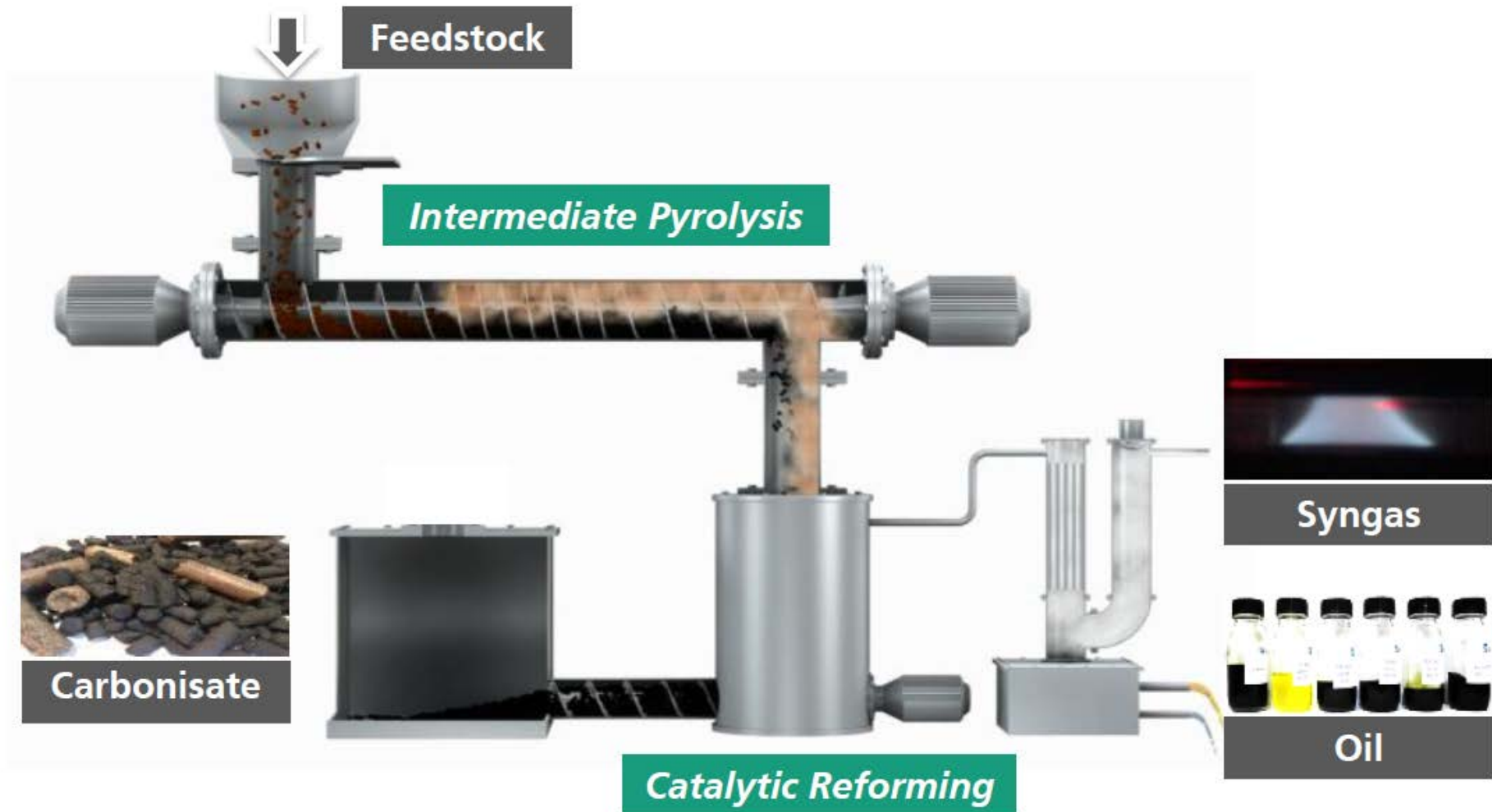


# Project Overview - *Goals*

- Demonstrate technical viability and cost-competitiveness of bioenergy value chains  
TCR → PSA → HDO
- Production of green hydrogen, diesel and gasoline equivalent liquid fuels from sewage sludge
- Validate logistical advantages of the integrated small-scale hydrogen separation and purification (PSA) and HDO modules with the TCR unit vs. centralized petrochemical infrastructure.
- Contribute to the Renewable Energy Directive targets for renewable energy by validating waste feedstocks for the production of fuels
- Showcase for future sustainable investment and economic growth across Europe
- Development of a business case, LCA and dissemination of results

