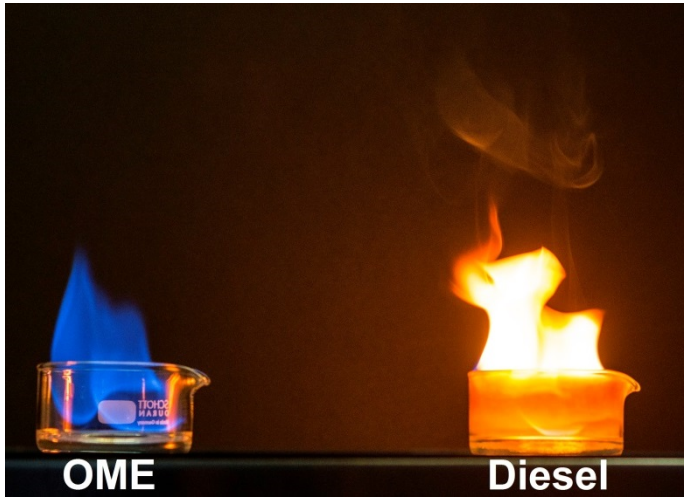
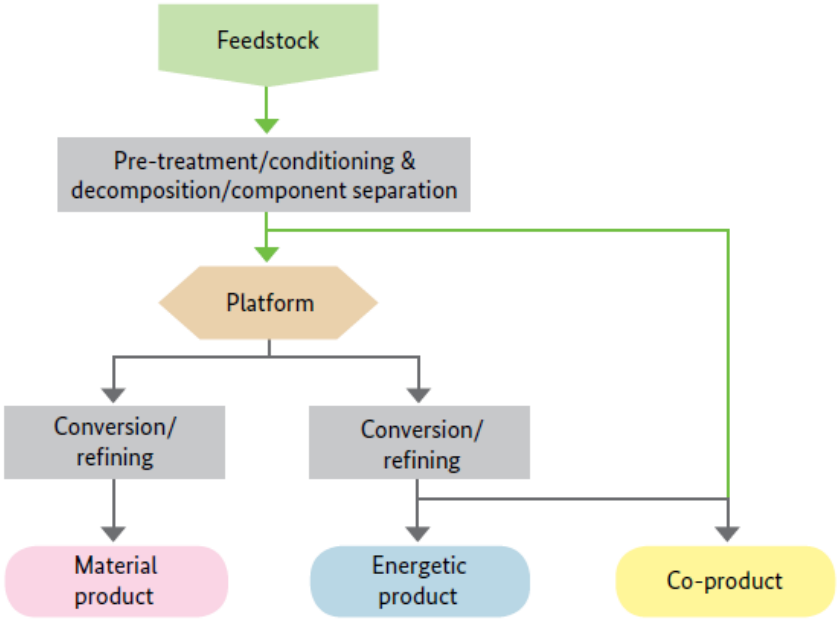
bioliq® as flagship project for biomass conversion to synthetic fuels

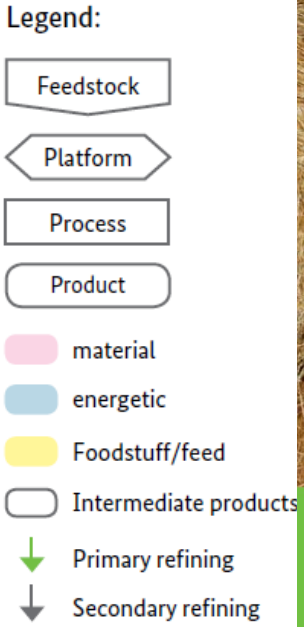
Prof. Dr. Nicolaus Dahmen, Prof. Dr.-Ing. Jörg Sauer

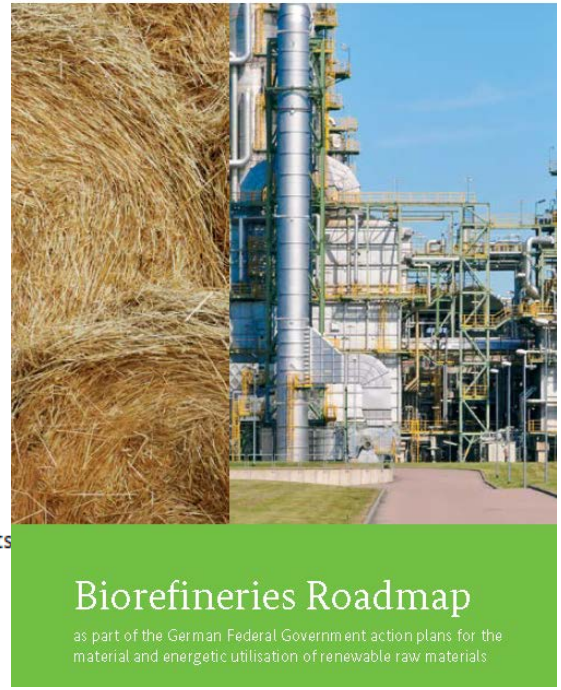
Institute of Catalysis Research and Technology (IKFT)



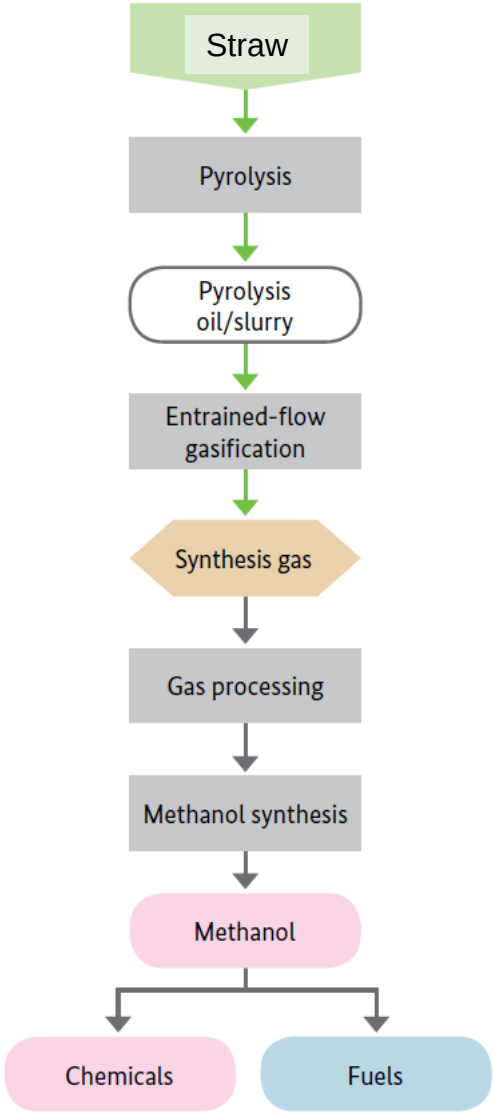
German Biorefinieries Roadmap Value Chains 2012

