Karlsruher Institut für Technologie

bioliq
Biomass to Liquid Karlsruhe

Thermochemische Verfahren zur energetischen und stofflichen Nutzung von Biomasse

Nicolaos Boukis, Nicolaus Dahmen, Axel Funke, Andrea Kruse, Klaus Raffelt, Jörg Sauer, Hamm, 22.07.2015

Institute of Catalysis Research and Technology - Project bioliq



Outline

- Motivation
- Hydrothermal Processes, Hydrothermal Gasification
- The bioliq Approach to BtL
- Conclusion and Outlook

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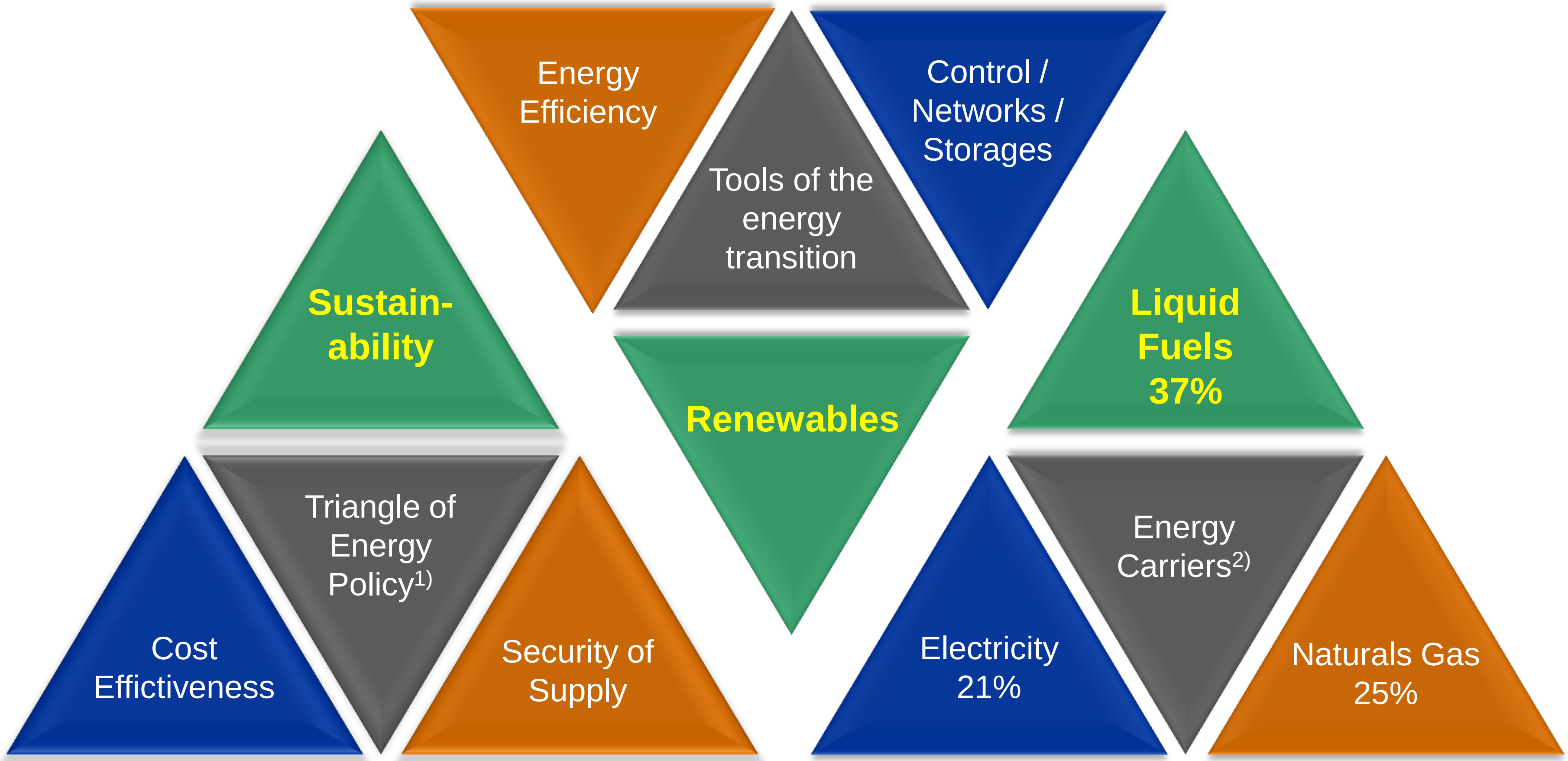
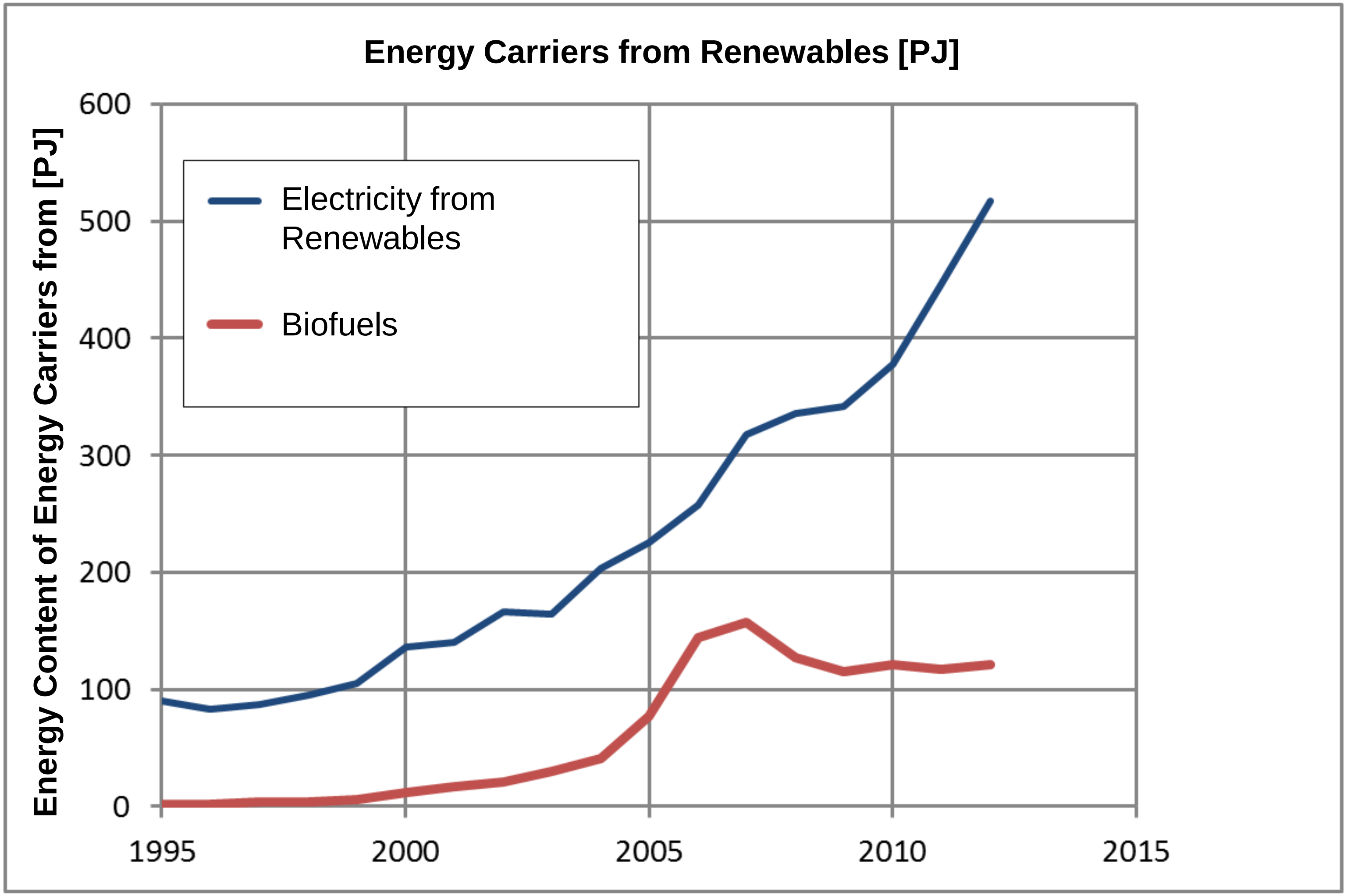
„Magic Triangles“ of the German Energiewende



1) Zweiter Monitoring-Bericht „Energie der Zukunft“, Bundesministerium für Wirtschaft und Energie (BMWi), Berlin, März 2014
2) AGEB, Arbeitskreis Energiebilanzen, September 2014, www.ag-energiebilanzen.de/ entnommen am 21.09.2014

„Energiewende in Germany" – Biofuels and Electricity[1)]



1) AGEB, Arbeitskreis Energiebilanzen, September 2014, www.ag-energiebilanzen.de/ retrieved on 2014-09-21

Erdöl - Zahlen

- Erdöl Tagesproduktion: 83 Mio bbl per day
  = 13,2 Mio m^3/Tag
- Zum Vergleich:
  Speichervolumen des Brombachsee 164 Mio m^3
  - Zeit bis zum Auffüllen des Brombachsees mit weltweiter Erdölproduktion: 12 Tage 10 Stunden

Source: IEA, Energy Technology Perspectives 2014
http://www.landeskraftwerke.de/brombachsee.htm, entnommen am 14.07. 2014
http://www.zv-brombachsee.de/, entnommen am 14.07. 2014

