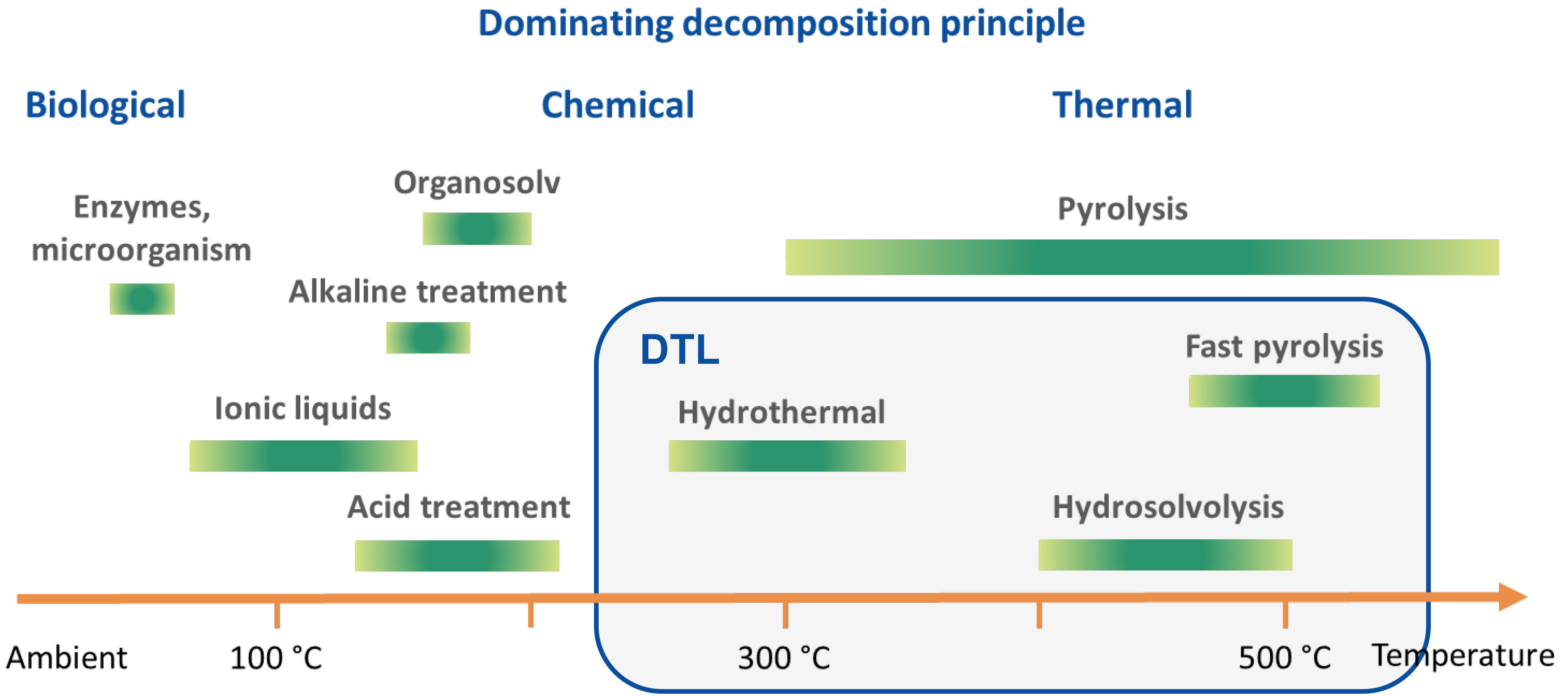
Fast pyrolysis oils and their application

Axel Funke, Frederico Fonseca

Overview

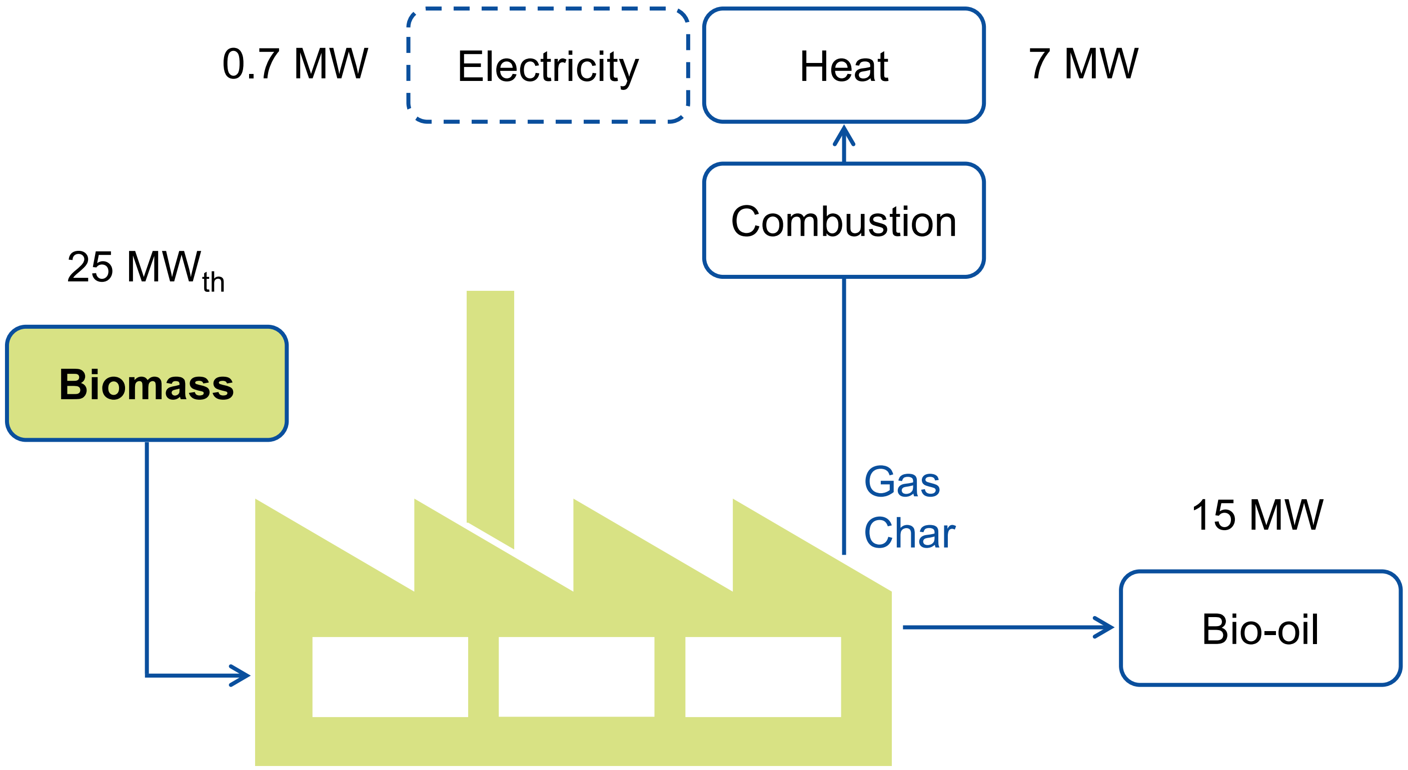
- Fast pyrolysis

Direct Thermal Liquefaction



Funke, A. and Dahmen, N. “Direct Thermochemical Liquefaction: Characteristics, processes and technologies” (2020), https://task34.ieabioenergy.com/dtl-brochure/