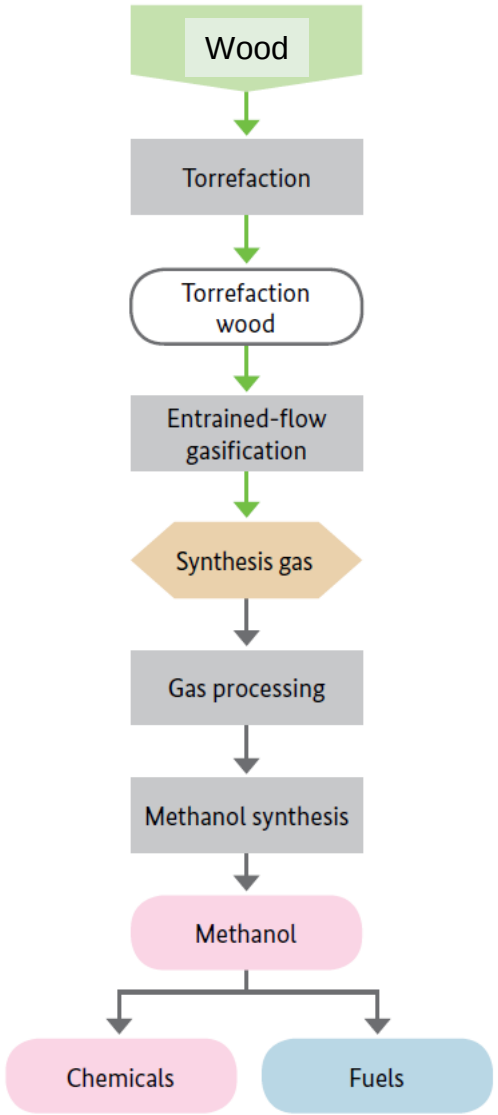




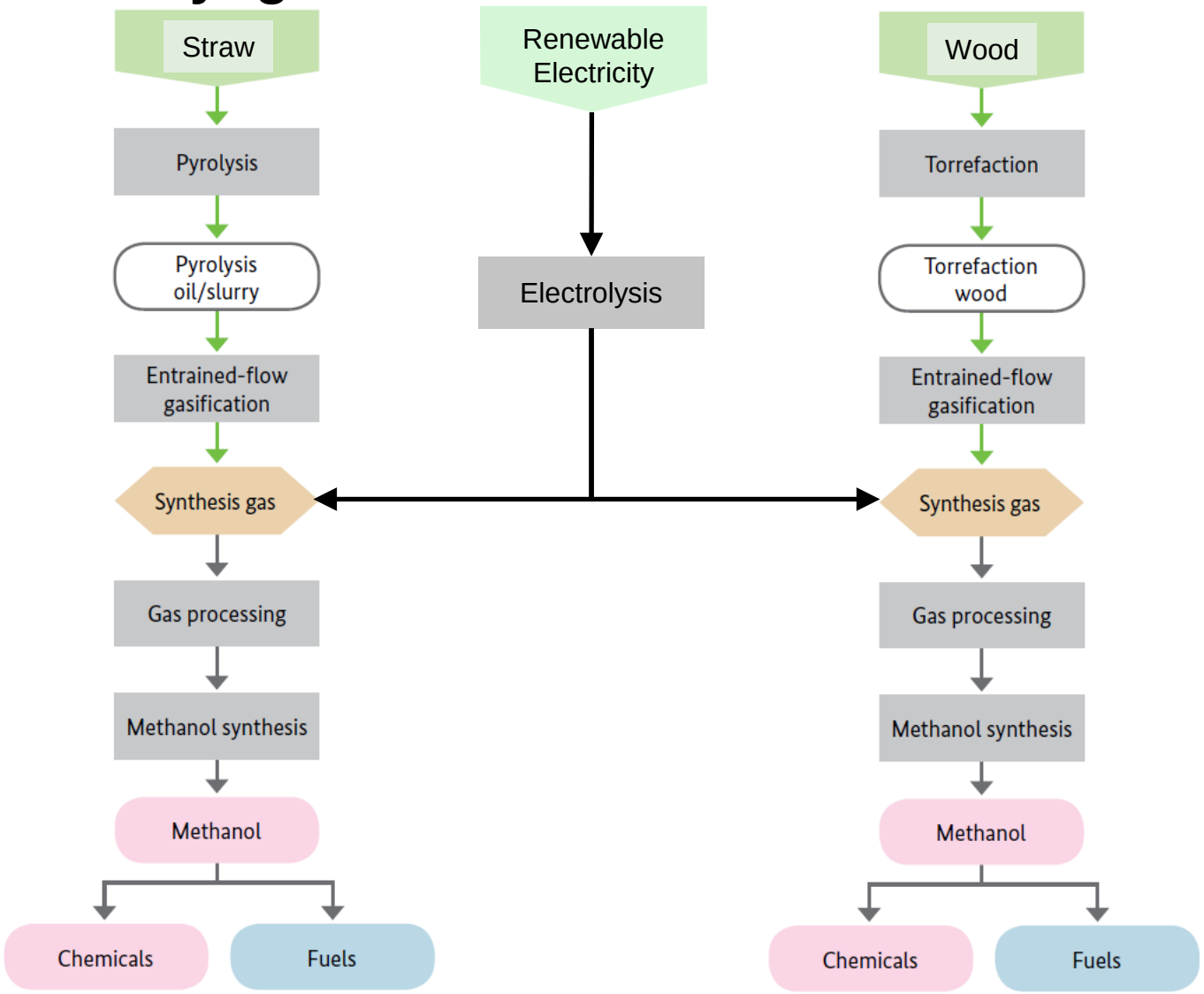


Options for Syngas Platform to BtL

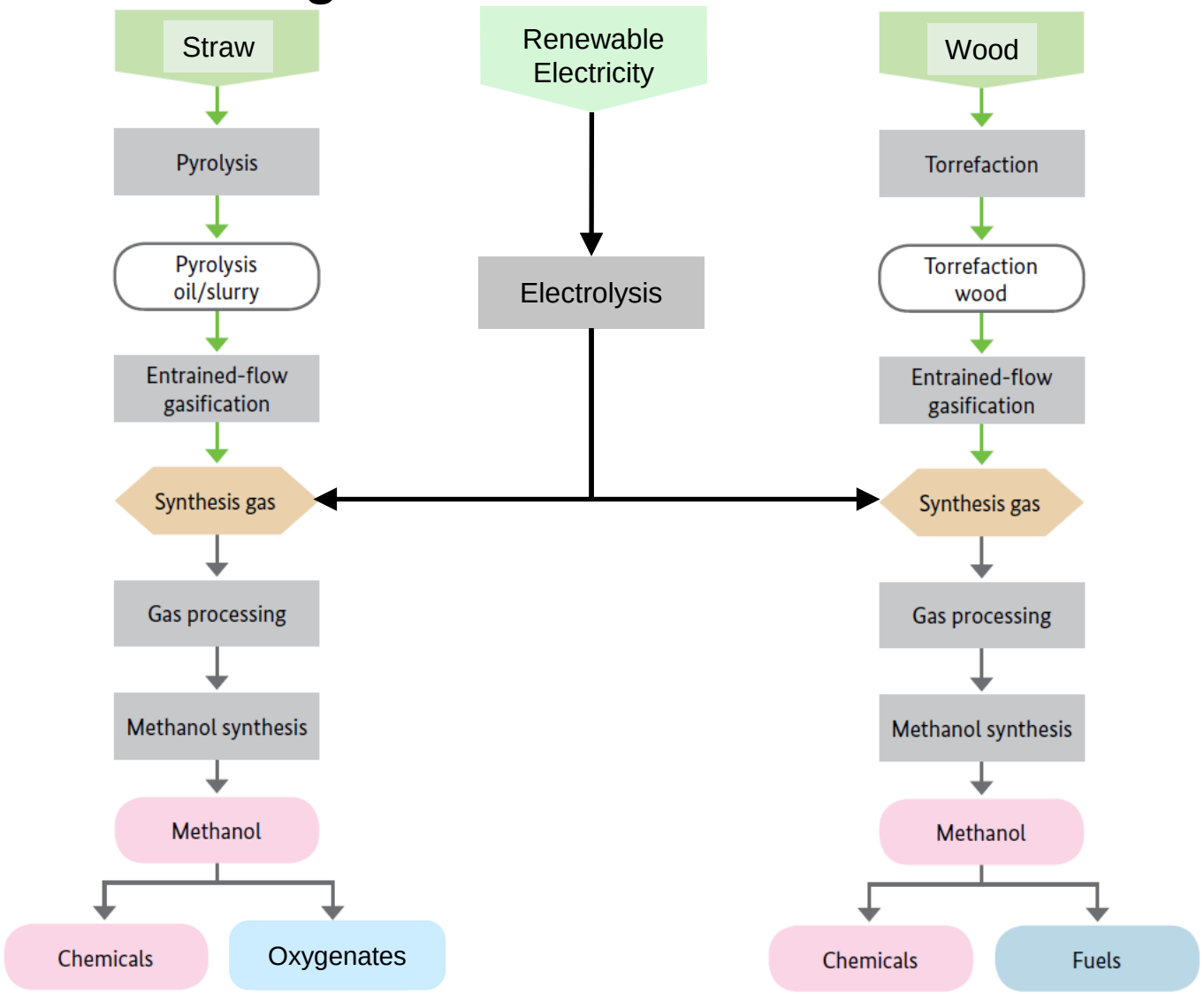




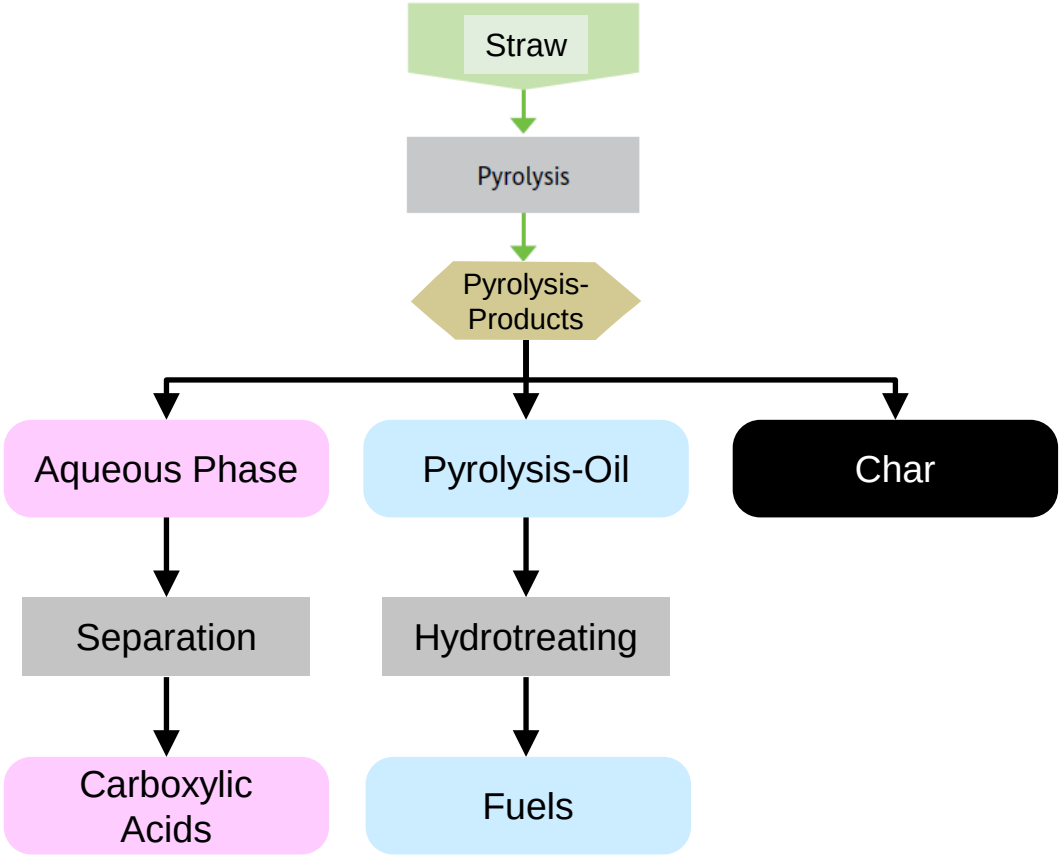
Options for Syngas Platform to BPtL



Oxygenates as High Performance Fuels



Direct Liquefaction of Pyrolysis Oil



Hypothesis

- Biomass is at present the only renewable carbon source

On a long term, biomass gains importants as raw material for fuels and chemical intermediates