Noch mehr Zahlen

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■ Investitionssumme für Pearl GTL	18,5 Mrd USD
Produktionsmenge	0,14 Mio bbl per day
Anteil an der Welt-Ölproduktion	0,17%
Investkosten pro bbl	130.000 USD/(bbl per day)
Mitarbeiter für Anlagenbau:	ca. 50.000
■ Hochrechnung auf Weltöl-Produktion:	
Kosten:	10,8 Billionen USD
Investbudget der Ölkonzerne (2012):	260 Mrd USD (x **41**)
ExxonMobile (2013):	42,4 Mrd USD (x **254**)
■ Hochgerechneter Personalbedarf	ca. 30 Mio für 5 Jahre

Source: http://www.platts.com/
http://www.shell.com/
http://ir.exxonmobil.com/
http://energypolicy.columbia.edu/
entnommen am 13.07.2014

Contribution of the Negative Residual Load

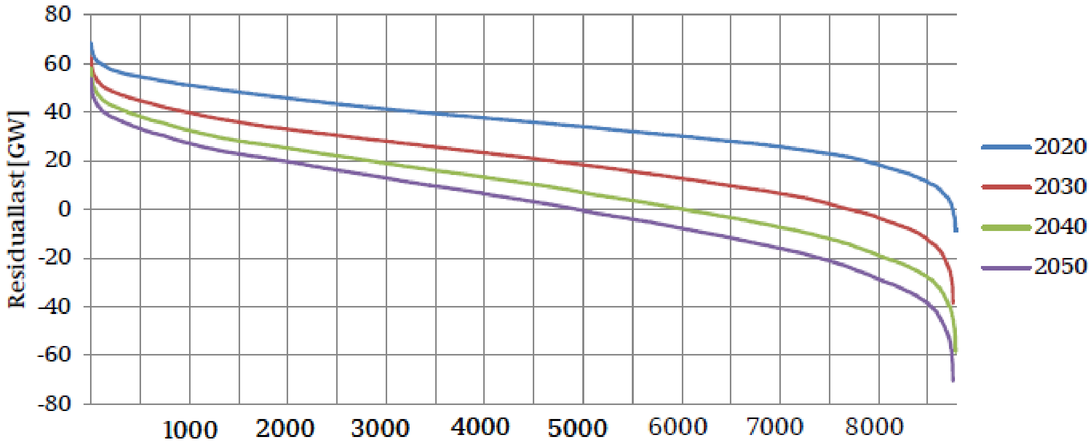

Abbildung 4-34: Geordnete Dauerlinie der Residuallast.

Negative residual load:	66TWh = 240 PJ
After conversion losses:	33TWh = 120 PJ
Liquids consumption Germany 2012:	1290TWh = 4640 PJ
Potential for Liquids from residual load	2,2 Mio to (2,6%)
Availability	max. 3000h

Sources: Deutsche Energie-Agentur GmbH (dena), Integration der erneuerbaren Energien in den deutschen/europäischen Strommarkt, 2012
AGEB, Arbeitskreis Energiebilanzen, September 2014, www.ag-energiebilanzen.de/ entnommen am 21.09.2014

Feedstocks for Future Bionenergy Applications

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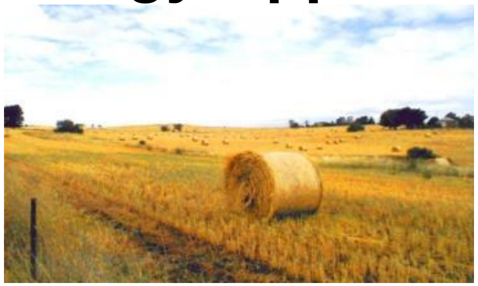
- Agriculture
  - Straw, hay, ….
  - Energy crops
- Forestry
  - Residues (brash, tops, stumps)
  - Thinnings
  - Short rotation plantation
- Marginal Farmland
  - Streets, railway tracks
  - Power transmission lines
- Organic residues
  - Recovered waste wood
  - Organic waste fractions
- Algae



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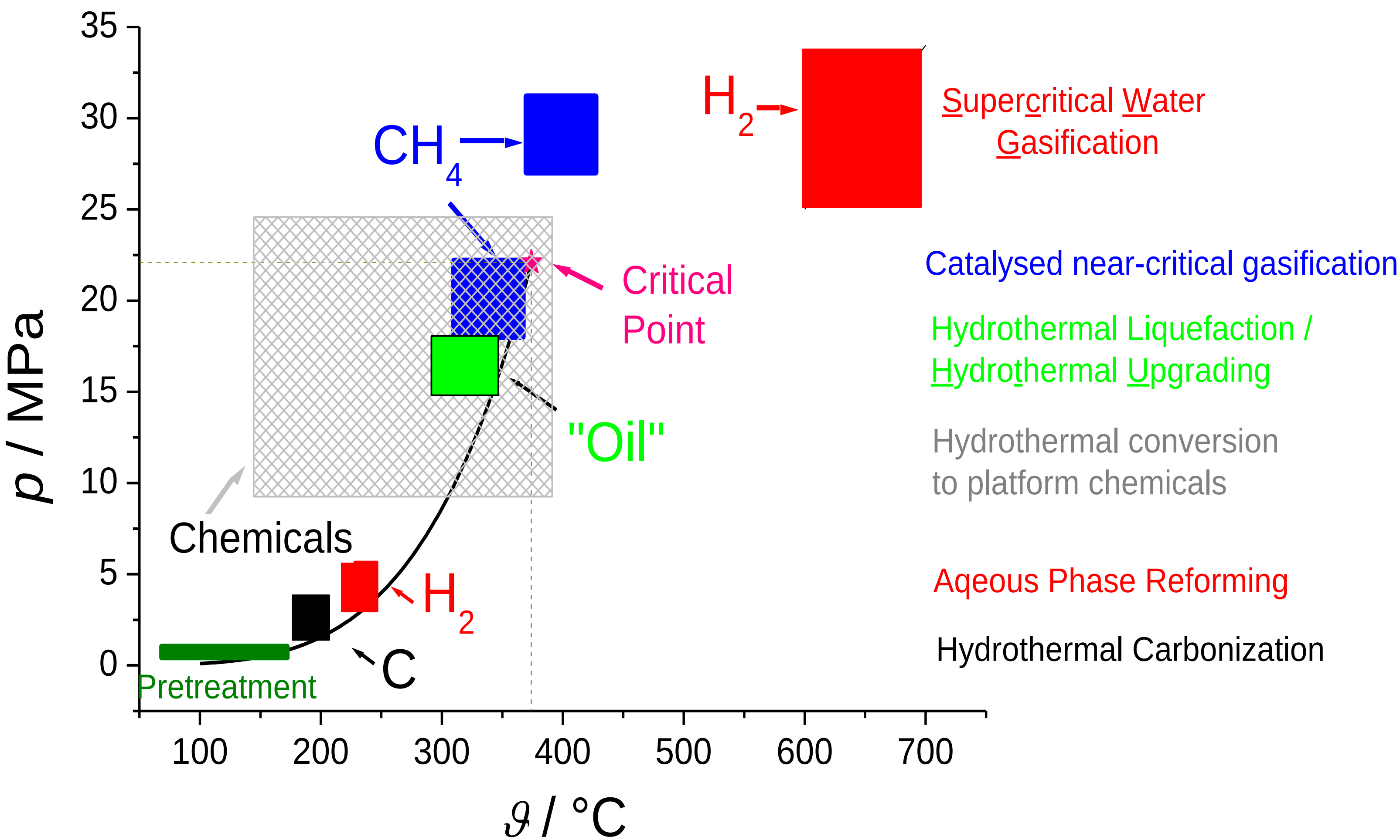
Regimes for Hydrothermal Conversion