State-of-the-art: Fast Pyrolysis

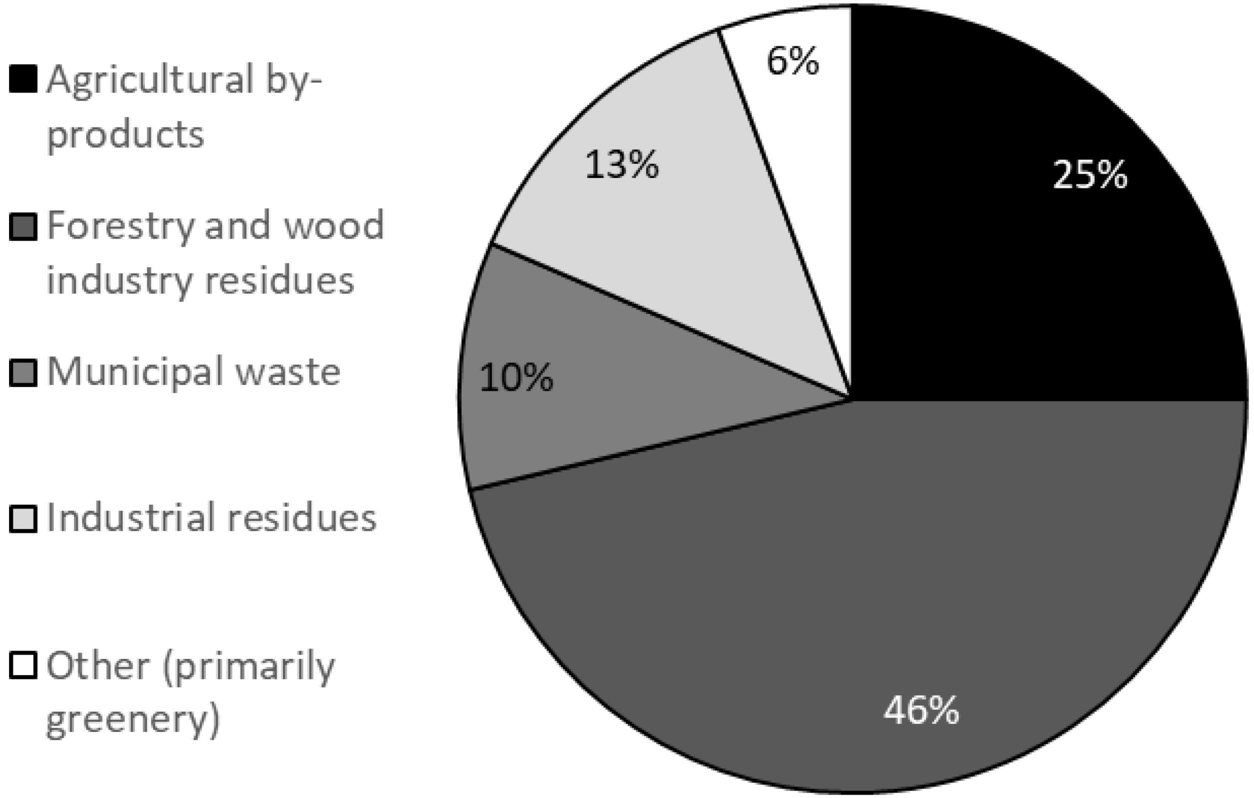


Data from: IEA Bioenergy Inter-Task Project on High Temperature Heat for Industry “Industrial heat case study 3: Process steam in a dairy factory via fast pyrolysis bio-oil” (2020), www.ieabioenergy.com

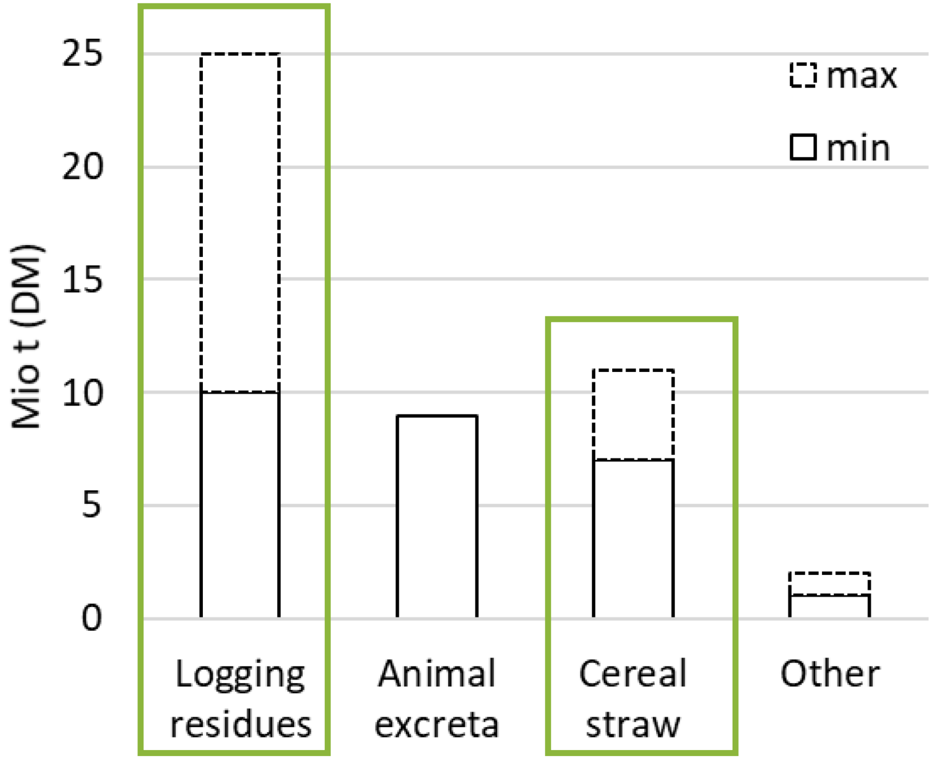
- Commercial operation for wood (residues)
  - decentralized
- Main product bio-oil is standardized product
  - REACH registered
  - EN 16900 (>1 MW boilers)
  - ASTM D7544 (industrial boilers)
- Integrated CHP from byproducts is ‚best case‘

Biomass residue potential Germany

Technical potential: 94-123 Mio t



Unused: 27-47 MTon



Brosowski et al. *Biomass and Bioenergy* 95 (2016) 257

Focus: hard-to-abate sectors

Heat	Biofuels	CO_2 removal (CDR)
(High temperature) process heat Housing Flexible power supply with CHP	Aviation Shipping Heavy duty transport	Reforestation CO_2 Sequestration Biochar
Combustion/ CHP	**Gasification/ Synfuels**	**CCS**
• Concepts with increased flexibility • Local heating networks	• Efficient process chains with downstream fuel synthesis • Realization at scale	• Not proven for bioenergy, yet • Need to match bioenergy source

- Use of **biogenic residues** (low energy density, different/varying compounds that complicate processing
- **Fast ramp up** of technology to achieve the emission reduction targets (in the next 10-20 years)

Projections for bioenergy 2050: Germany

Karlsruhe Institute of Technology

Final Energy Today

900 PJ bioenergy

- Electricity from biomass dominated by biogas/ energy crops
- Bioenergy for heating characterized by decentralized micro installations
- Low share of biofuels for transportation

Transition (2030)

Focus on system services
- Renewable carbon
- Advanced biofuels
- Process/ residential heat with CHP
- Solutions for negative CO_2 emissions
- Material use

CCS
(Cost) efficiency
Decentralized Solutions

Avoid Lock-in Effects

Social Acceptance

Risk Minimisation

2050

Energy
660 PJ

Imports
1220 PJ
PtX
BtL

CCS
>35 Mt CO_2 p.a.