# Project Overview

## *TCR<sup>®</sup> Technology*

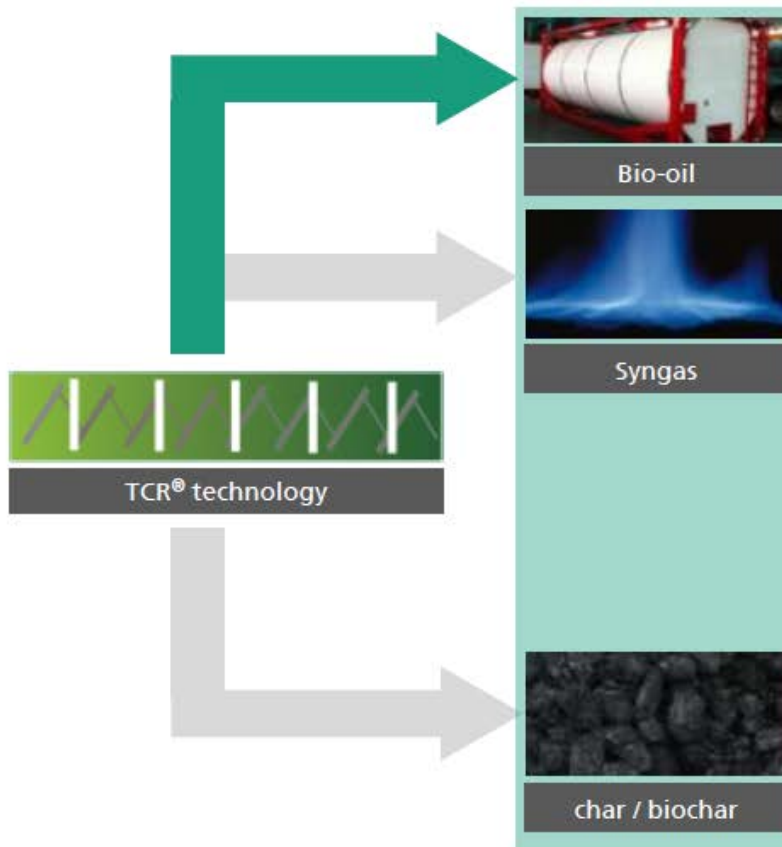


# variety of feedstocks which the TCR can treat, all validated at TRL-5:

- lignin cake from bioethanol production
- grape pomace from wineries
- oil pressing pomace (eg. from rape seed, palm fruit, olives) from oil mills
- sugar cane bagasse or sugar beet pulp from sugar plants
- animal processing residues from meat processing industry
- glycerol from bio diesel production and lignin stillage from bioethanol production from Bio fuel production
- anaerobic digestate from biogas plants
- paper production residues – eg. black liquor, de-inking sludge, bio sludge and reject residues
- waste woods from construction and furniture industry
- sewage sludge from waste water treatment plants
- the organic fraction from waste processing facilities
- brewer's spent grain from breweries
- cattle manure