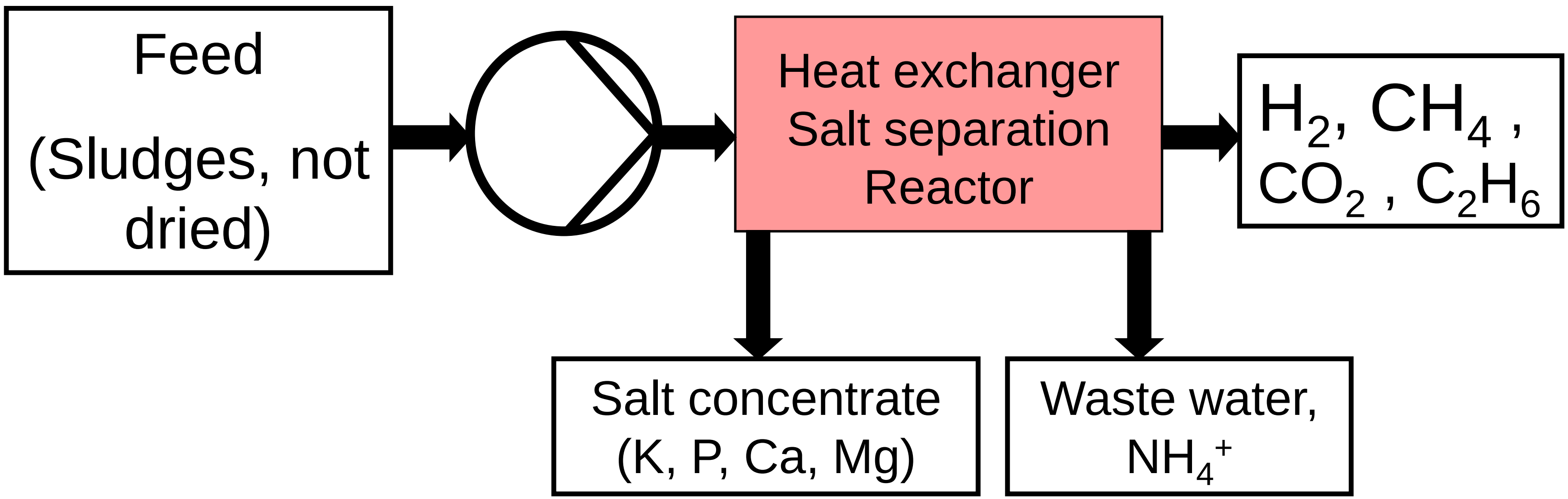


Kruse et al., 2013, modified

Gasification of Waste Biomass and Organic Waste Fractions

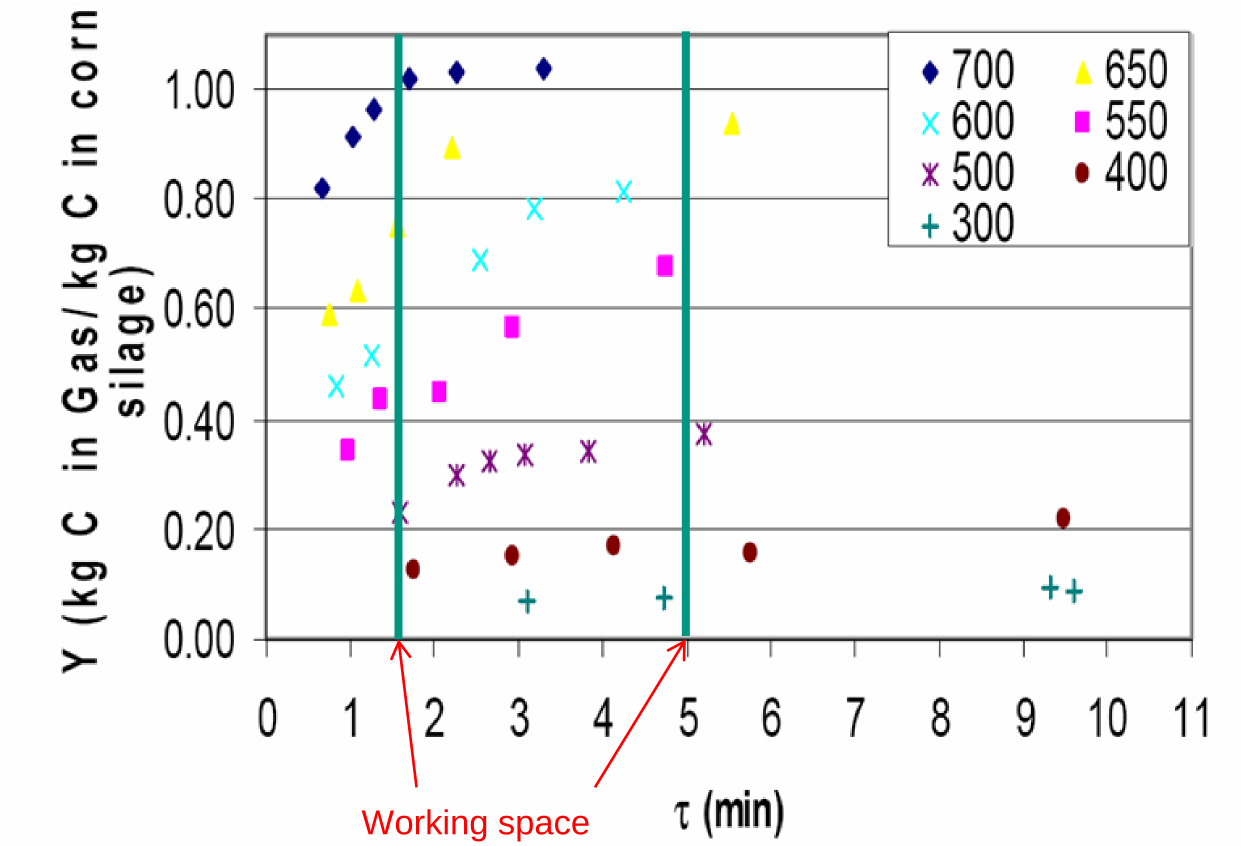
Process

Conditions: T ≈ 650 °C; p ≈ 280 bar



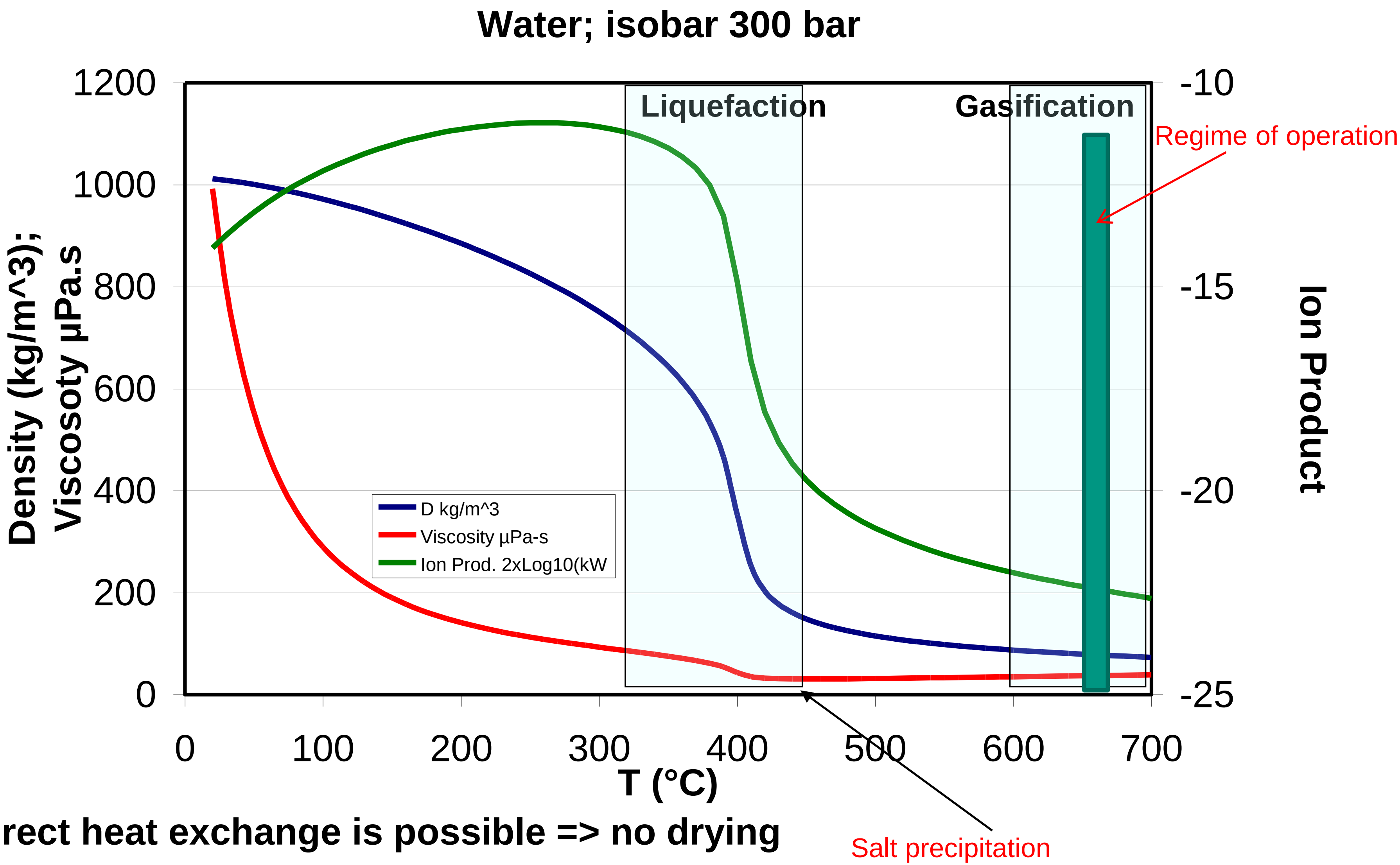
Gasification Yield as Function of the Residence Time and the Reaction Temperature

[**Corn silage**] = 5 wt%, p=250 bar



P. D´Jesus, N. Boukis, B. Kraushaar-Czarnetzki, E. Dinjus. Ind. Eng. Chem. Res. 2006, 45, 1622-1630

Properties of Water at High Temperatures and Pressure (T_c=374 °C, p_c=221 bar)