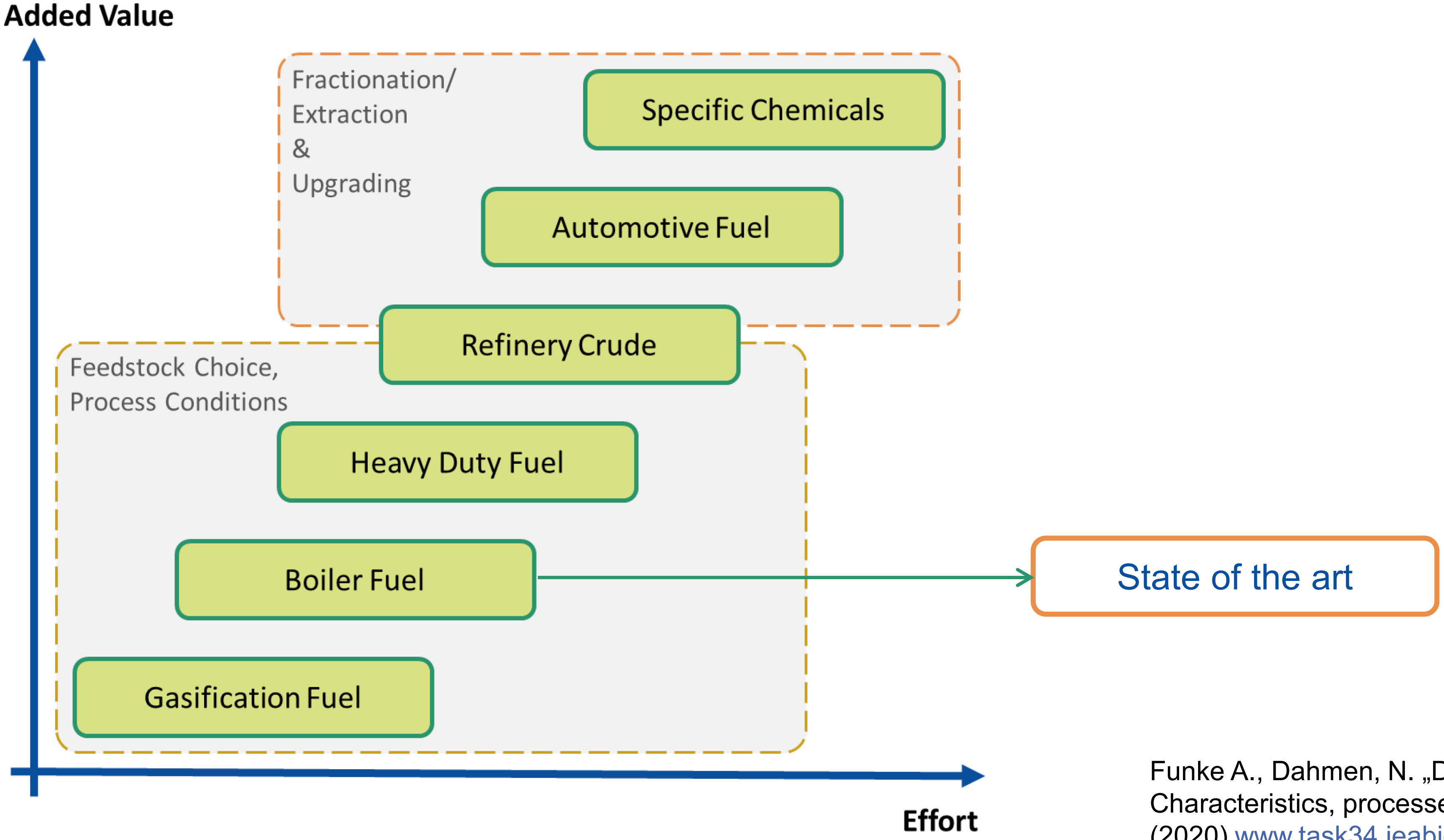
Carbon Products
(n.q.; 180 PJ imports)

‚dena-Leitstudie Aufbruch Klimaneutralität' (Deutsche Energieagentur), 2021
Leopoldina Position Paper 'Biomass: Striking a balance between energy and climate policies', 2019

Overview

- Bio-oil applications

Bio-oil applications – Overview



Funke A., Dahmen, N. „Direct Thermochemical Liquefaction: Characteristics, processes and technologies“ IEA Bioenergy (2020) www.task34.ieabioenergy.com