# Thermo-Catalytic Reforming TCR®

## Various applications - Bio-oil



High quality, engine-ready

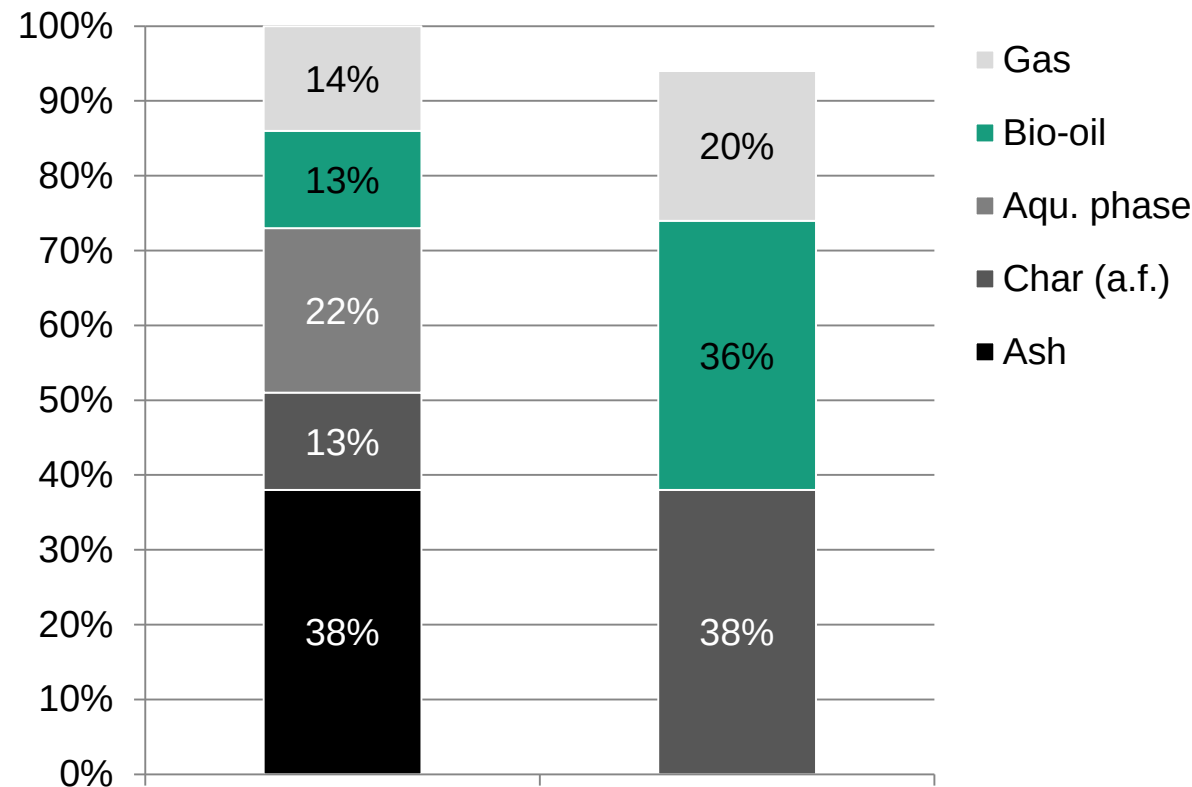
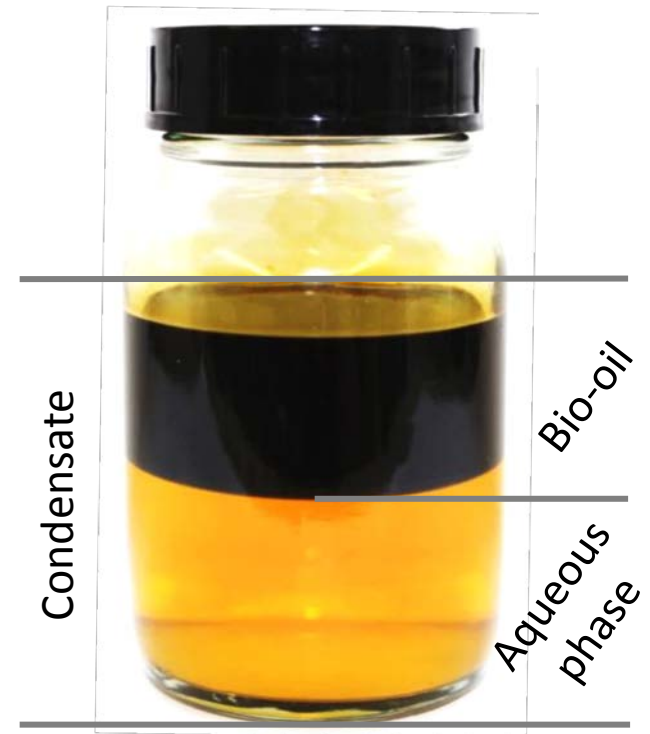
- Low acid number
- High calorific value
- Miscible with common fuels
- No tar issues
- Low Viscosity
- Thermal stability