Direct heat exchange is possible => no drying

LENA – Test Rig, continuous flow,

T_{max}=700 °C, max. flow rate 2 l/h, $V_{Reactor}$=270 cm^3

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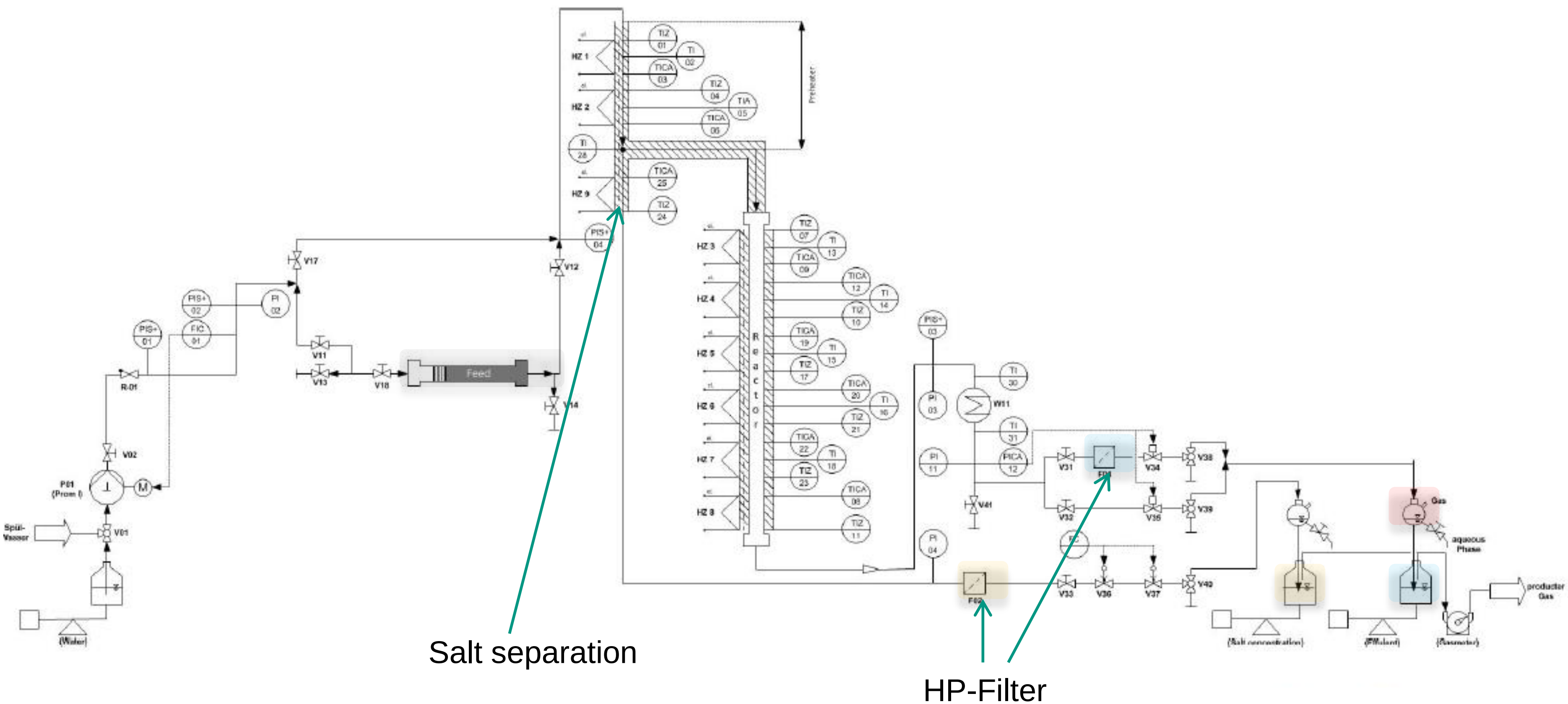


Sewage Sludge from Oljen and Lelystad

Type	w_{DM} Dry matter, wt.%	Ash content by 550 °C, wt.%
Lelystad	17,5	18,8
Oijen	27,4	20,40

	Feed analysis	
Parameter	wt. [%] Oijen	wt. [%] Lelystad
TC	41,6	43,5
TIC	0,1	0,1
TOC (C)	41,5	43,4
H	4,22	6,37
N	4,22	7,28
P	2,4	3,16
S	0,78	1,11
Ca	2,25	1,4
K	0,36	1,14
Mg	0,31	0,72
Na	0,088	0,105
Si	2,65	2,63
Al	1,22	0,56
As	0,02	0,02
Cd	0,01	0,01
Cu	0,56	0,018
Pb	0,011	0,02
Zn	0,086	0,032
Cr	0,0039	0,01
Fe	1,38	0,38
Mo	0,02	0,02
Ni	0,02	0,02

Main results, steady state operation
Total sewage sludge treated 2 – 3 kg per experiment

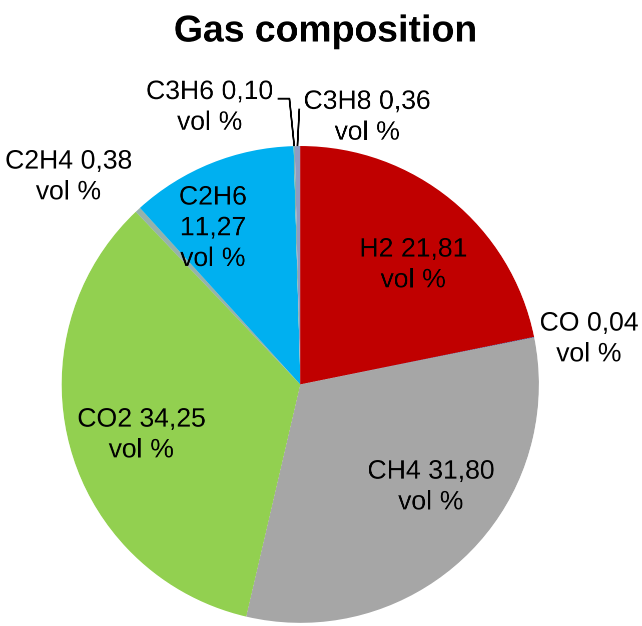
Type	Time steady state	Feed steady state	C_{total} steady state	Plugging	Y_{Gas}	Y_C	TOC-destruction	TOC-waste water	NH_4^+-waste water	TNb-waste water
[-]	[h]	[g]	[g]	[after h]	[%]	[%]	[%]	[mg/l]	[mg/l]	[mg/l]
Lelystad	5	2115	109,18	No	67,95	80,67	97,8	1953	11724	9300
Oijen	3,93	1656,5	88,86	6,5	71,21	81,83	96,7	2141	8821	5580

Carbon balance during steady state operation is 80 % an indication of accumulation of Carbon in the system (insoluble carbonates in the filter cakes)

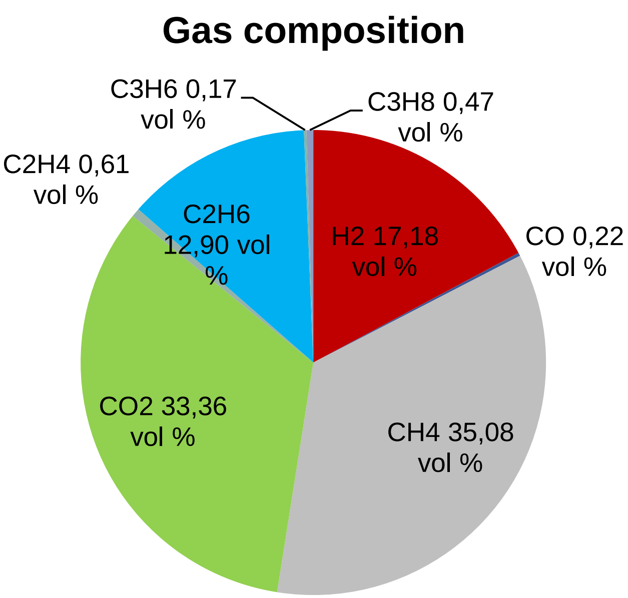
Hydrothermal Gasification of Sewage Sludge

Sewage sludge	$T_{Reaction}$	Concentration	mean res. time
type	[°C]	[wt. % DM]	[min]
Lelystad	653	11,69	2,75
Oijen	649	12,71	2,76

Type Lelystad

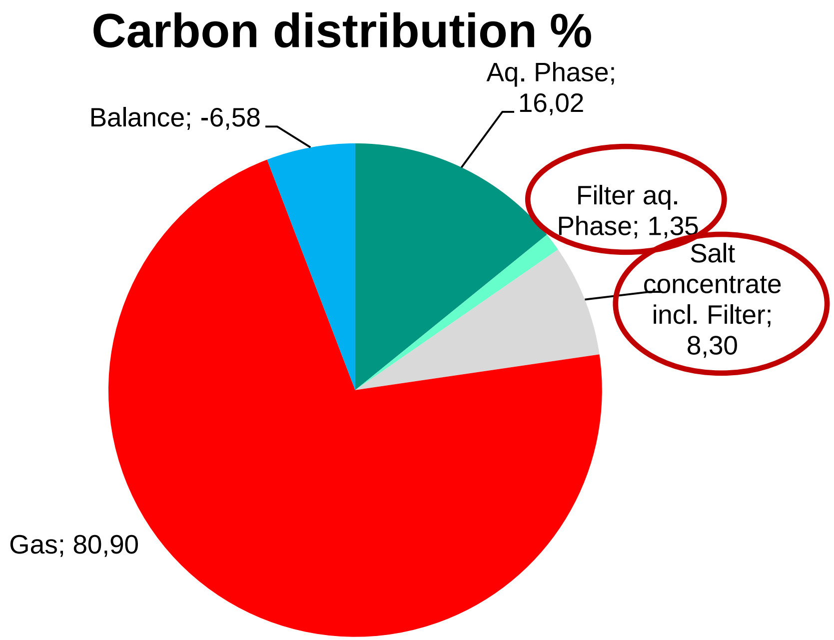


Type Oijen

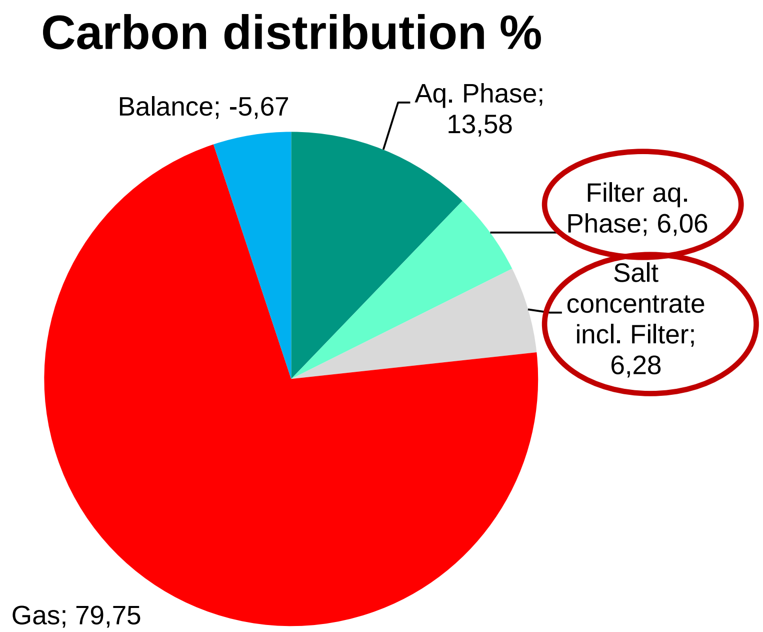


The Carbon Balance

Type “Lelystad”