FPBO as boiler fuel

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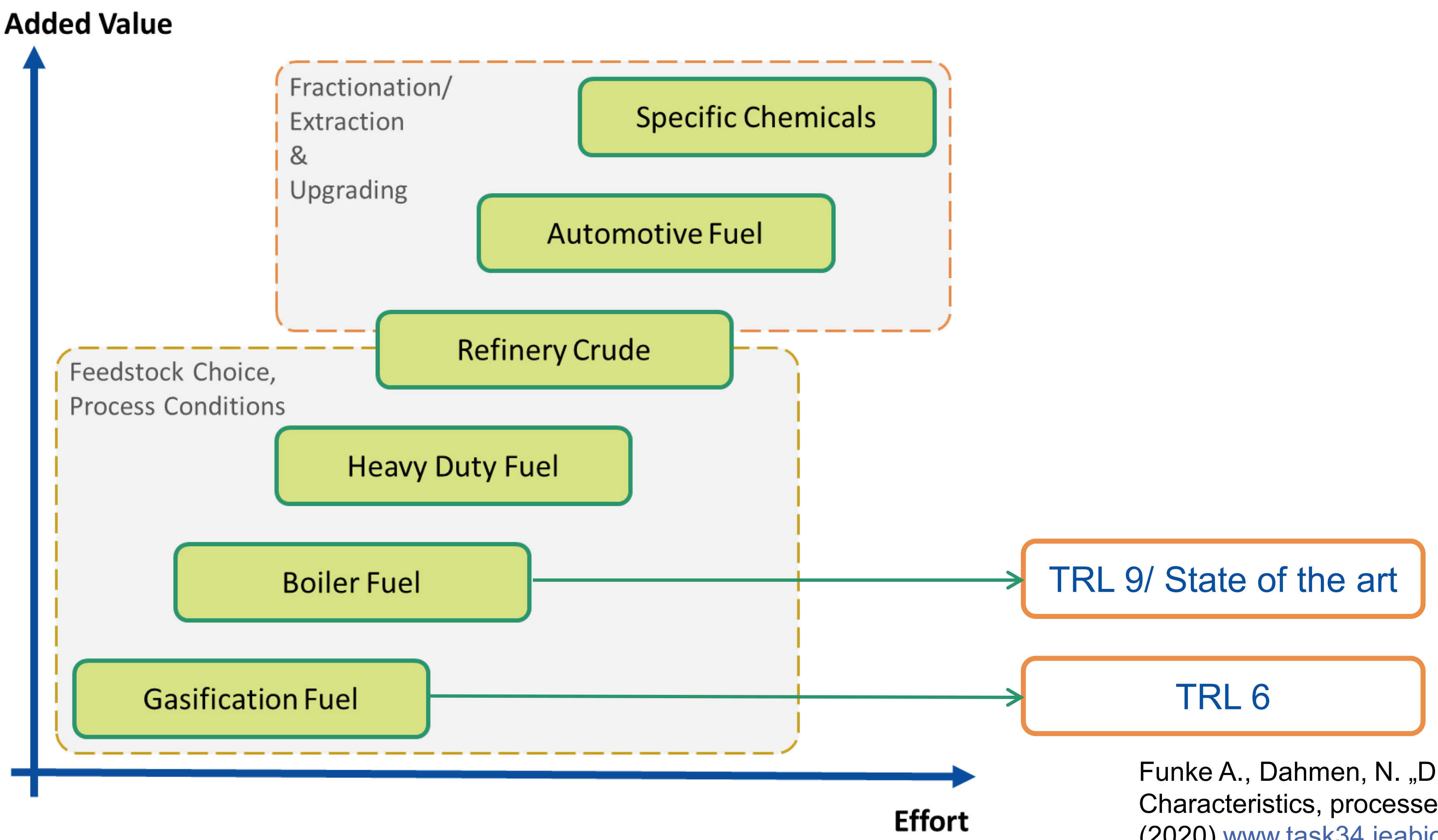
- Standardized fuel for industrial boilers (>1 MW)
  - EN 16900
  - ASTM D7544
- Fuel characteristics differ from fossil fuel oil
  - Adapted boilers are available on the market
- Enables CHP operation on (residual) biomass resources
  - Small scale application under development (e.g. H2020 Residue2Heat project)

Analysis	FPBO	Fuel oil
C, dry (wt%)	50 – 60	86
H, dry (wt%)	6 – 7	11 – 14
O, dry (wt%)	35 – 40	0 – 3
Nitrogen (wt%)	< 0.4	0 – 0.3
Sulfur (wt%)	< 0.05	0.2
Water (wt%)	20 to 30	0.025
Solids (wt%)	0.01 to 0.1	0
Ash (wt%)	0.01 to 0.2	0.01
Viscosity @40 C	15 – 35	3.0 – 7.5
Density @15 C	1.10 – 1.30	0.89
Flash point (°C)	40 – 110	60
Pour point (°C)	-9 to -36	-15
LHV (MJ/kg)	13 – 18	40.3
pH	2 – 3	neutral

Adapted from: www.task34.ieabioenergy.com

Bio-oil applications – Overview



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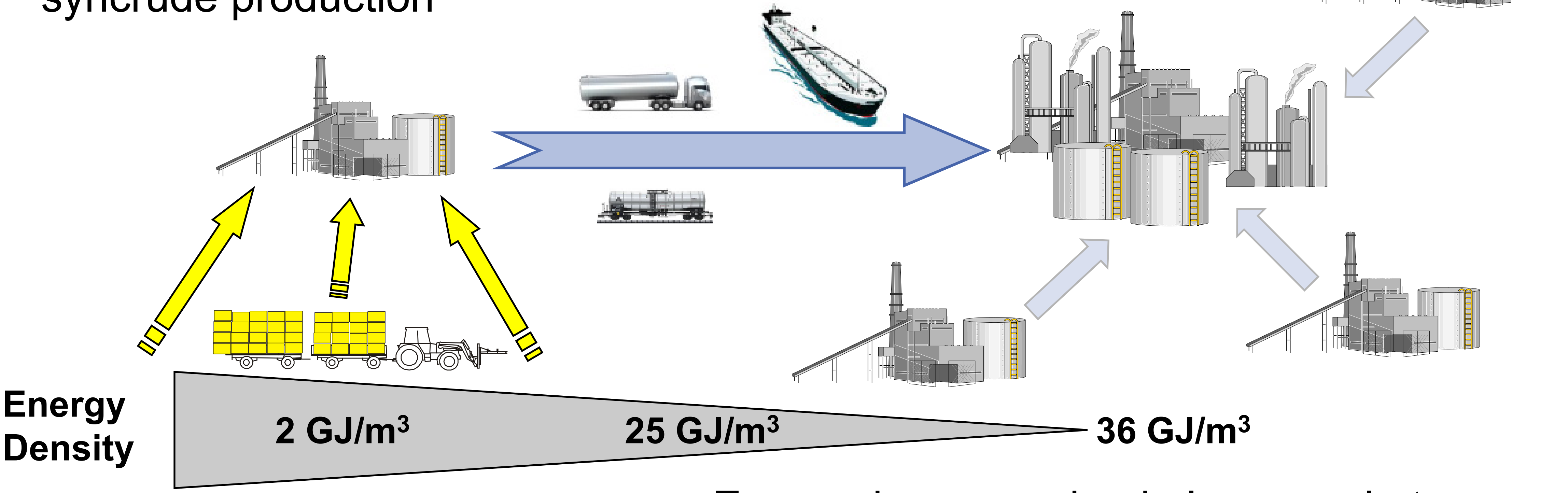
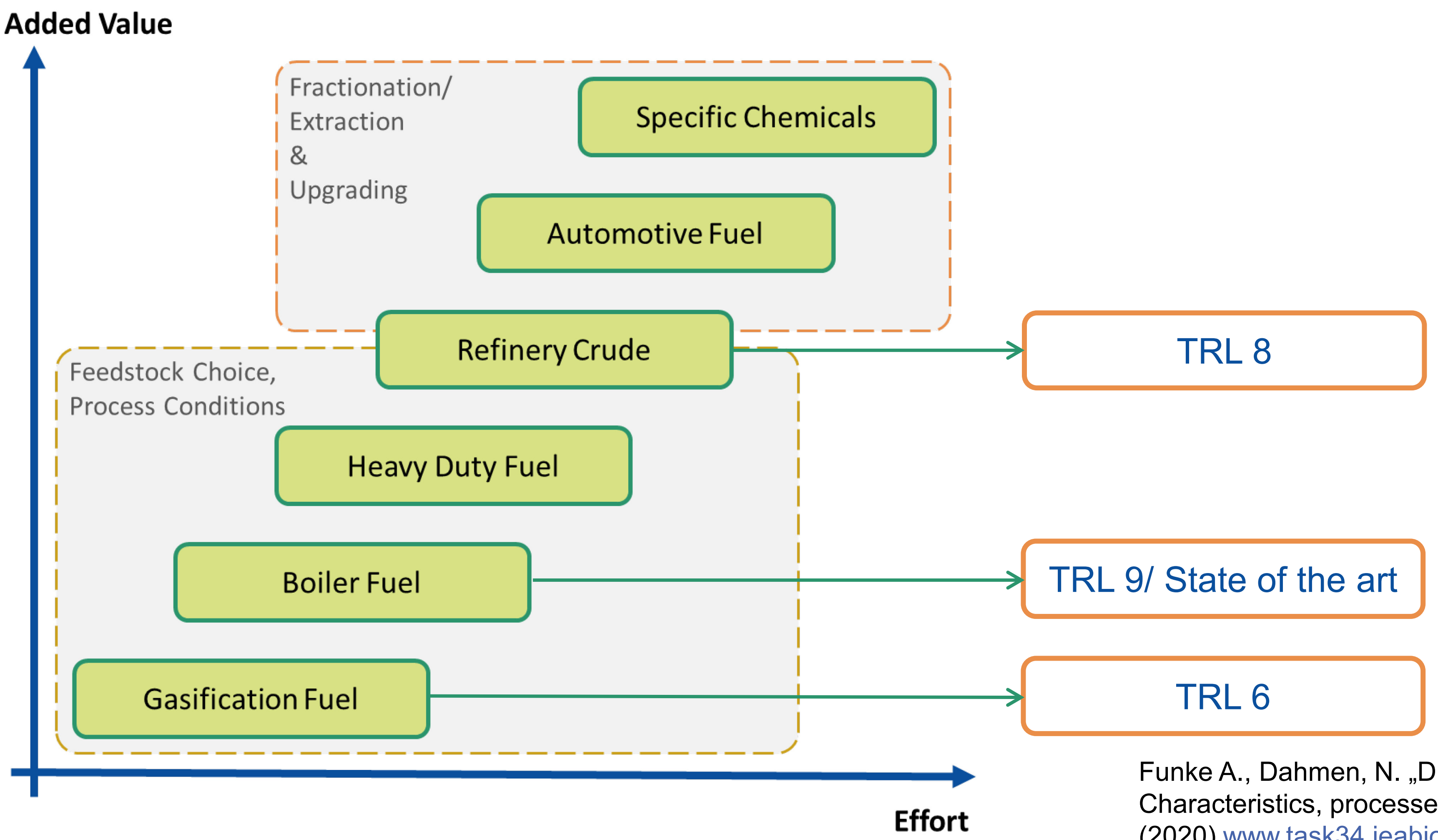
bioliq® concept to enable gasification at scale