# Thermo-Catalytic Reforming

## Product distribution for sewage sludge

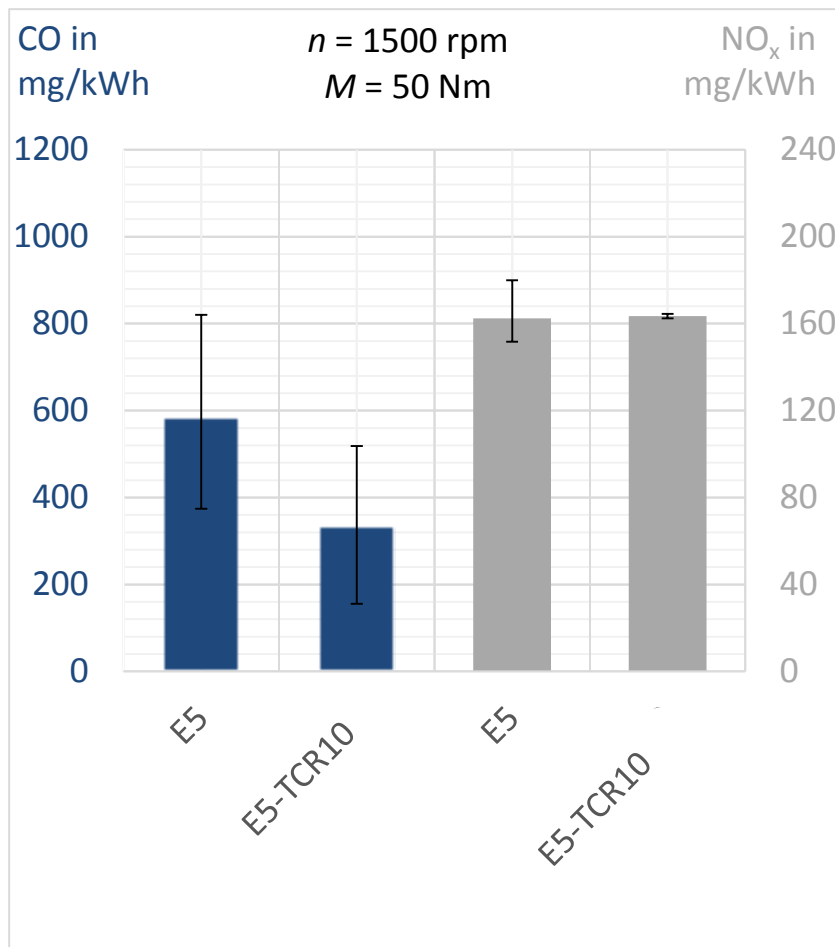
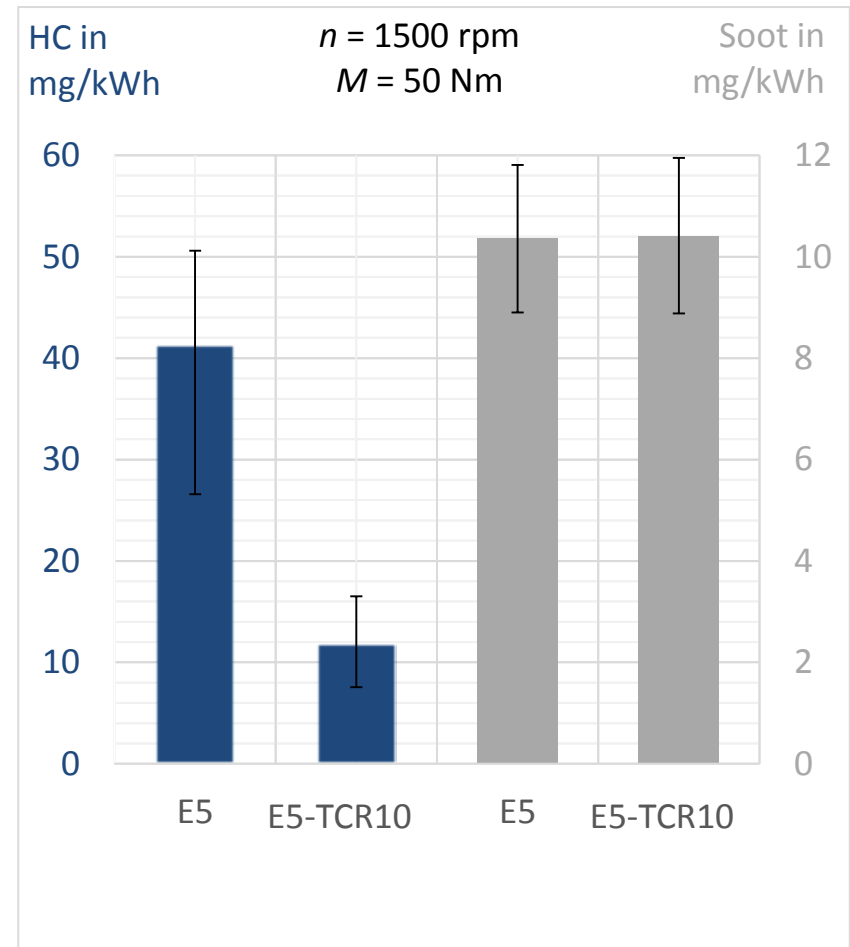
MASS BALANCE