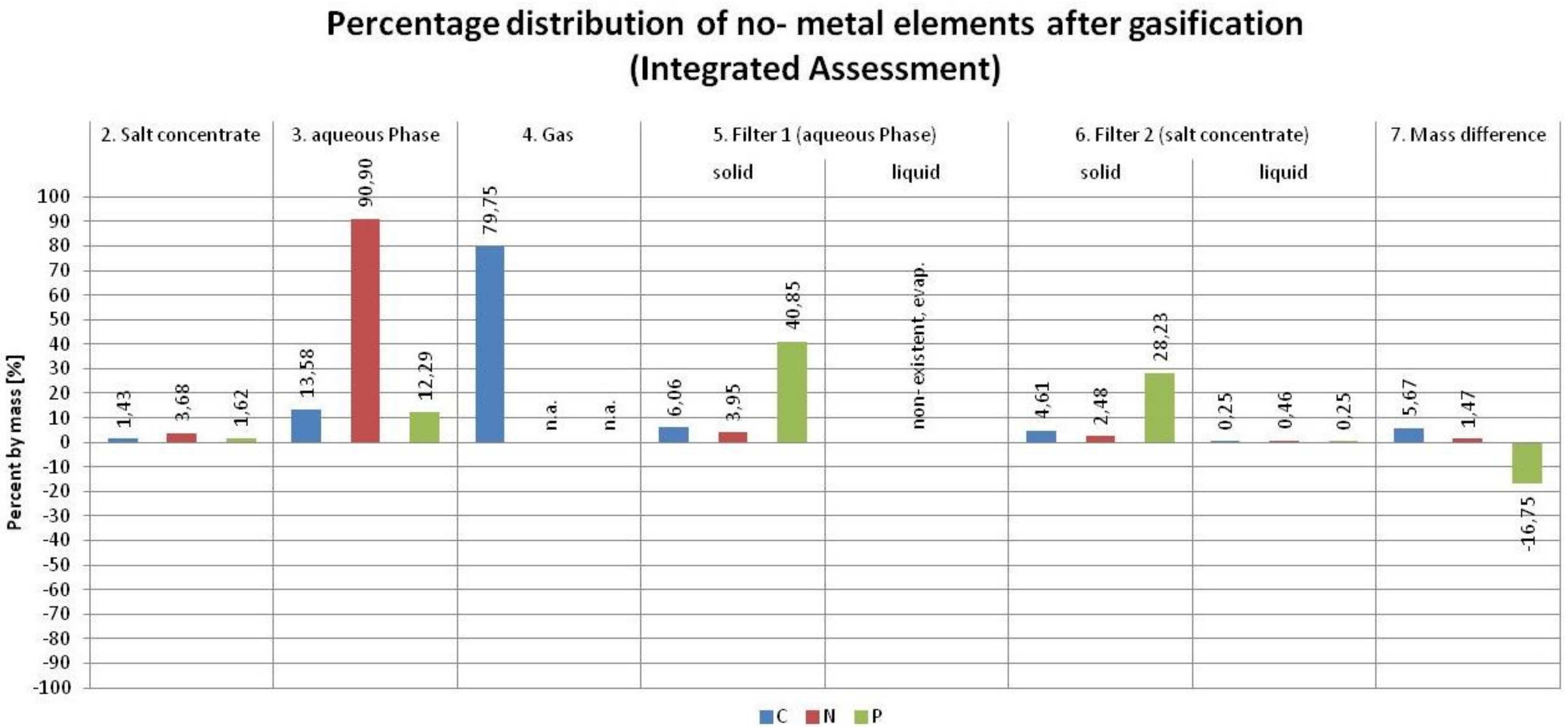


Type “Oijen”

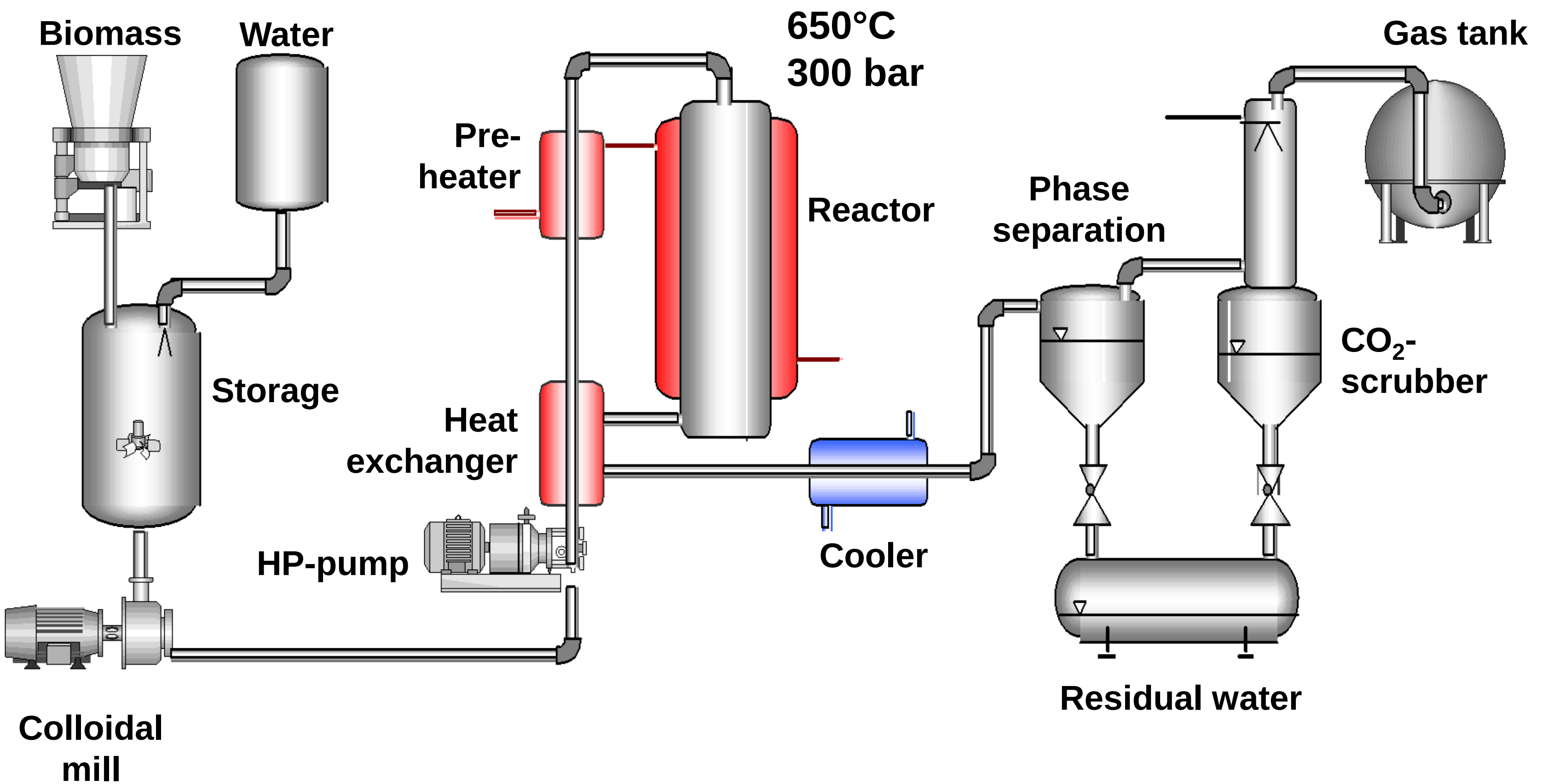


The carbon balance for the whole experiment is much better.
About 10 % of the Carbon forms carbonates

Type Oijen C, N, P Detailed Analysis



Scale-up to Pilot Scale (1)



VERENA pilot plant at KIT

Scale-up to Pilot Scale (2)

Reactor

35 L volume
0,11 m i.D., 3,7 m length
Inconel Ni-Alloy
External Heating
35 Mpa; 700 °C

Feeding

100 kg / h
5-20 % dmc

Conclusions for Hydrothermal Gasification

- Stable operation with “difficult feedstock” sewage sludge is possible
- Good carbon balance in lab scale (100 ± 10 %)
- High gasification yield (80 %) and η (up to 0.9). Acceptable efficiency at 12 wt.% DM possible

Challenges

- Salt separation is of utmost importance
  - Fouling/ scaling e.g. in heat exchangers
  - Corrosion
- HTG of sewage sludge operates at the frontier of development modern materials of construction
- Suitable models for reaction kinetics and gasification reactor are missing