- Energy densification of biomass residues in regional distributed plants by bioliq® syncrude production



- Economic conversion in large scale to syngas and further refining into fuels & chemicals

Bio-oil applications – Overview



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Co-feeding of FPBO in refineries

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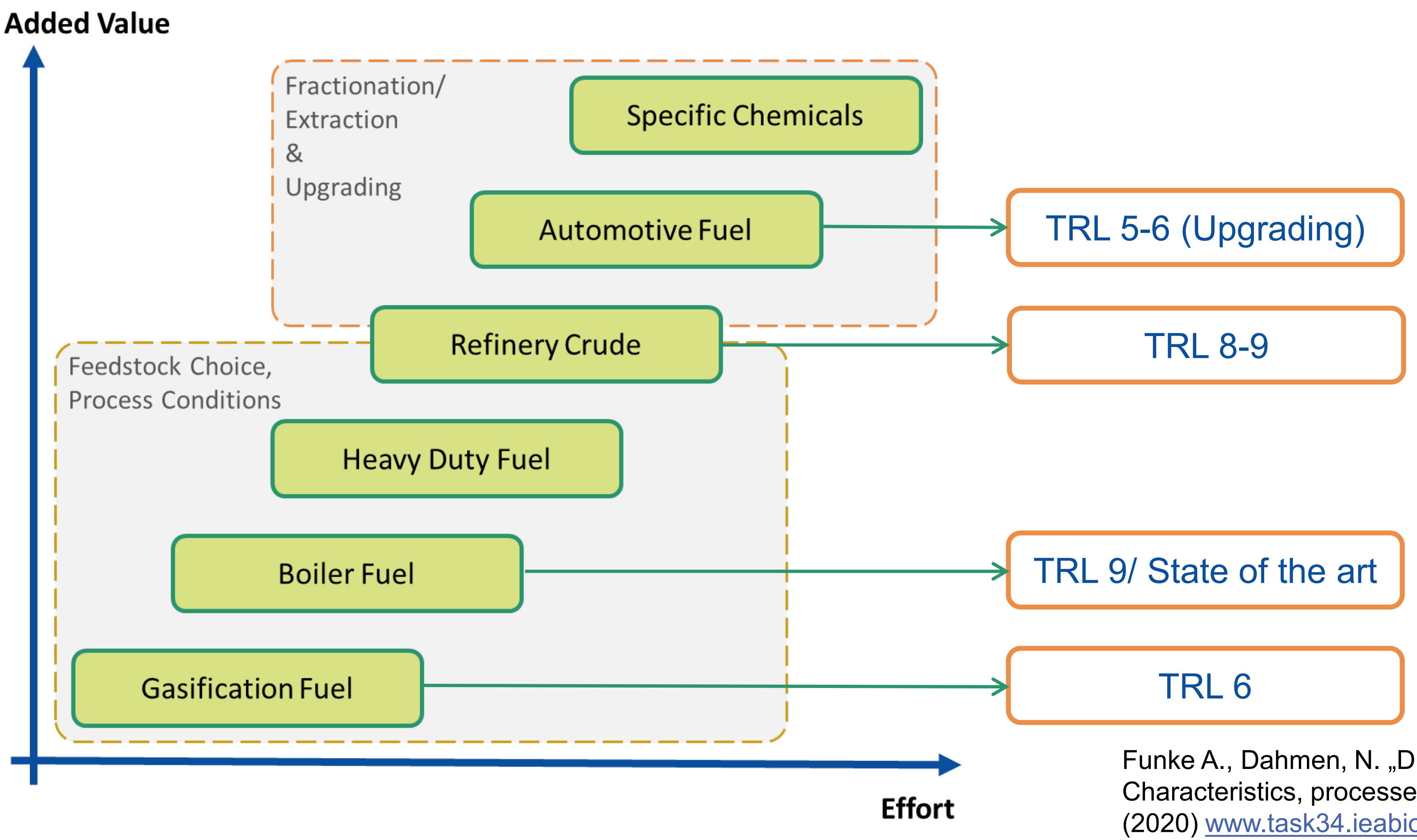
Image source: https://www.btg-bioliquids.com/plant/pyrocell-gavle-sweden/

- Untreated FPBO is currently being tested at Preem refinery/ Sweden
  - Co-feed of 1-3% of untreated FPBO
  - Long term operation 2022/2023
- Larger shares of co-feeding potentially possible with upgraded FPBO
- Fate of carbon largely unclear, yet
  - Refinery mass balances indicate compliance with RED II advanced biofuels, i.e. >80 % GHG reduction

Bio-oil applications – Overview



Funke A., Dahmen, N. „Direct Thermochemical Liquefaction: Characteristics, processes and technologies“ IEA Bioenergy (2020) www.task34.ieabioenergy.com