ENERGY BALANCE



# Renewable TCR<sup>®</sup> naphtha from sewage sludge

## Gasoline engine test bench application



# Thermo-Catalytic Reforming

## Properties of various crude TCR<sup>®</sup> bio-oils

DIGESTATE 1



|                  |              |
|------------------|--------------|
| C                | 76.9 wt%     |
| H                | 9.2 wt%      |
| N                | 2.4 wt%      |
| S                | 0.4 wt%      |
| O (diff.)        | 9.4 wt%      |
| H <sub>2</sub> O | 1.7 wt%      |
| TAN              | 3.2 mg KOH/g |
| H <sub>u</sub>   | 34.1 MJ/kg   |

1 from energy crops

DIGESTATE 2



|                  |              |
|------------------|--------------|
| C                | 79.6 wt%     |
| H                | 7.0 wt%      |
| N                | 5.2 wt%      |
| S                | 1.1 wt%      |
| O (diff.)        | 7.0 wt%      |
| H <sub>2</sub> O | 2.0 wt%      |
| TAN              | 5.1 mg KOH/g |
| H <sub>u</sub>   | 35.2 MJ/kg   |

2 from animal manure

STRAW



|                  |              |
|------------------|--------------|
| C                | 77.8 wt%     |
| H                | 10.8 wt%     |
| N                | 0.2 wt%      |
| S                | < 0.1 wt%    |
| O (diff.)        | 10.4 wt%     |
| H <sub>2</sub> O | 0.7 wt%      |
| TAN              | 3.9 mg KOH/g |
| H <sub>u</sub>   | 35.6 MJ/kg   |