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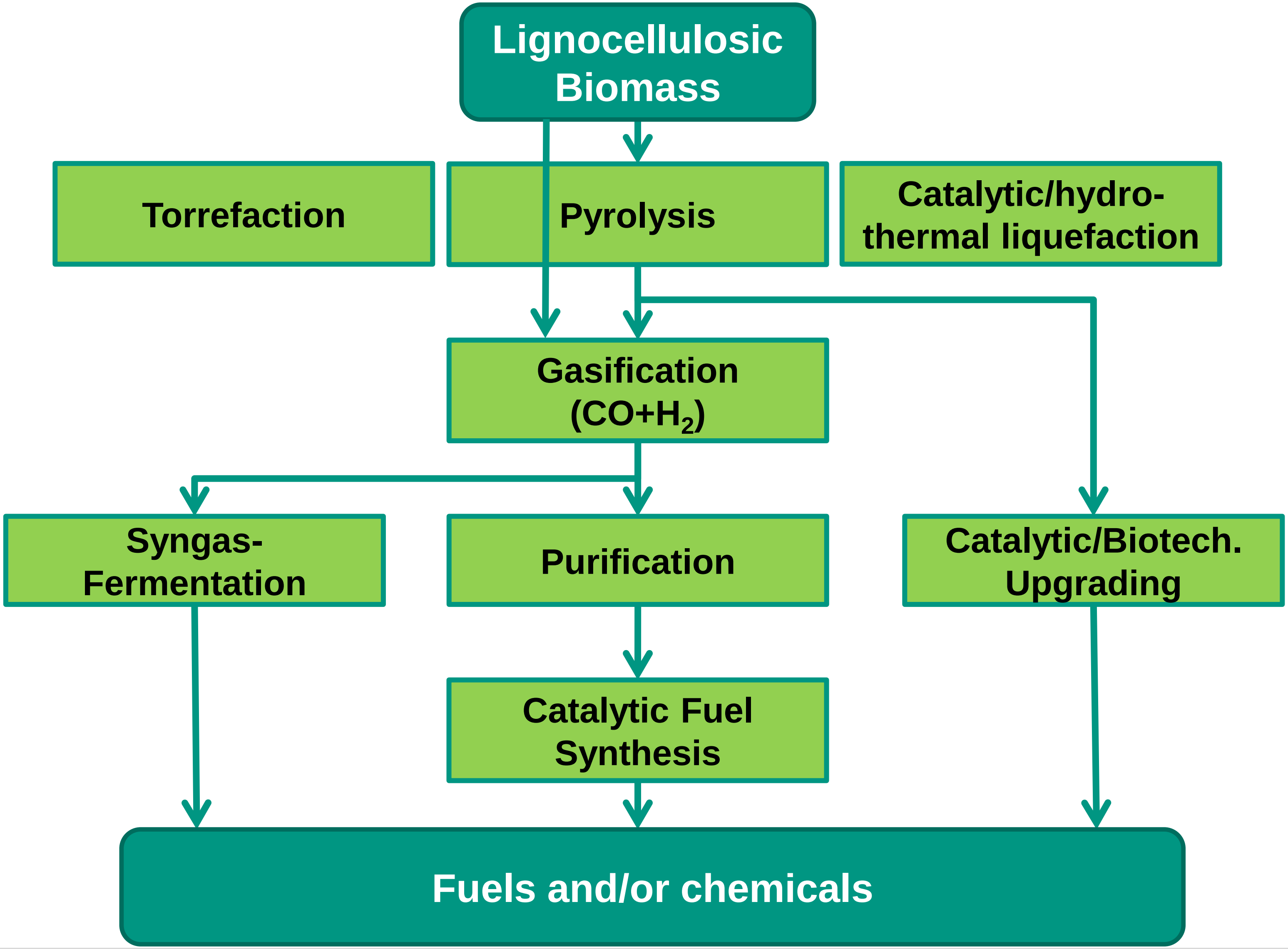
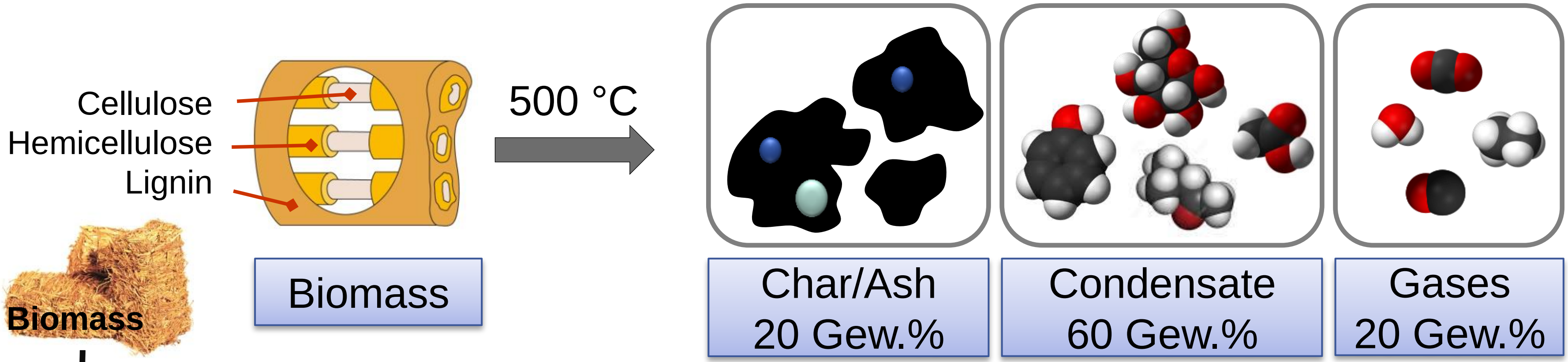
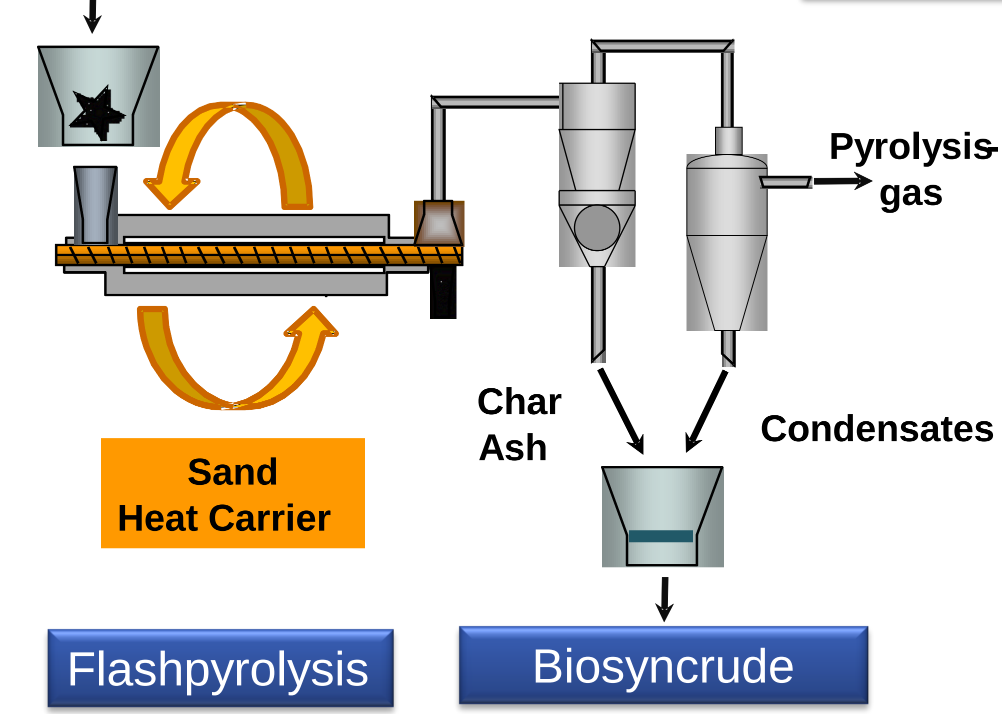
Thermochemical BtL Value Chains