Upgrading to produce transportation fuels

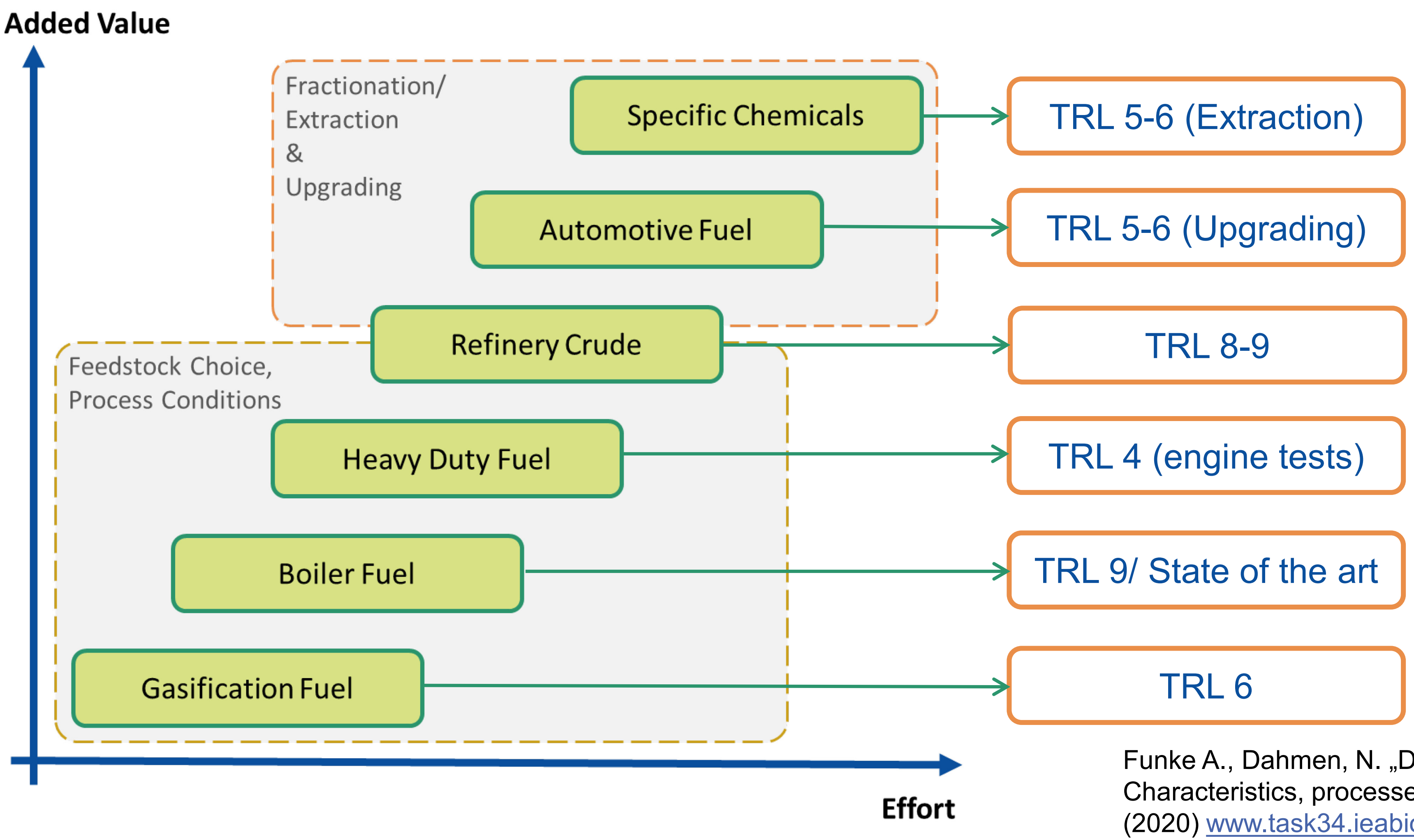
- Many activities around hydrotreatment of FPBO (TRL 2-8)
  - Specific needs to address sugar chemistry for (hemi)cellulose fragments

- Shell IH2 operates catalytic fast pyrolysis with integrated hydrotreatment and H_2 production
  - Demo-unit at TRL 7-8
  - Commercial unit at sawmill in Amli/ Norway planned by Biozin

Image source: https://www.gti.energy/producing-alternative-transportation-fuels-from-renewable-resources-with-ih2/

Bio-oil applications – Overview

Karlsruhe Institute of Technology



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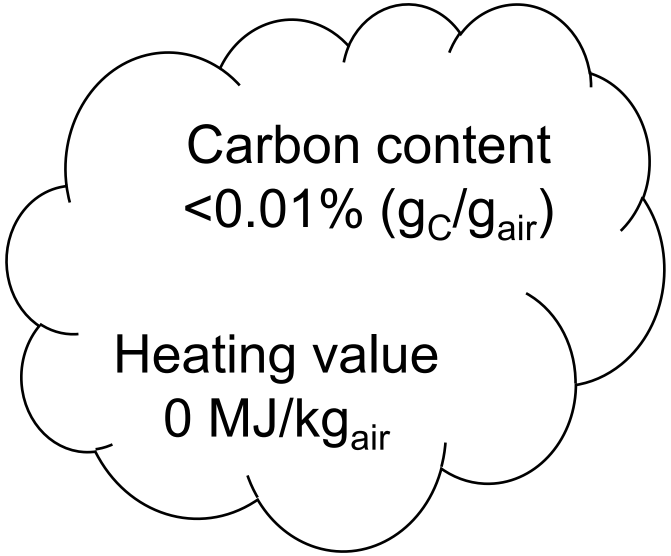
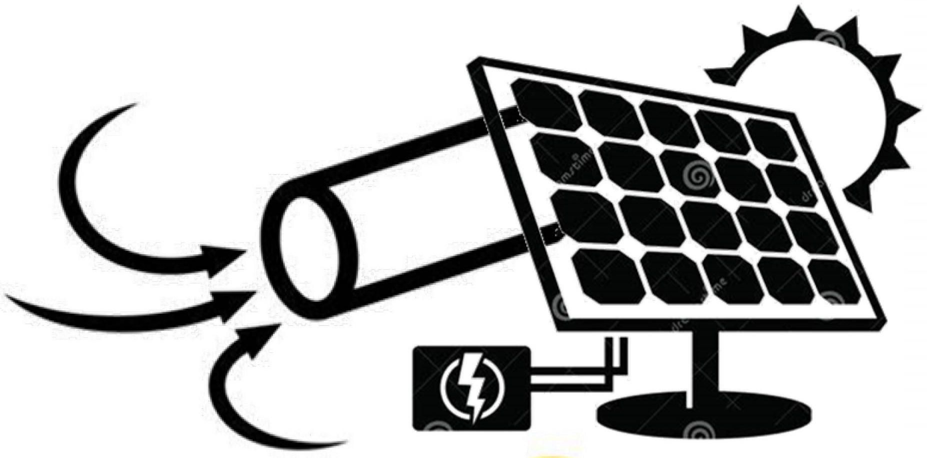
Overview