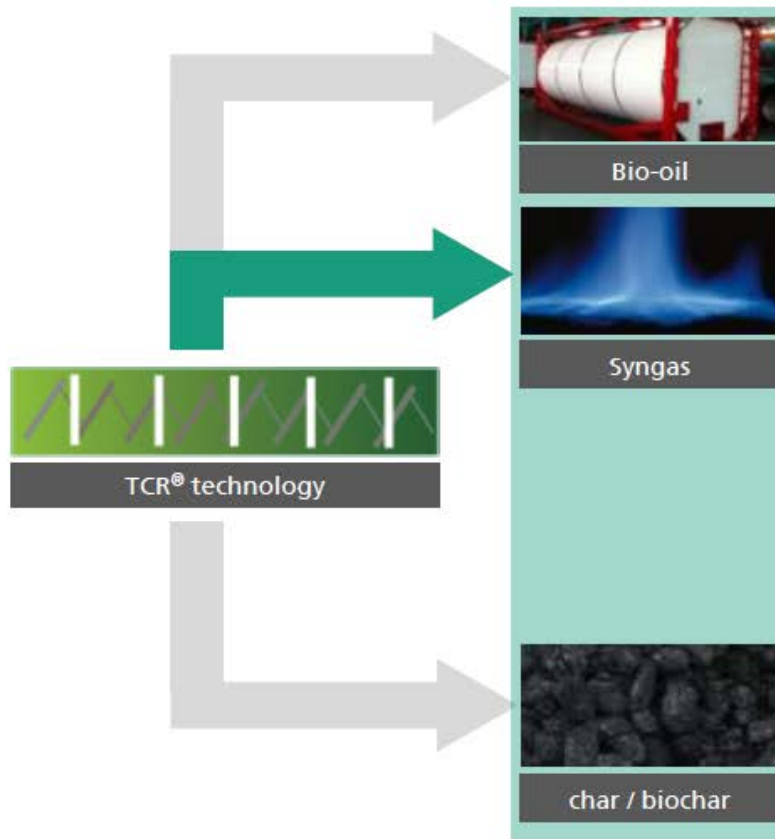
OLIVE POMACE



|                  |              |
|------------------|--------------|
| C                | 84.4 wt%     |
| H                | 7.4 wt%      |
| N                | 3.2 wt%      |
| S                | 0.3 wt%      |
| O (diff.)        | 3.5 wt%      |
| H <sub>2</sub> O | 1.2 wt%      |
| TAN              | 2.1 mg KOH/g |
| H <sub>u</sub>   | 35.2 MJ/kg   |