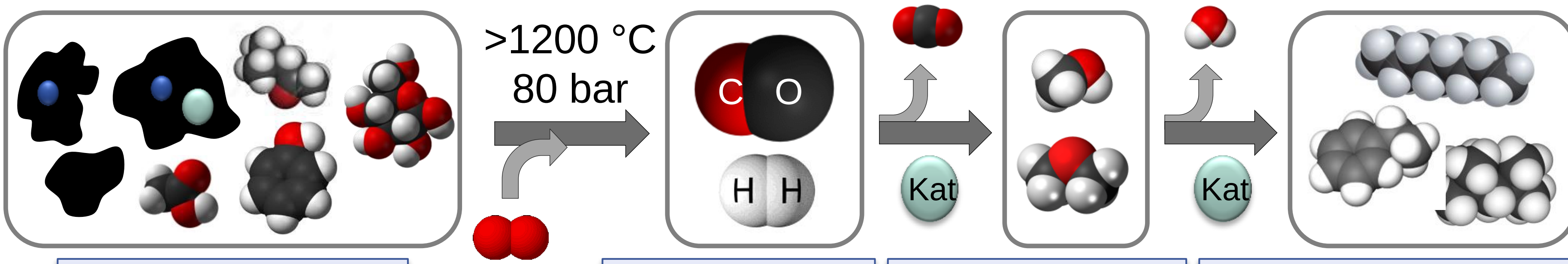


Chemistry and Technology – decentralized





Chemistry and Technology – centralized

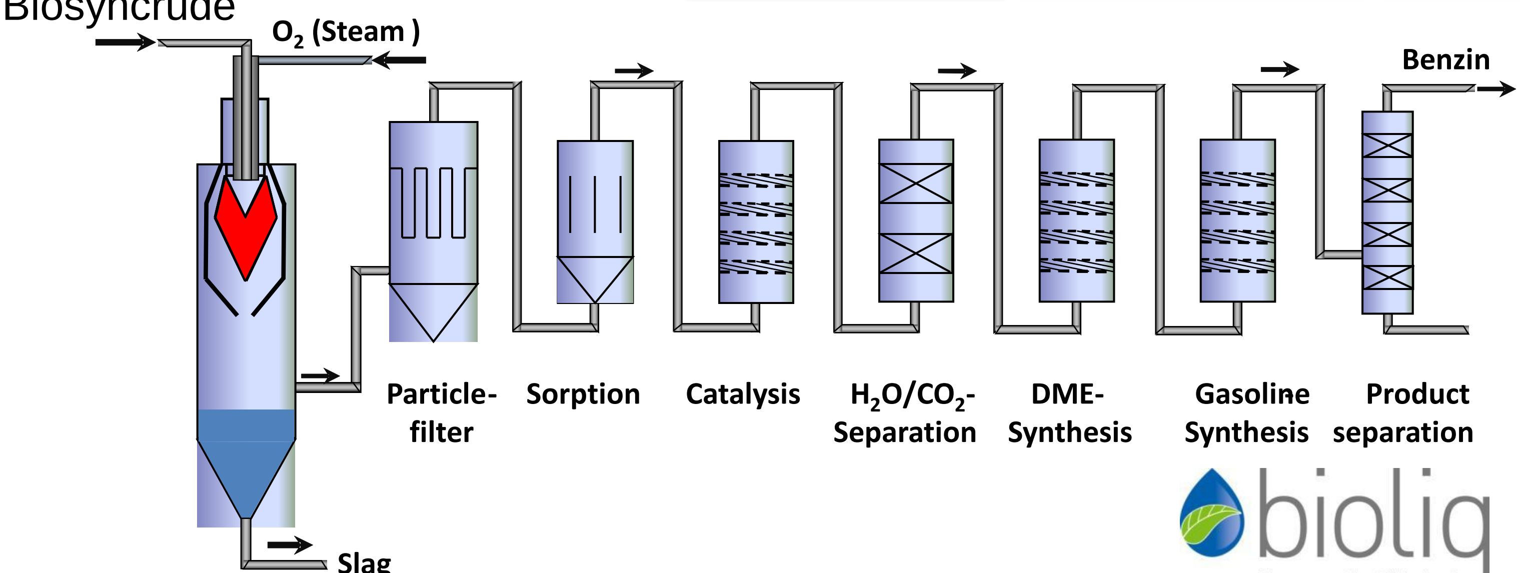


Biosyncrude

Syngas
CO_2, u.a.

Methanol
Dimethylether

Hydrocarbons



Diesel
Kerosine
Ethylene
Propylene
Methane
Hydrogen
…
Synthetic biofuels

Entrained Flow Gasification | Gas Cleaning | Fuel Synthesis

bioliq®-Pilot Plant at KIT

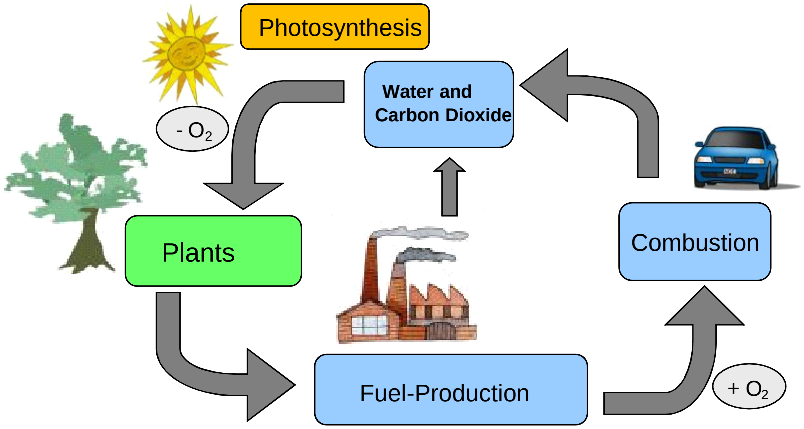
Fast Pyrolysis Biosyncrude-Production	Gasification Syngas-Production	Gas-Cleaning and Fuel Synthesis

Technical Validation & **Platform for Research**

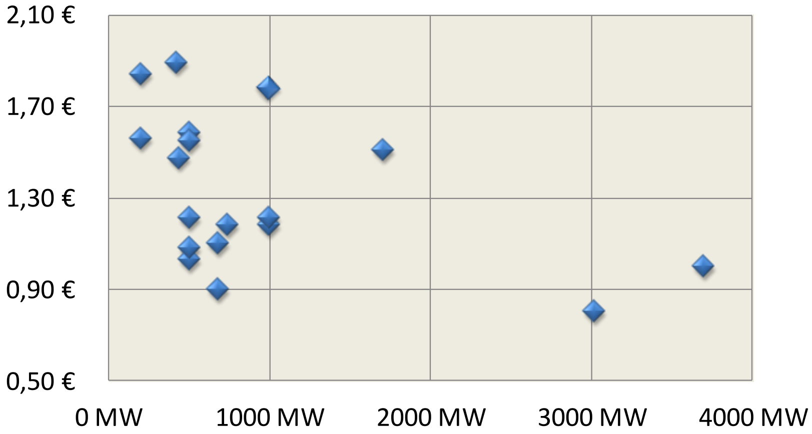
- Mass and energy balances
- Scale-up
- Stability and availability
- Production costs

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

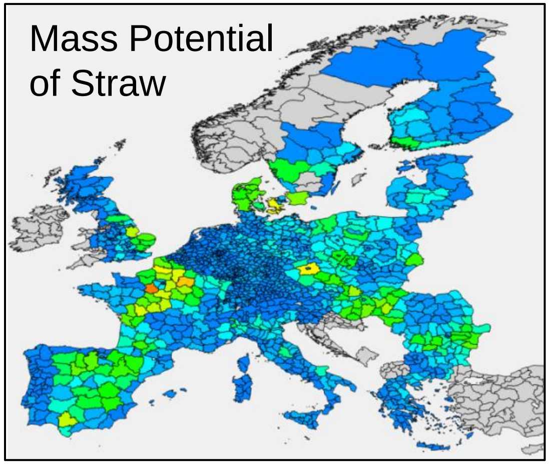
Contributions to the Analysis on the System Level



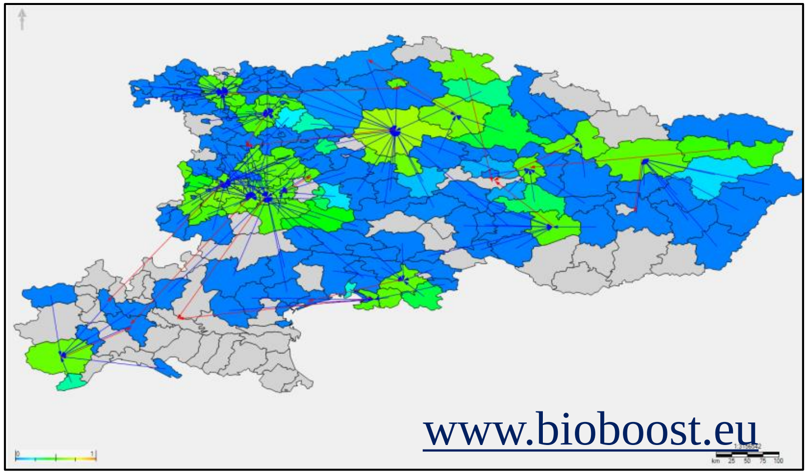
CO_2 reduction potential > 80 %



Production Costs



Potentials of sustainable supply



Logistics simulation and production network

Next steps

- Improve availability of pilot plants
- Process optimization and further development
- Development of business models
  & market implementation plans
- Creation of a consortium for the development
  of high performance fuel components

Units → Chains → Networks → Systems

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aufgrund eines Beschlusses des Deutschen Bundestages

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

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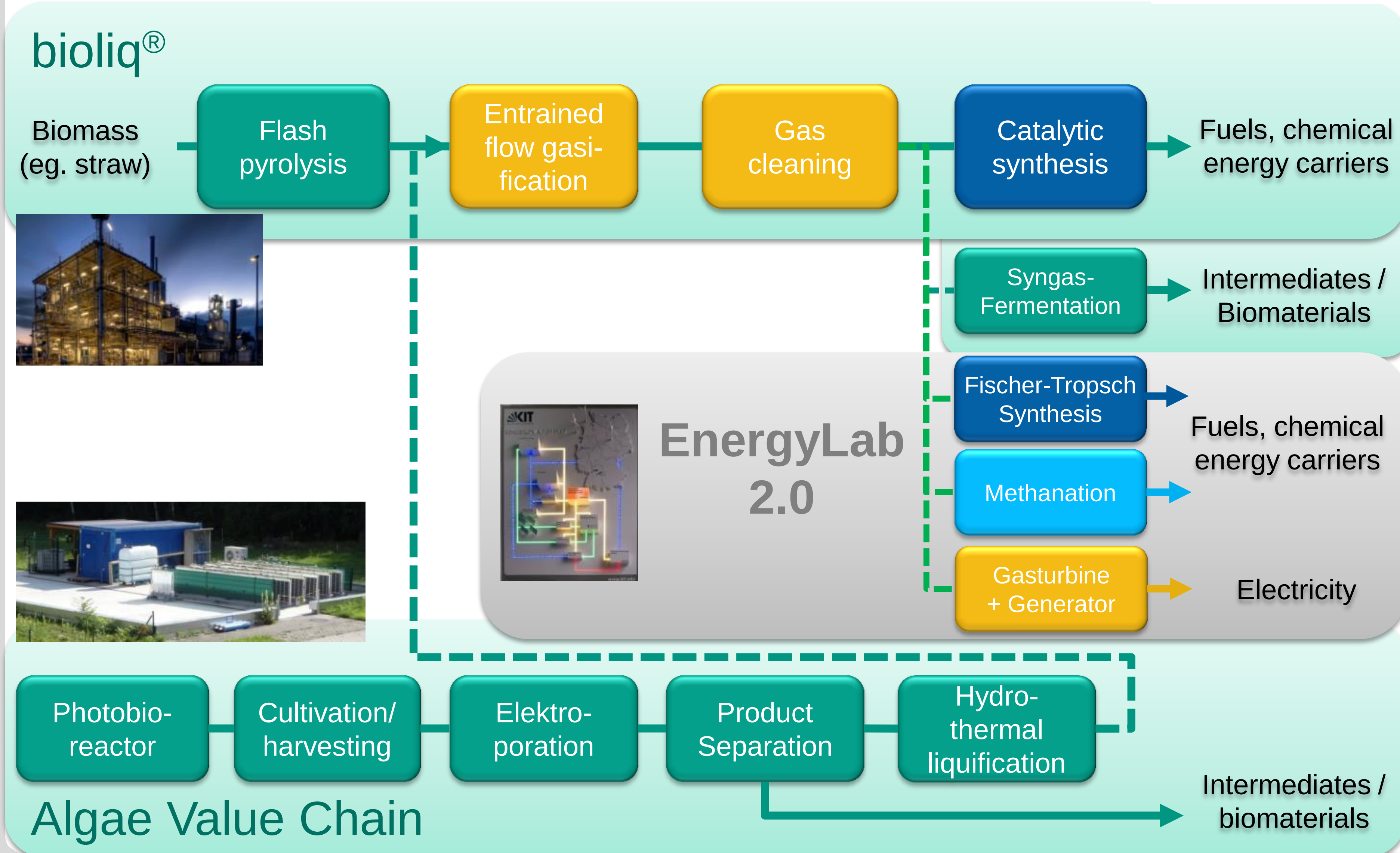
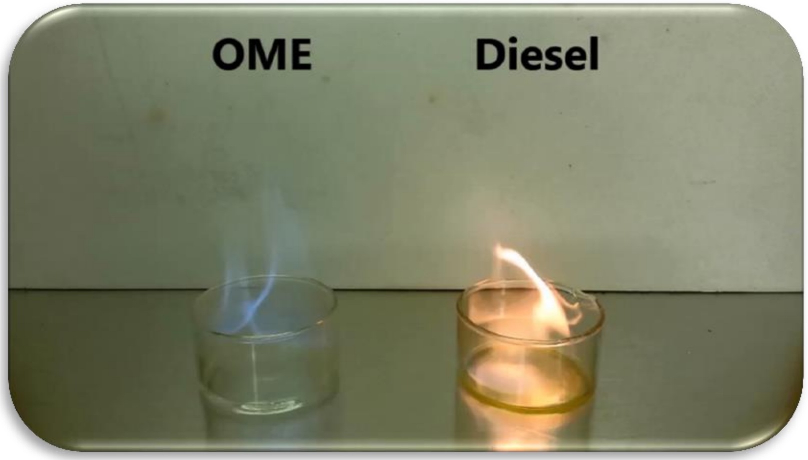
The Future of Bioenergy Research at KIT (1)
„Integration into the Energy System“