- Net CO_2 negative biofuel via fast pyrolysis

Carbon accumulation during biomass growth





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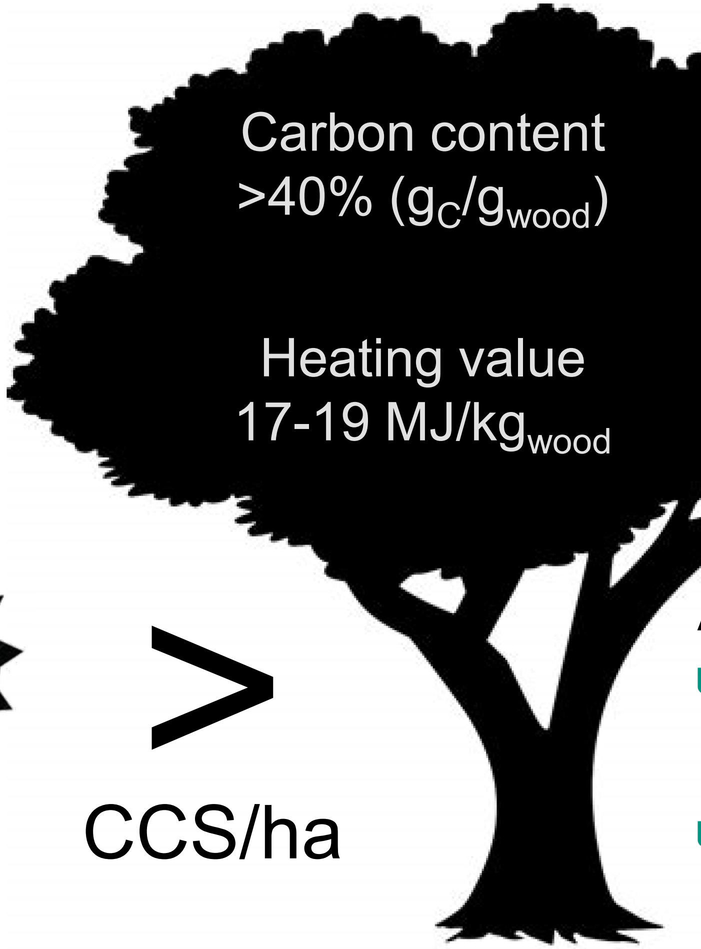
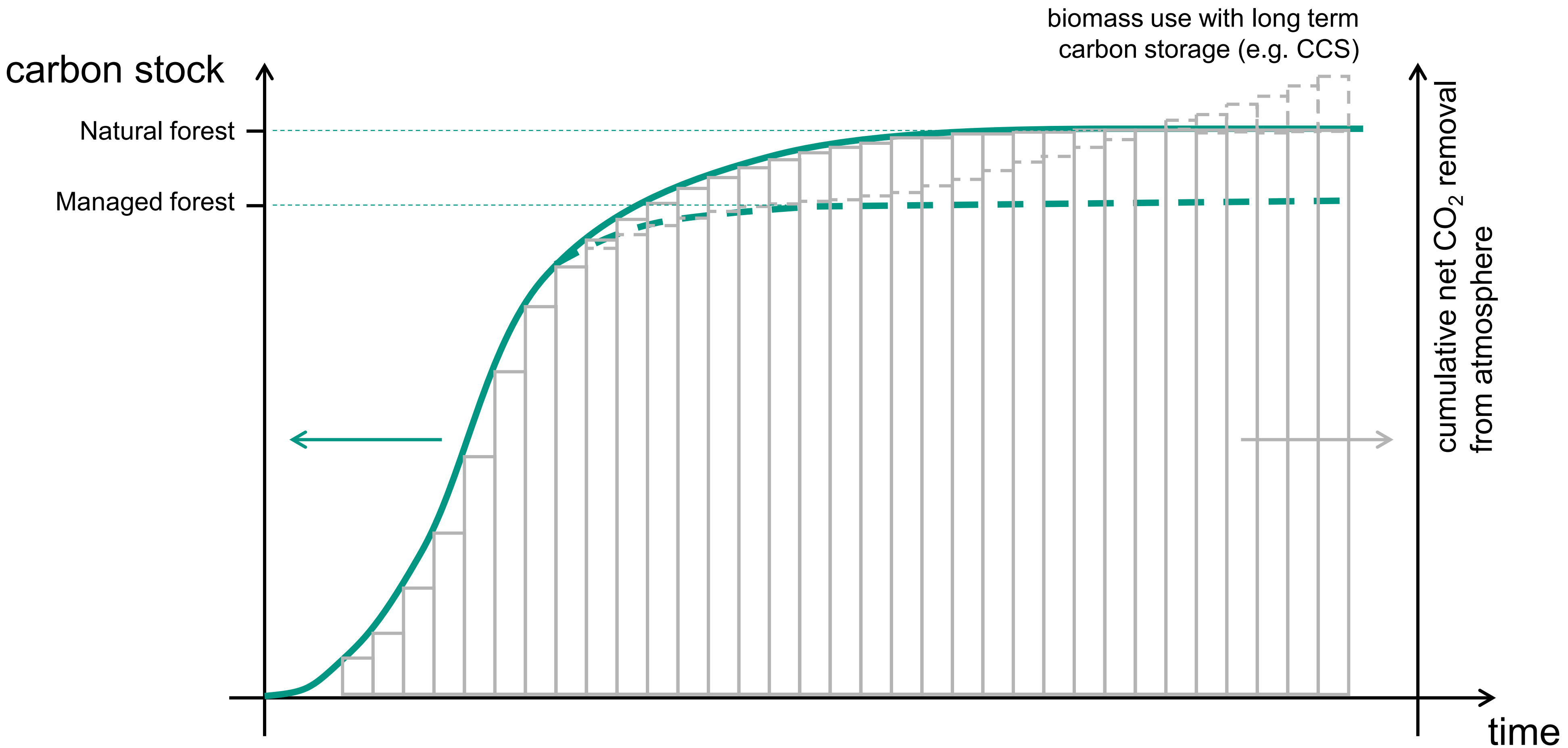