# Thermo-Catalytic Reforming TCR®

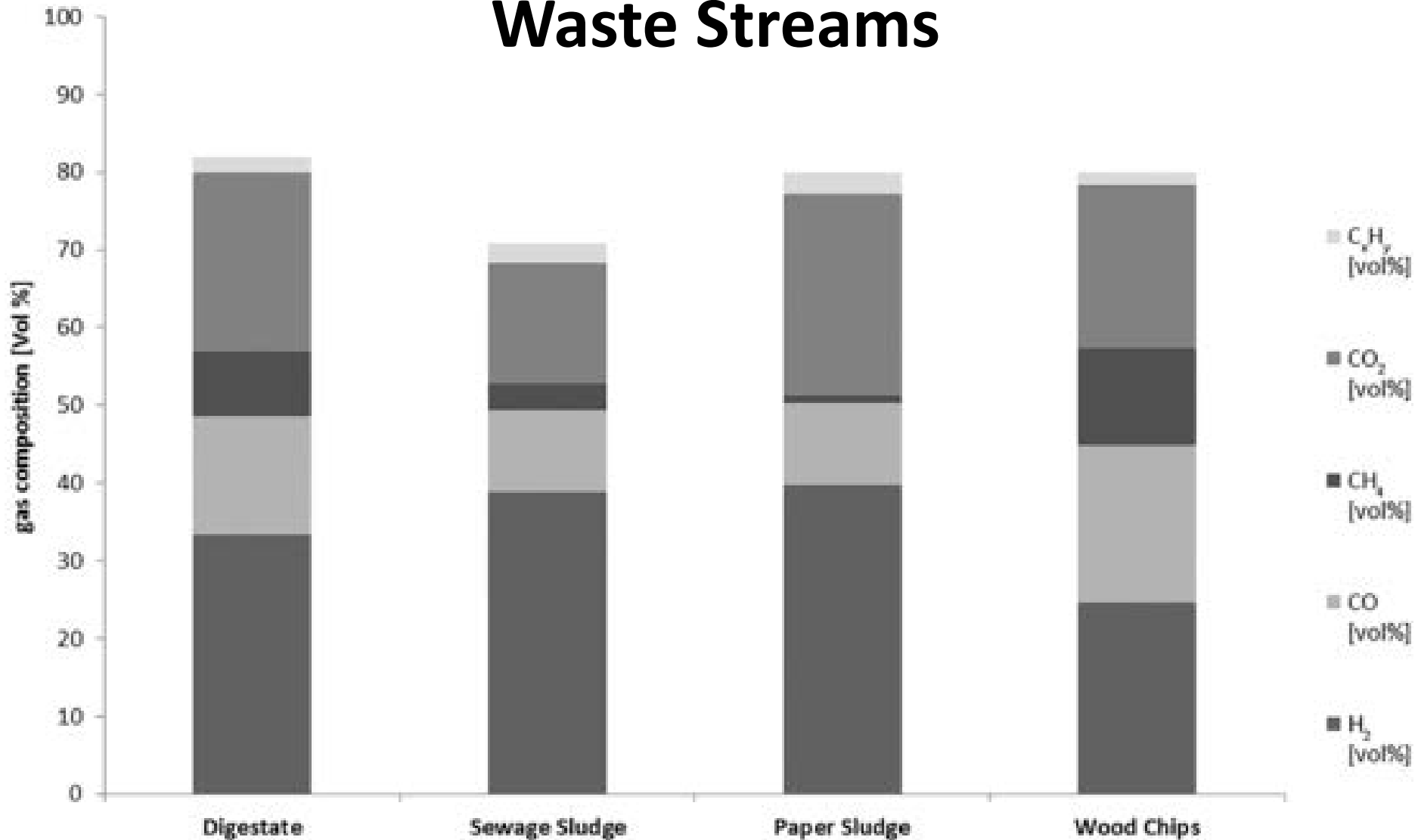
## Various applications - Syngas



### Engine-ready gas

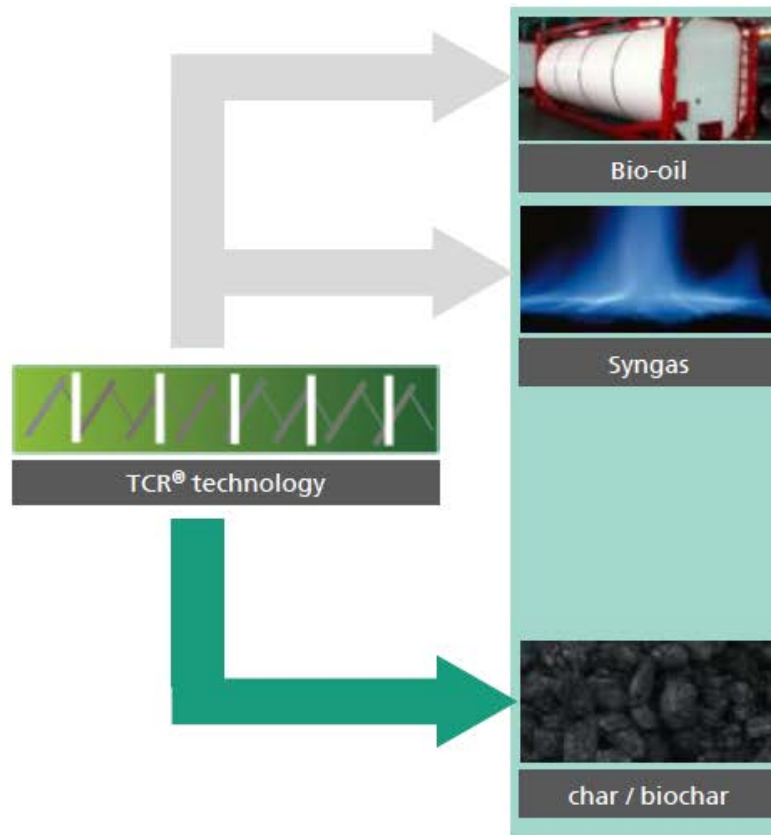
- Tar and dust free syngas
- Direct suitable for engines
- High hydrogen content
- Free of aromatic-compounds

# Thermo Catalytic Reforming of Biomass Waste Streams



# 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

# Properties of char.

| Biochar       | Content [%] |      |     |     |      |     |                  | HHV                    |
|---------------|-------------|------|-----|-----|------|-----|------------------|------------------------|
|               | N           | C    | H   | S   | ash  | O   | H <sub>2</sub> O | [MJ kg <sup>-1</sup> ] |
| digestate     | 1.5         | 48.3 | 2.0 | 0.3 | 47.8 | 0.1 | 0.6              | 17.5                   |
| sewage sludge | 1.3         | 19.9 | 0.5 | 0.7 | 76.2 | 1.3 | 0.4              | 5.9                    |
| paper sludge  | 0.2         | 16.4 | 0.3 | 0.7 | 82.3 | 0.1 | 0.3              | 3.6                    |
| wood chips    | 0.4         | 84.9 | 1.7 | 0.1 | 3.2  | 9.8 | 0.3              | 30.6                   |

# Project Overview

## *Project Partners (12 partners, 5 countries)*



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA



UNIVERSITY OF  
BIRMINGHAM