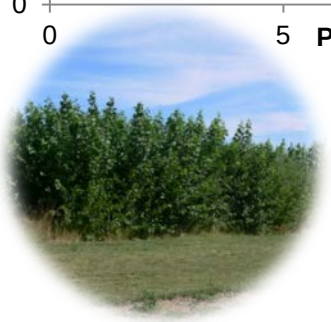
- The biomass potential is limited

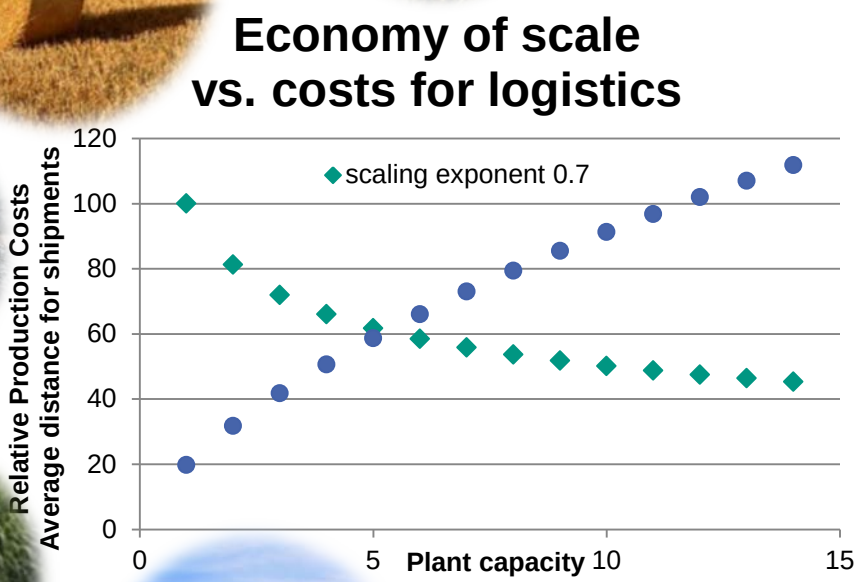
What are the most sustainable Technologies – Value Chains – Production Networks?

- Integrated concepts of thermochemical, catalytic and biotech routes are superior