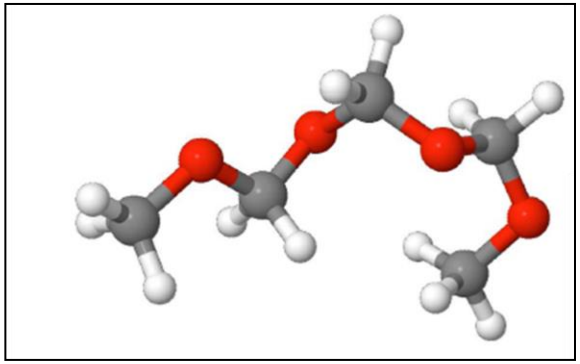


The Future of Bioenergy Research at KIT (2) „Synthetic High Performance Fuel Components“

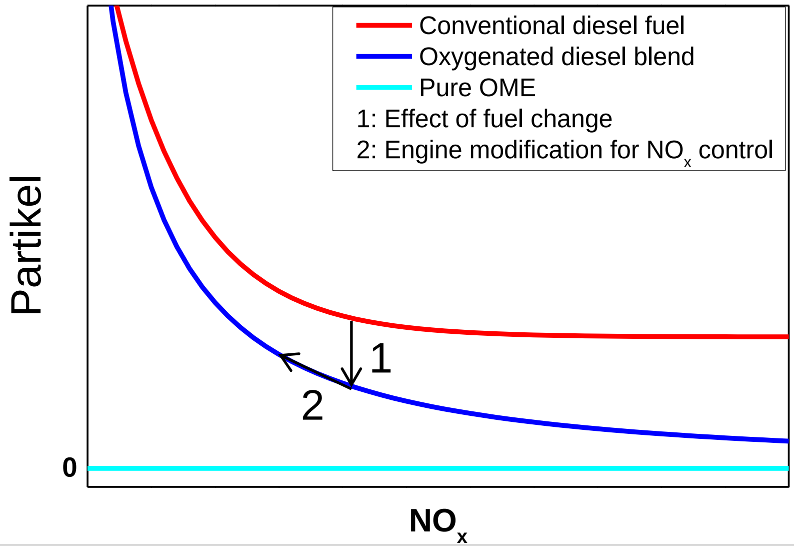


Elements

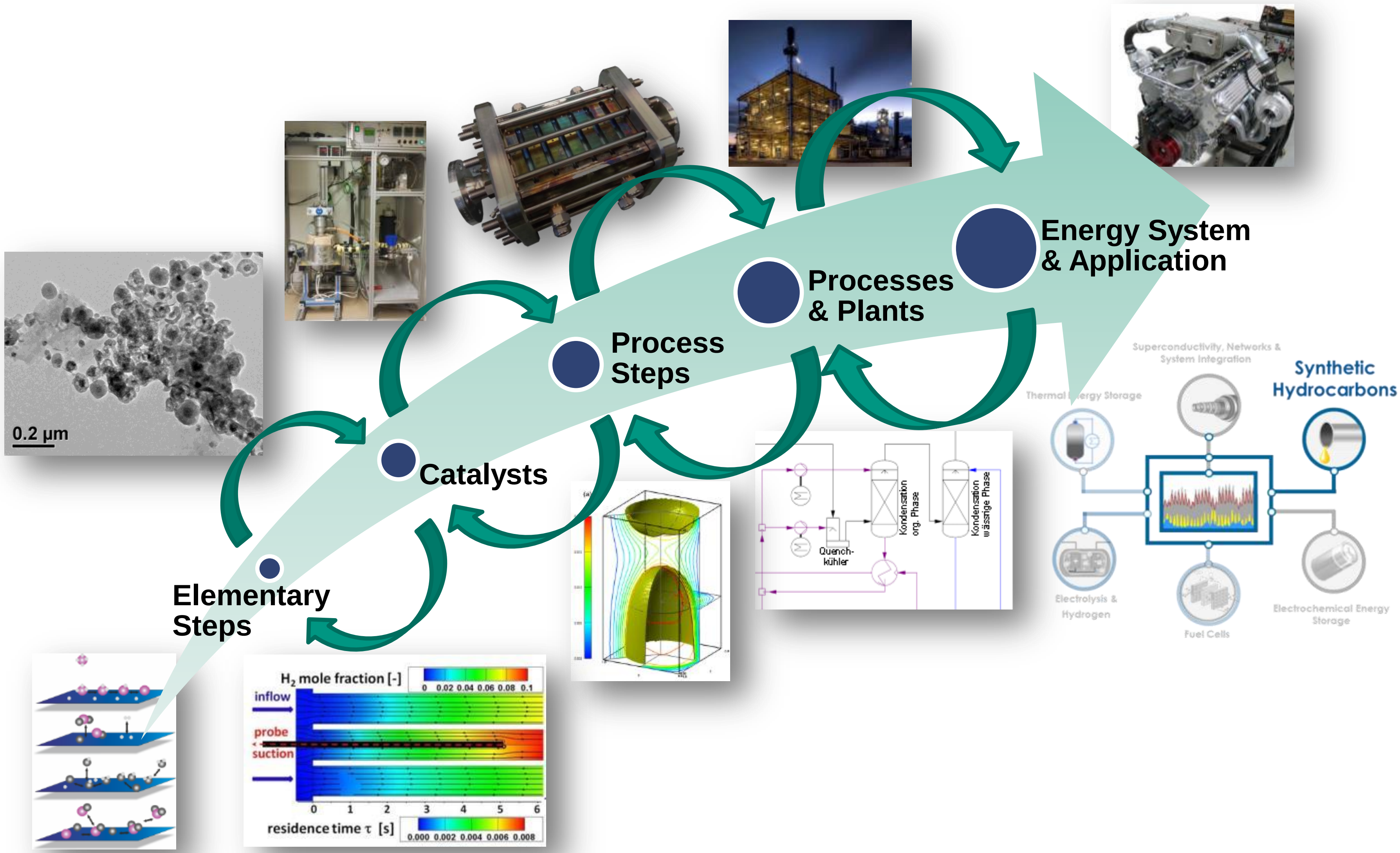
- Compatible to present fuels (drop-in)
- Reduced emissions
- Increased performance
- Reduced fuel consumption
- Reduced CO_2-footprint



Bsp.: Oxymethylenether (OME)



From Fundamentals to Applications and the Integration into the Energy System



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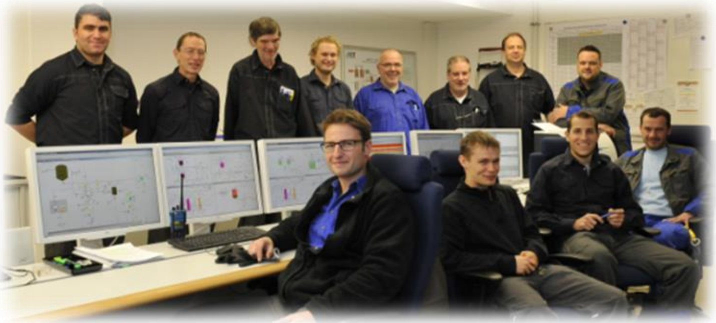
- The teams from KIT

- The audience for your kind attention



HELMHOLTZ
GEMEINSCHAFT

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

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Bundesministerium
für Ernährung
und Landwirtschaft

aufgrund eines Beschlusses
des Deutschen Bundestages

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