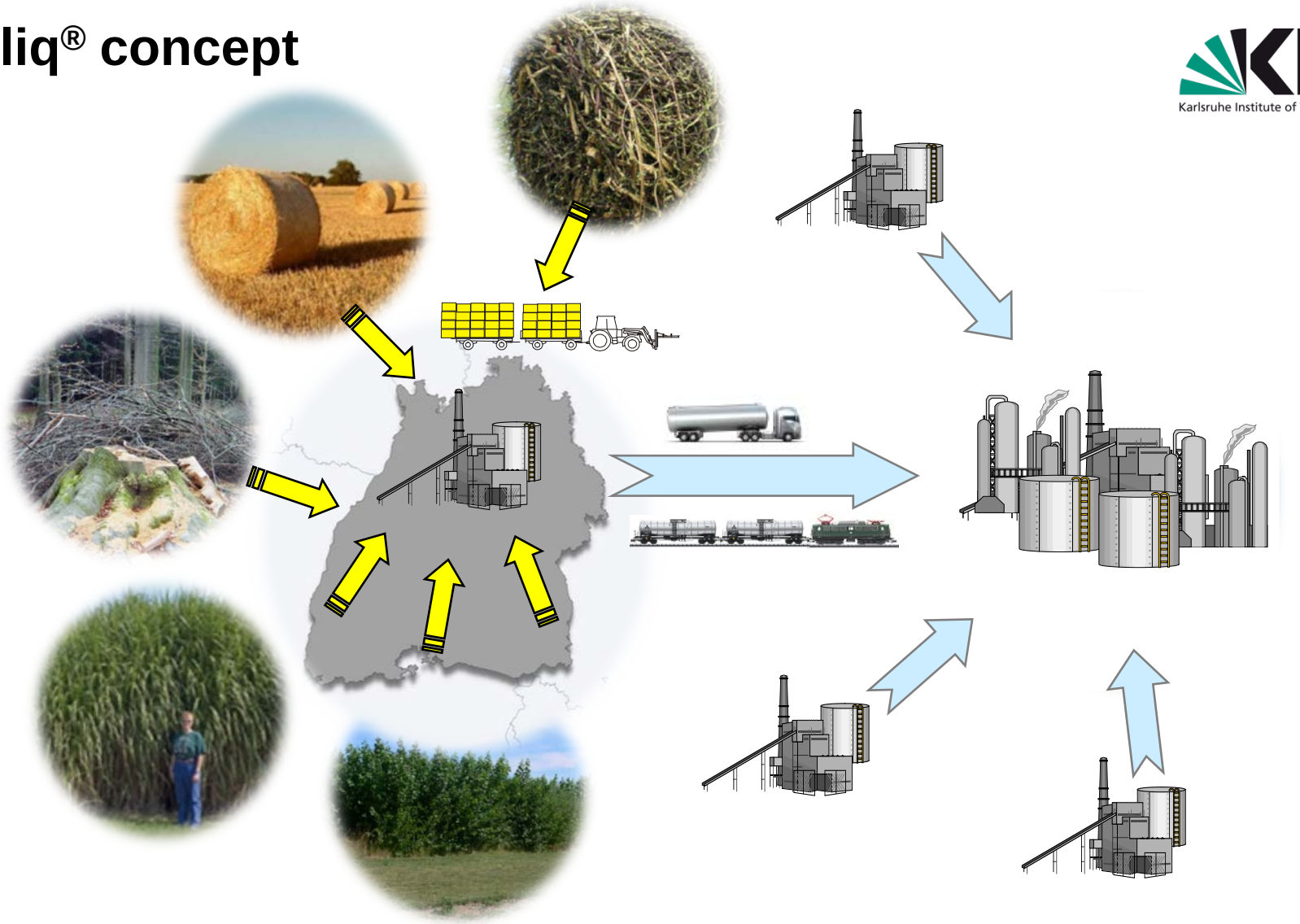
Example: synthetic biofuels

bioliq®-Concept



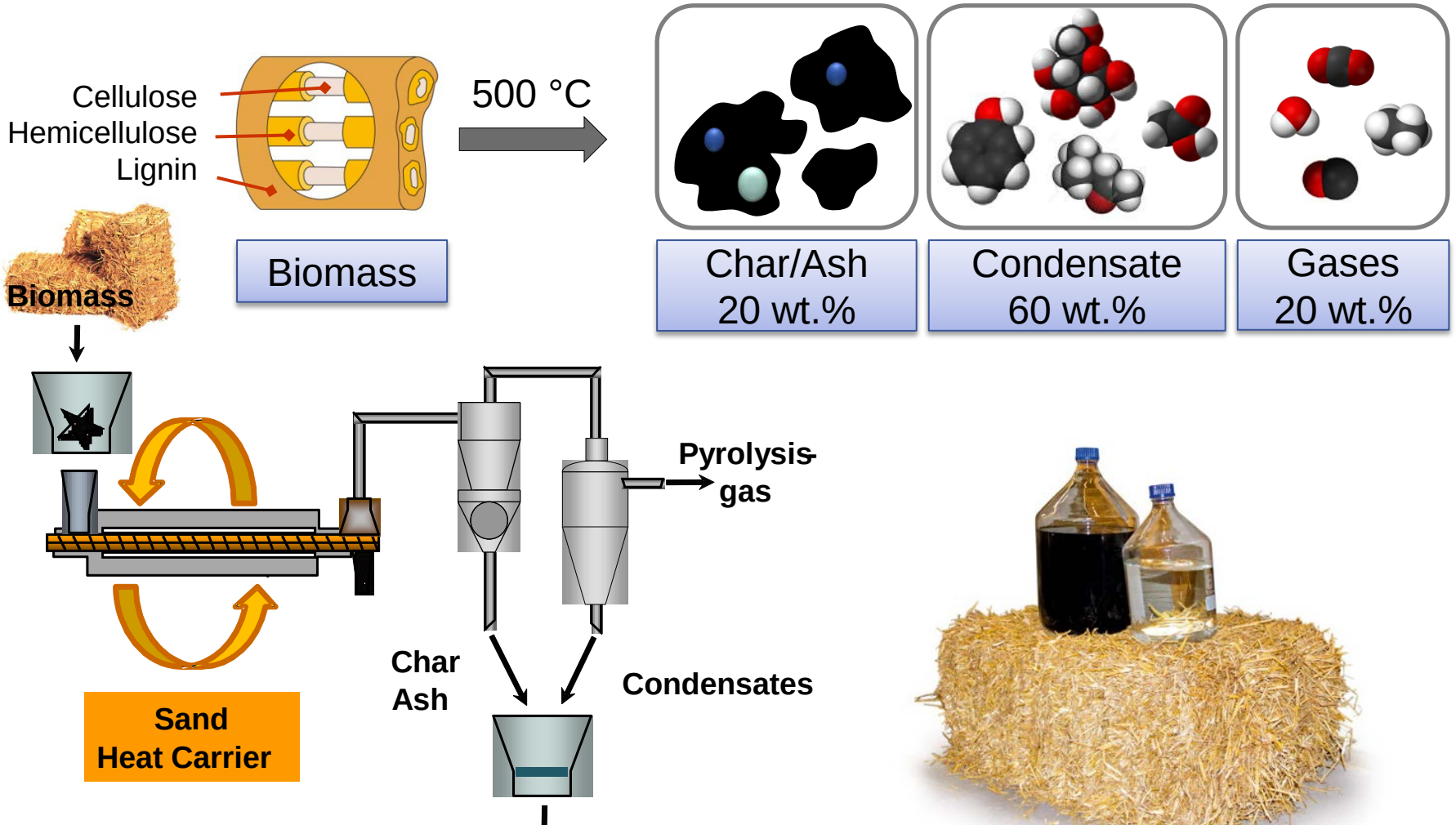


bioliq® concept

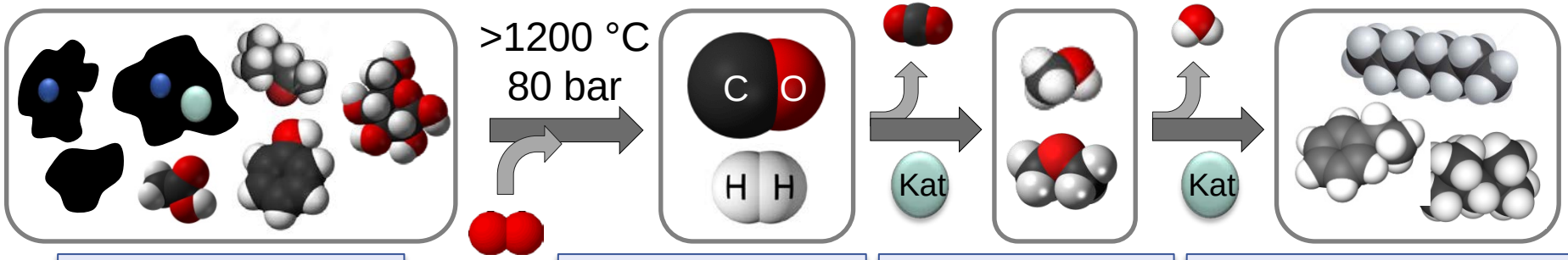


Biomass Production and Supply	„Decentralized Energy Densification“	Trans-portation	Centralized Gasification and Fuel Production

Chemistry and technology – decentralized



Central conversion technology

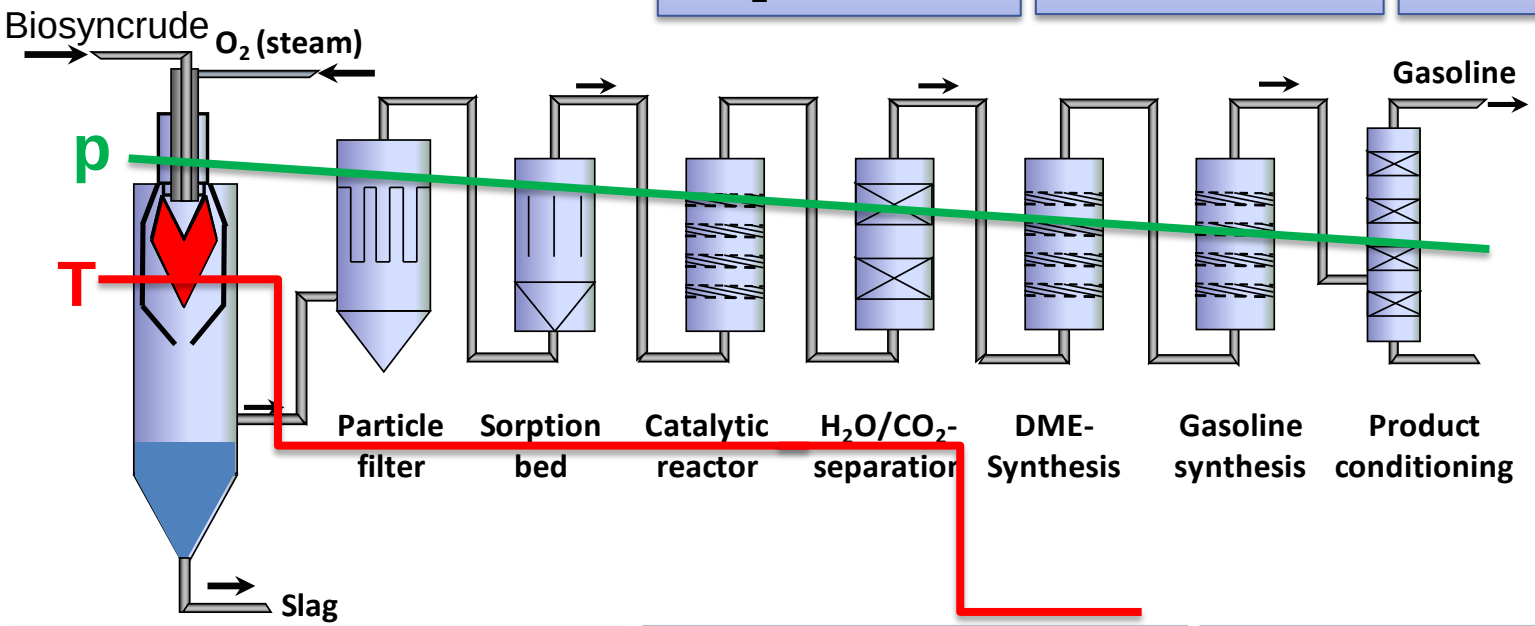


Biosyncrude

Syngas (1:1)
CO_2, impurities

Methanol
dimethylether

Hydrocarbons



Gasoline
Diesel
Kerosene
Ethylene
Propylene
Methane
Hydrogen
Advanced biofuels

Entrained flow gasification

Hot gas cleaning

Fuel synthesis

bioliq® pilot plant at KIT

bioliq Biomass to Liquid Karlsruhe

KIT Karlsruhe Institute of Technology

Fast Pyrolysis Biosyncrude-Production	Gasification Syngas-Production	Gas-Cleaning and Fuel Synthesis

Technical Validation

- Mass and energy balances
- Scale-up
- Stability and availability
- Production costs

&

Platform for Research

- Improved insights in processes
- Optimization and development
- Diagnostics, modelling, simulation
- New applications of products

bioliq® Highlights

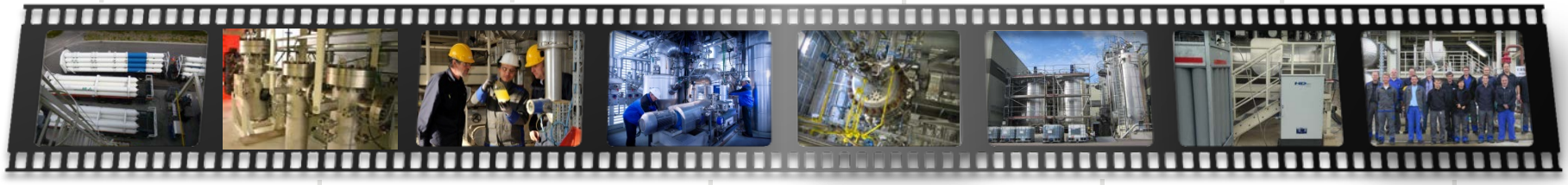
Intense co-operation of EE and EMR along the bioliq® process chain

2013 — Commissioning of synthesis plant

2014 — First synthetic fuel produced

2015 — Straw based syngas

2017 — Syngas supply to partners



2014 — Hot gas cleaning in operation

2015 — Value engineering fast pyrolysis verified

2016 — Tank farm extended

2017 — Proof of concept by bio-gasoline production

bioliq® Highlights

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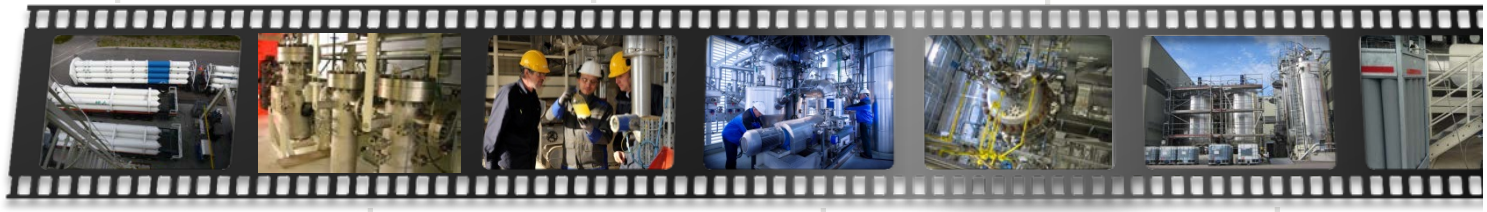


2014 Hot gas cleaning in operation

2015 Value engineering fast pyrolysis verified

2016 Tank farm extended

2017 Proof of concept by bio-gasoline production

Fast Pyrolysis in the bioliq process

Task:

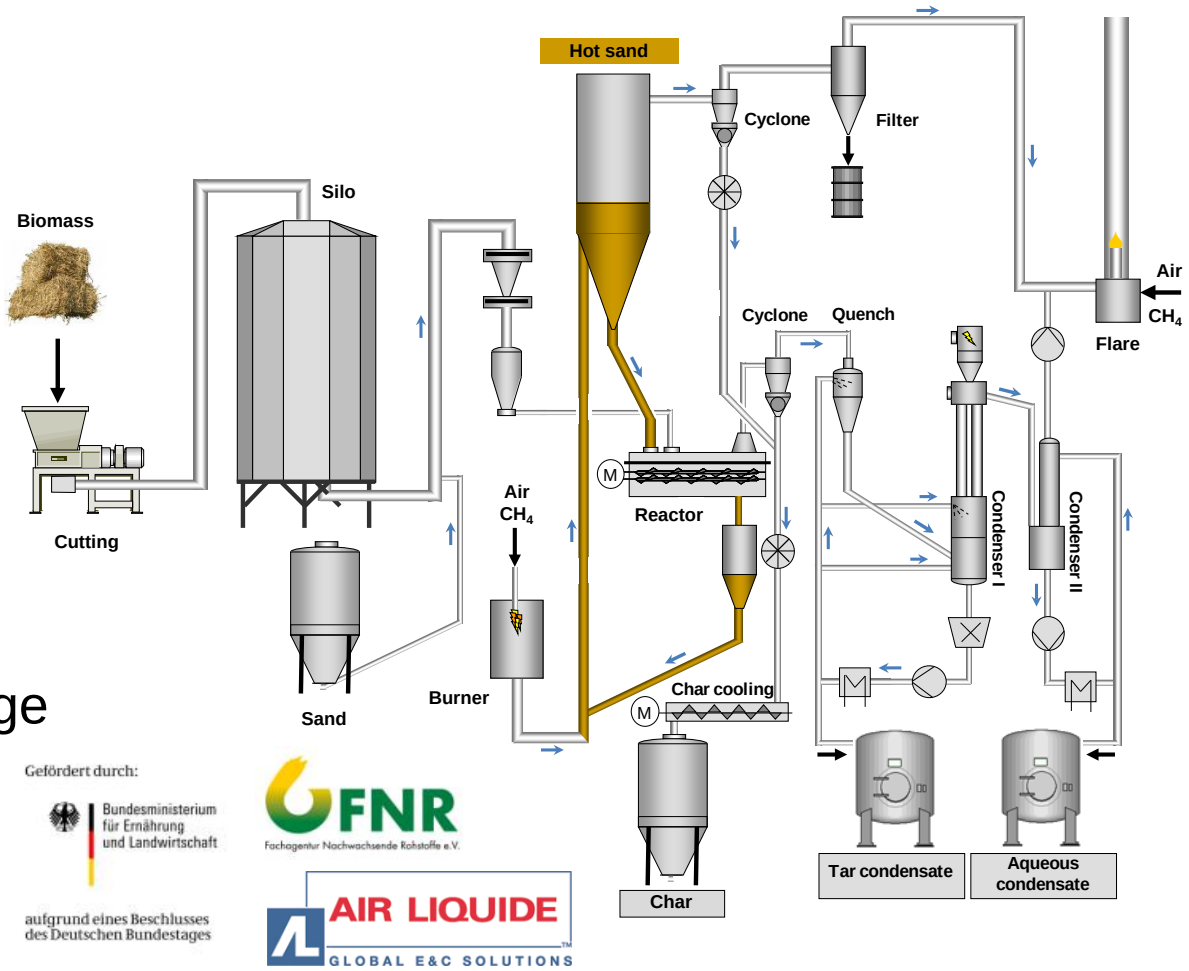
- Energy densification in the bioliq® process

Technical features:

- Twin screw reactor
- Sand heat carrier loop
- Staged condensation

Goal:

- Process design package
- Technical optimization
- Variable feedstocks



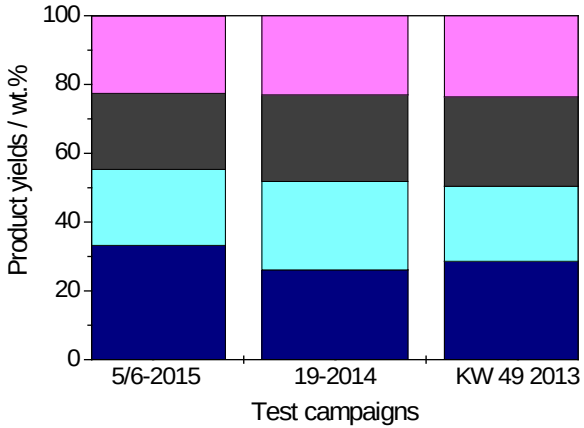
Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages
FNR
Fachagentur Nachwachsende Rohstoffe e.V.
AIR LIQUIDE
GLOBAL E&C SOLUTIONS

N. Dahmen et al., Energy & Fuels 2016

Fast pyrolysis process development

- Stable operation and representative product yield and quality
- New equipment in pilot plant testing
- Online-diagnostics for water and solids content
- Aerosol formation and behavior
- Reactor modelling
- Process design and simulation

Microwave sensor for water and solids detection



Pilot product yields

N. Dahmen et al., Energy & Fuels 2016

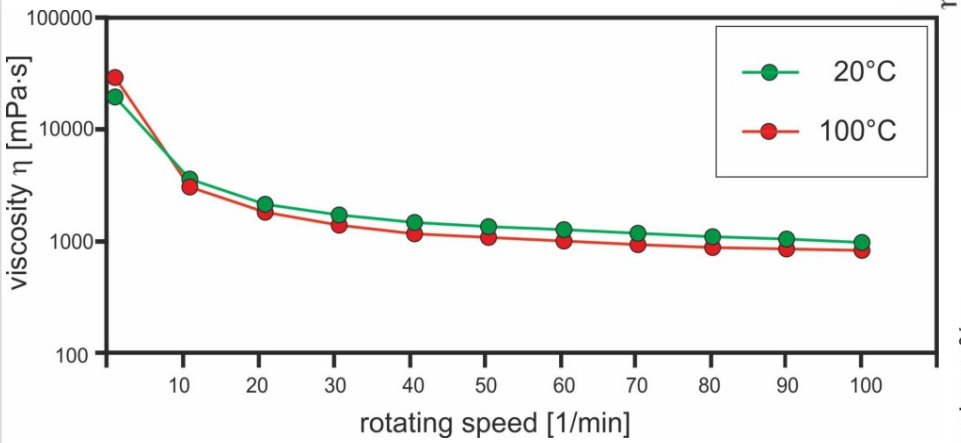
Fast pyrolysis reactor, 500 kg/h

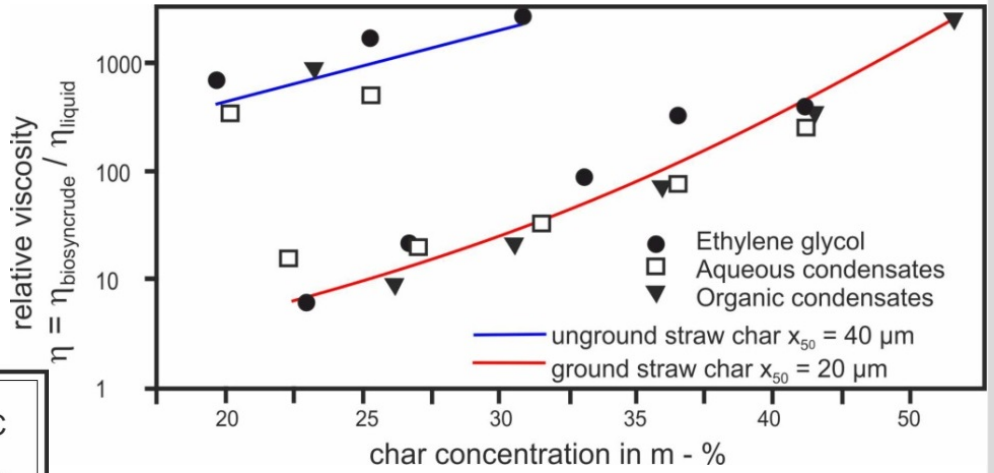
Spiral heat exchanger (© alfalaval)

Validation of the Application Concept for Biosyncrude

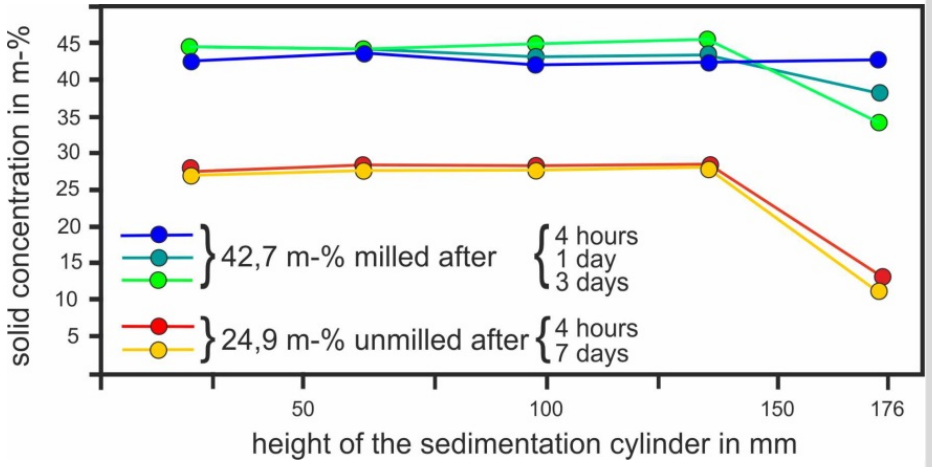
Requirement for gasification: Viscosity η < 1000 mPa·s when atomized

- Milling is essential for viscosity reduction





- At high solid contents (40%), shear rate has more impact on the viscosity than temperature

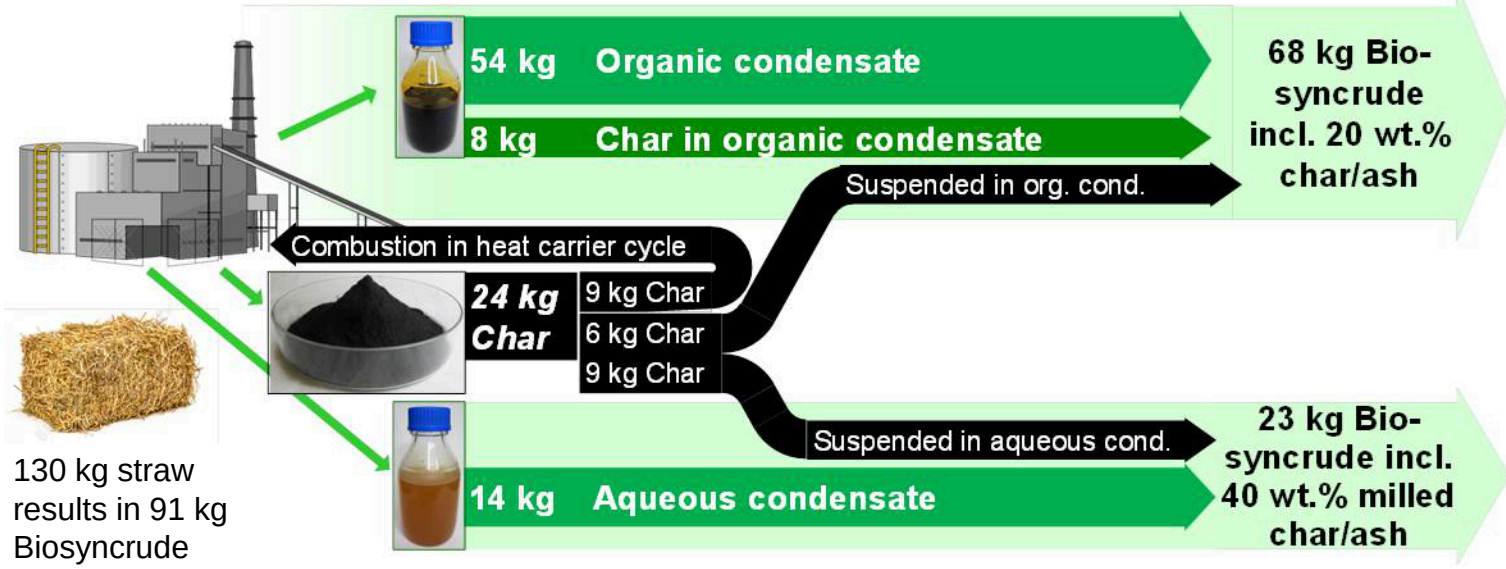


- Sedimentation: After milling the maximal solid content is increased by 70 % and the biosyncrude is stable for 8 – 12 hours.

Application Concept for Biosyncrude Verified

Energy content and consumption for a 50 m^3 silo

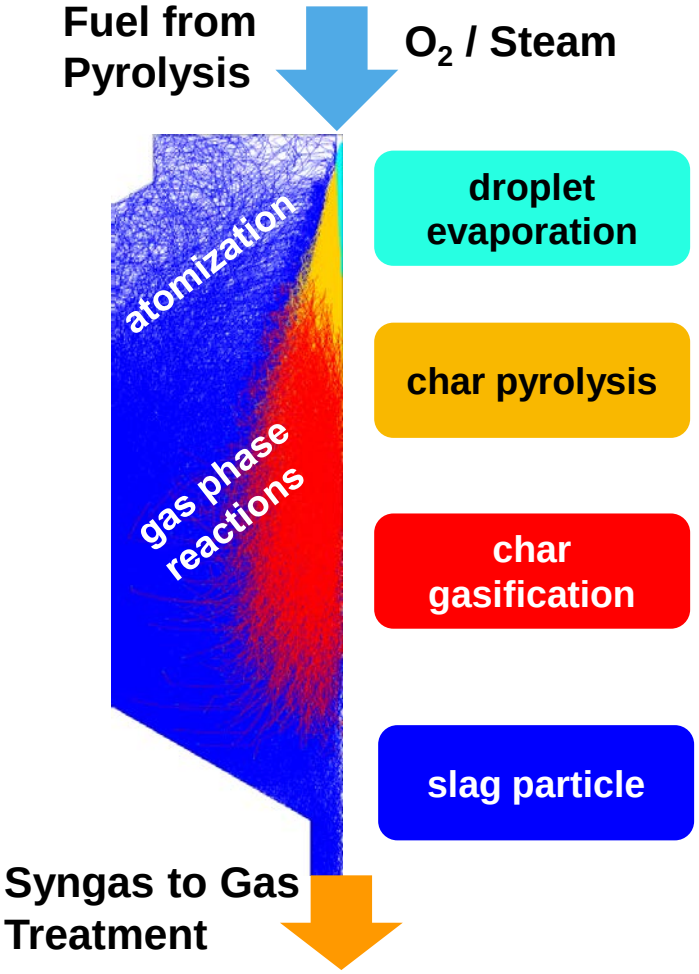
Condensate:	Aqueous	Organic
Char content	40 wt.%	20 wt.%
Energy content	550 GJ	1500 GJ
Milling	14.3 GJ (2.6%)	7.8 GJ (0.5%)
Mixing	6.8 GJ (1.2%)	4.8 GJ (0.3%)
Homogenization	1.0 GJ (0.2%)	1.0 GJ (0.1%)



130 kg straw results in 91 kg Biosyncrude

Th. Nicoleit, N. Dahmen, J. Sauer, Energy Technology 4 (2016) 221-229.

Entrained Flow Gasification of Suspension Fuels



Multiphase reacting system at high temperature and high pressure

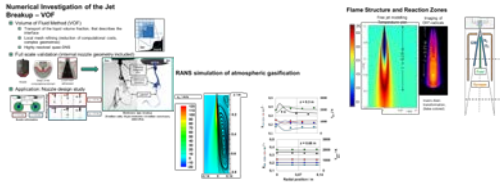
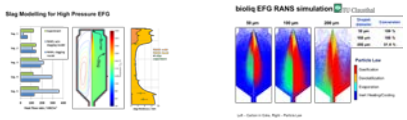
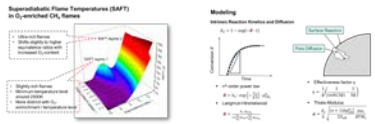
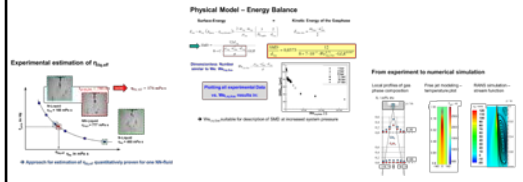
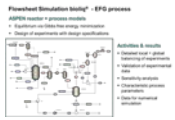
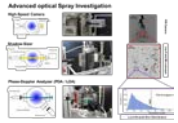
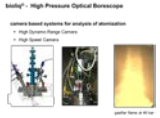
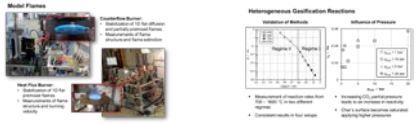
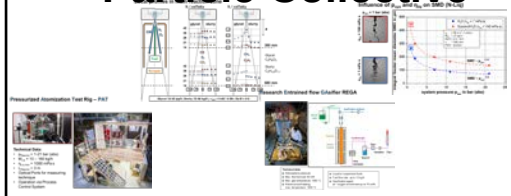
- Development and validation of mathematical models for sub processes
- Integration of sub models into total process model

➔ design and scale up of technical gasifiers

➔ optimization of process parameters for wide range of fuel specification

Integrated Research Approach

Karlsruhe Institute of Technology

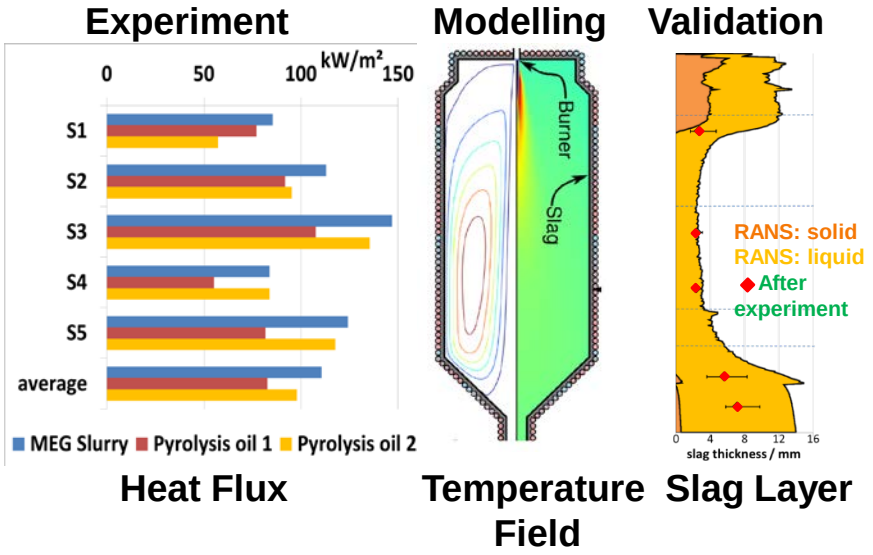
	Lab	Bench	Pilot
Simulation	**Novel Methods** 	**LES / RANS** 	**RANS** 
Model	**Basic Process** 	**Sub-Processes** 	**Process Model** 
Analytics	**New Systems** 	**Advanced Optical** 	**Process Adopted** 
Experiment	**Process Detail** 	**Particle Collective** 	**Technical System** 

High Pressure Entrained Flow Gasification

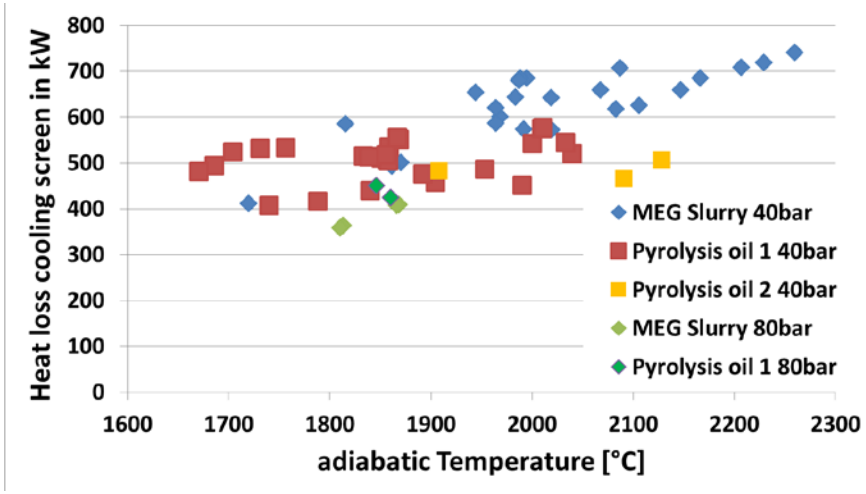
Objectives

Process data for process optimization and validation of CFD tool

- Unique instrumentation for global and local process data collection
- Syngas production within bioliq® process chain / process flexibility



Cooling screen heat loss versus $T_{adiabatic}$

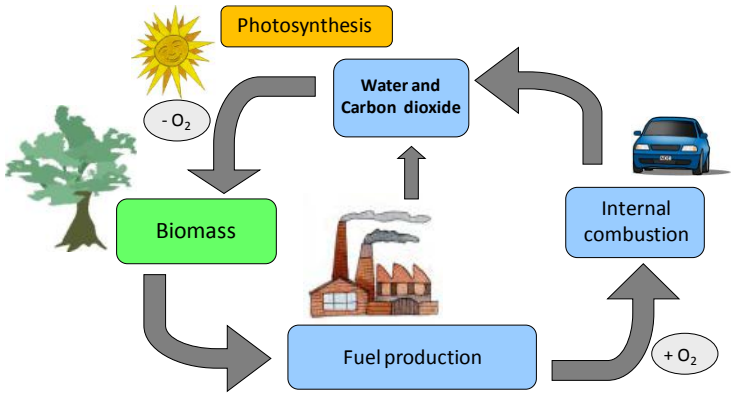


Eberhard et al., **Chemie-Ingenieur-Technik**, Jan 2018

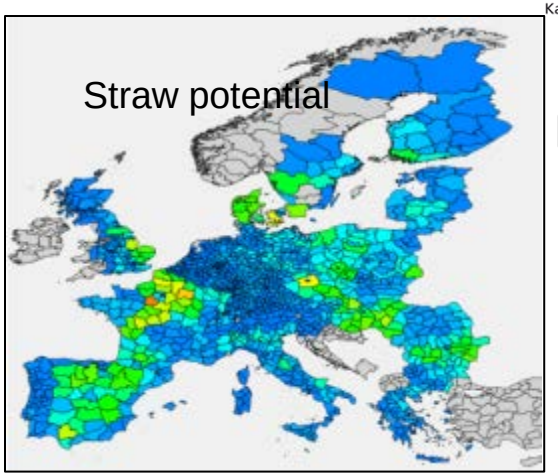
Activities & results

- Mass, species and energy balance for broad range of fuel specs and process parameters validated
- Heat flux and slagging correlated
- Development of RANS simulation for high pressure ongoing

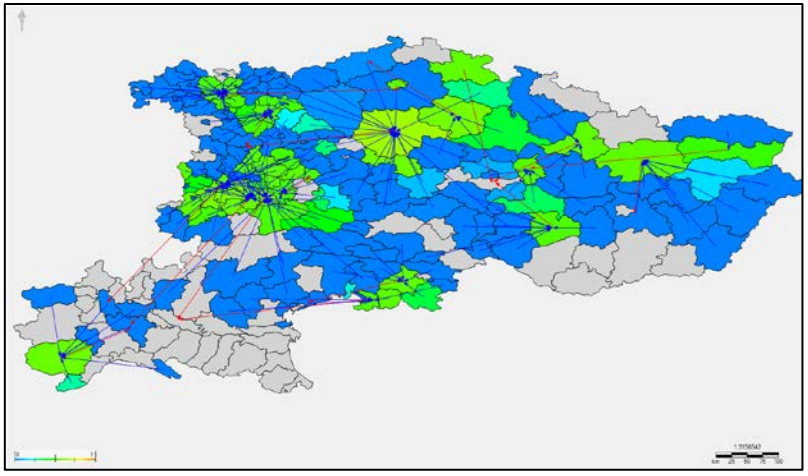
Systems analysis



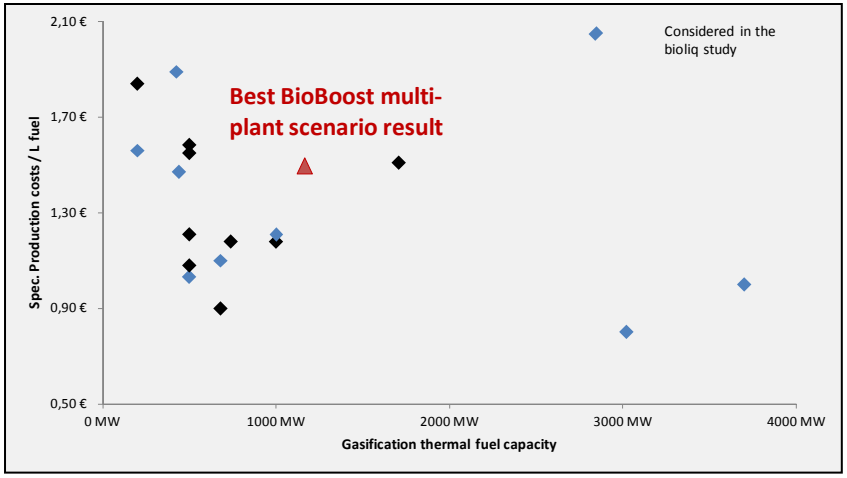
Life Cycle Assessment,
CO_2 reduction potential > 84 %



Sustainable resource potential

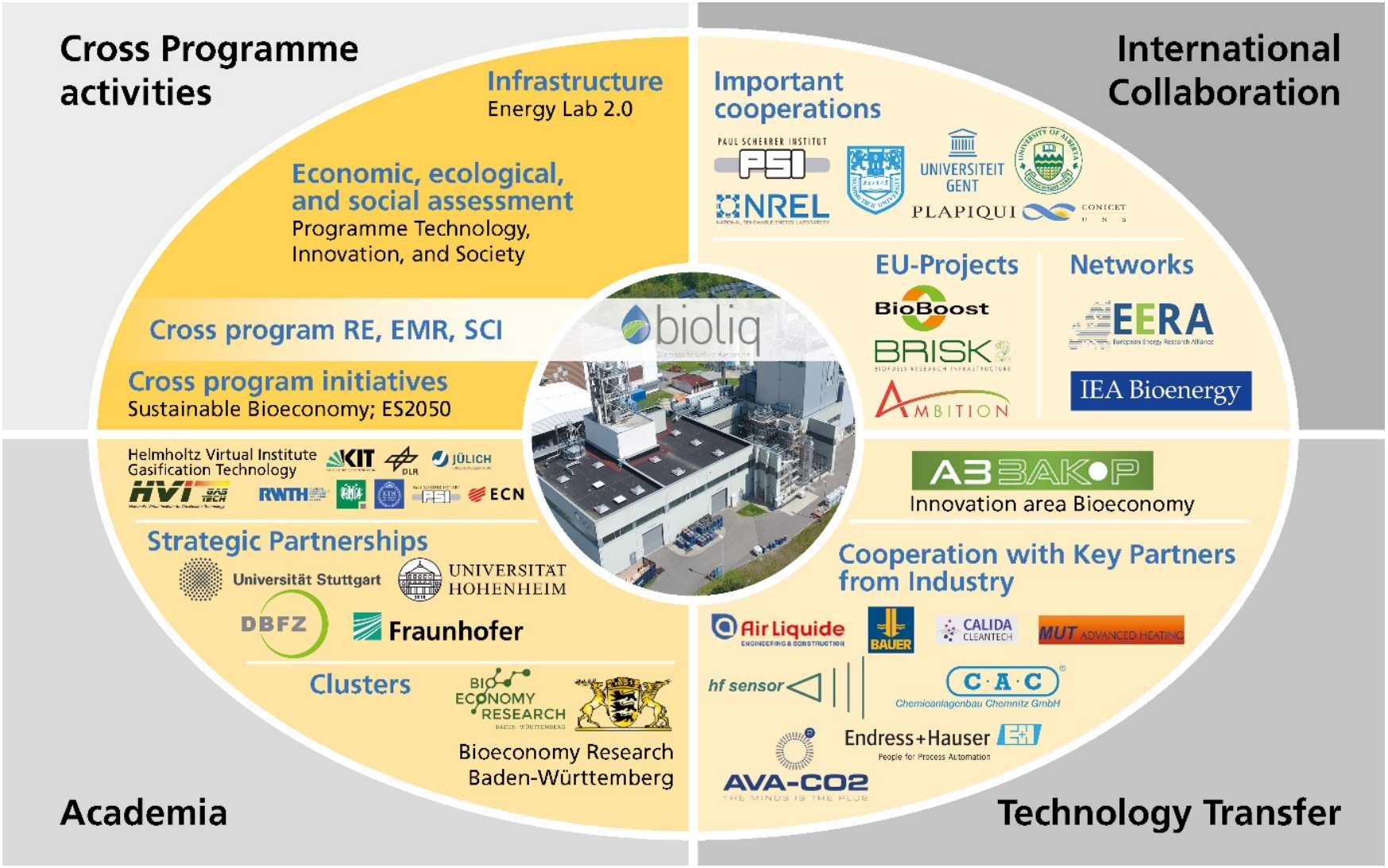


Simulation of transport/
conversion scenarios



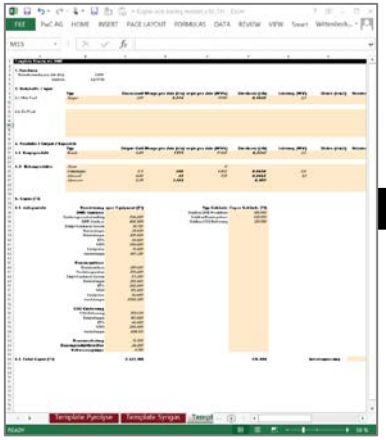
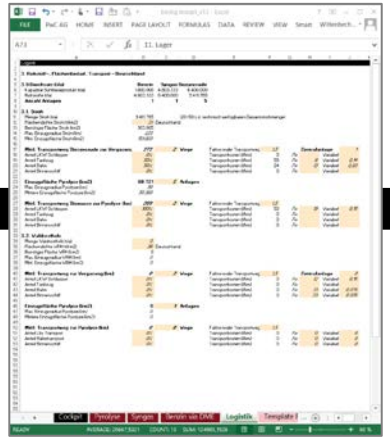
Production costs @
process efficiencies of 39 ±6 %

bioliq® as Nucleus for National and International Collaboration



Complex Cost Model for bioliq

Modules

	Material Flows & CapEx	Logistics	Scaleable process steps	Complete process
Module				
Content	*Templates for inputs of material flows, investments in individual process steps* *Basics for scalable cost modell*	*„Radial modell" with linear transportation cost s with linear costs in different categories for goods to be conveyed and means of transportation*	*Scalable cost model for individual process steps based on bioliq process flows and logistic costs*	*Input of fundamental assumptions , input of scalable process steps* *Overview over total costs and target prices*

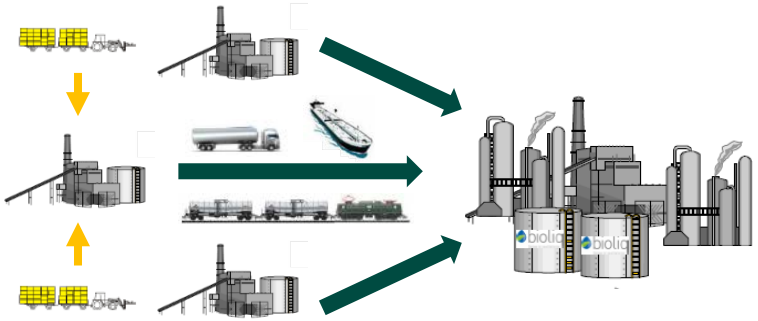
Quelle: KIT, PwC, Strategy&

bioliq® can produce 2nd generation synthetic biofuels out of residual biomass, economically in the long-term

Competitive advantages of the bioliq® process

Scalable and flexible process concept

Decentralized biomass pre-treatment | Centralized synthesis

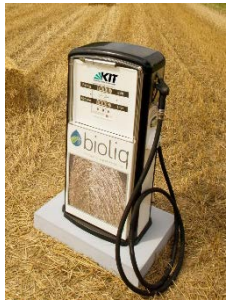


Strong competitive advantages

- Broad residual biomass flexibility and availability
- High scalability of bioliq® process
- Selective production of different synthetic biofuels (kerosene, diesel and gasoline)
- High comparability of bioliq® with fossil fuels
- Attractive economic efficiency

Successful pilot plant

Attrcative target price

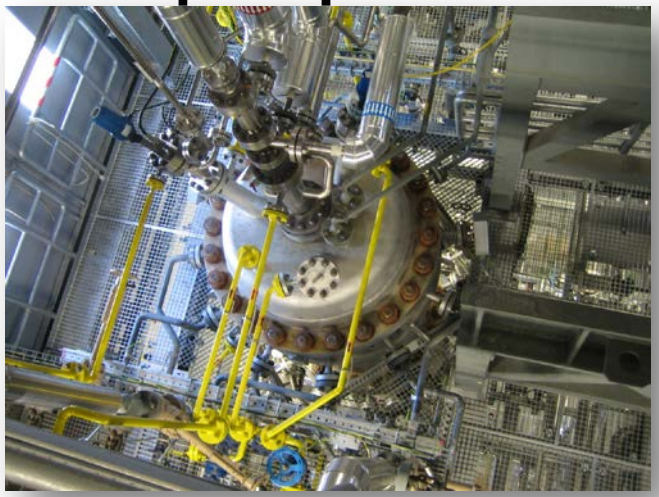


Target price

1,0 - 1,4 €/L

Dependent on scale, feedstock mix, and integration of commercial bioliq® plant

bioliq® impressions



12 km pipelines, 50 km wiring,
250 motors, 1500 t steel,

1200 I/Os, 40 pumps,
100.000 engineering hours

Hypothesis and Outlook

- Approaches for maximizing the value for customers, operating companies and society:
  - Selection of acceptable feedstocks „Food First“
  - Electricity production from biomass as service for stabilization of electricity grid
  - Combination of PtX and BtX
  - Integration of value chains (food, biomaterials, electricity, heat, fuels)
- Establishment of a feasible and accepted metrics for making choices
- Development of technologies that help to handle the entry barriers for investments
- What are market conditions that fertilize investments?

My Take-home Messages for „Biofuels“

- Fuels and Chemicals from sugar and plant oil are limited in quantity because of the fuel vs. food dilemma and may even be phased-out in the future
- Developments for fuel components with better compatibility and/or better performance are at the brink of commercialization
- The search for a viable business case is still critical but 1,0-1,4 €/l for 2. gen biofuels seem feasible und conditions of feedstock costs in central Europe
- Blending mandates and other regulations may or may not support investments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