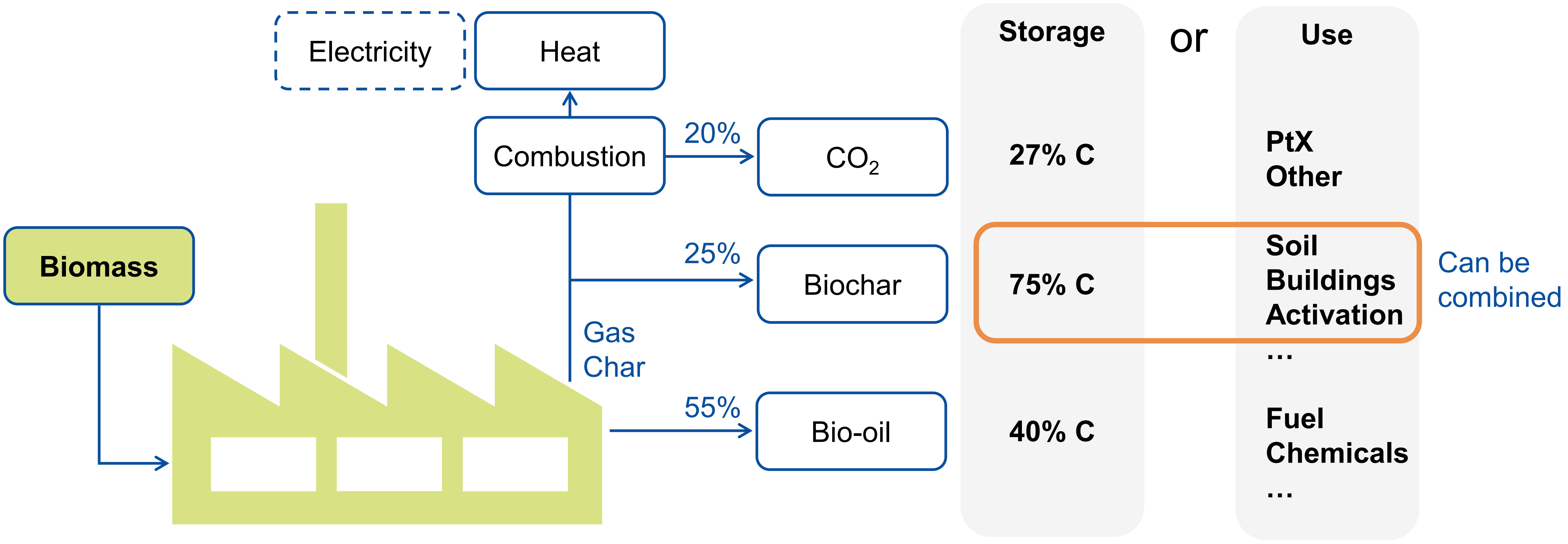
Advantages of biomass

- Combined accumulation **and** ‘activation‘ of CO_2
- Production of enriched/ pure CO_2 **and** simultaneous energy provision

Carbon stock in forests

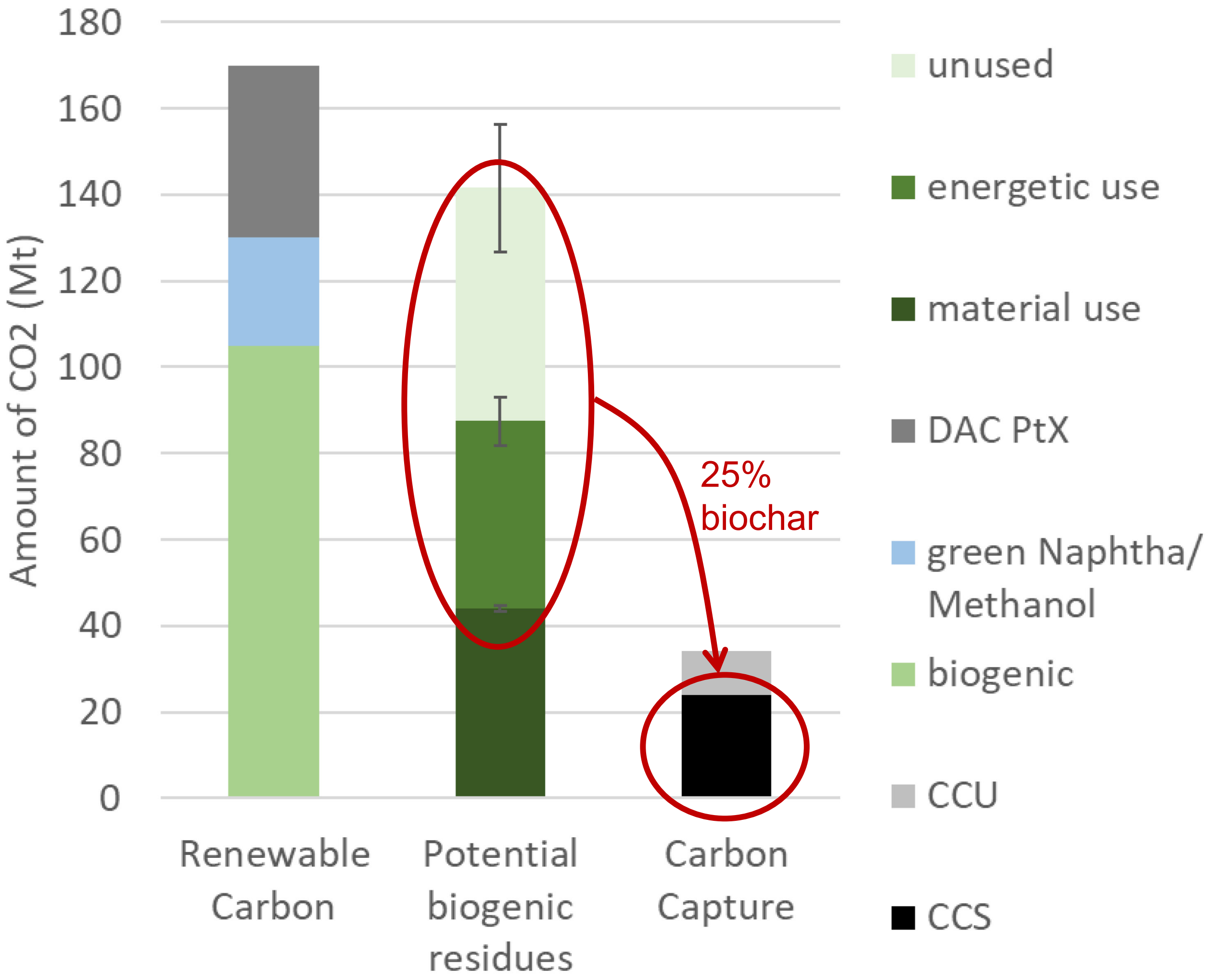


Fast pyrolysis with net negative CO_2 emissions



Data from: Funke, A. et al. "Fast Pyrolysis of Biomass Residues in a Twin-Screw Mixing Reactor." J Vis Exp 115 (2016): e54395.

Fast pyrolysis potential for the carbon cycle



- Energetic and unused residues sufficient to achieve anticipated CCS potential with biochar
- Produced liquid fuel reasonable for large scale applications
  - Unlocks additional BECCS potential
- Fast pyrolysis plants could potentially provide additional CO_2 for BECCU/S
- Long term need for carbon imports

‚dena-Leitstudie Aufbruch Klimaneutralität' (Deutsche Energieagentur), 2021

Conclusion: Fast Pyrolysis for Bioenergy

Karlsruhe Institute of Technology

Today | **Transition (2030-2040)** | **2050**

- Process Heat >1 MW_{th} (TRL 9)
- Residential heat/ CHP <200 kW_{th} (TRL 7)
- Co-refining Advanced Biofuels (TRL 8)
- Advanced Biofuels via Gasification (TRL 6)
- Material Use of Bio-oil Fractions (TRL 2-6)
- Biochar Carbon Sequestration (TRL 6/9)

Demonstrated for residues
(straw TRL 6, forestry residues TRL 8)

Lock-in risk minimization through product flexibility along key areas (CHP, biofuels, BECCS/ NET)

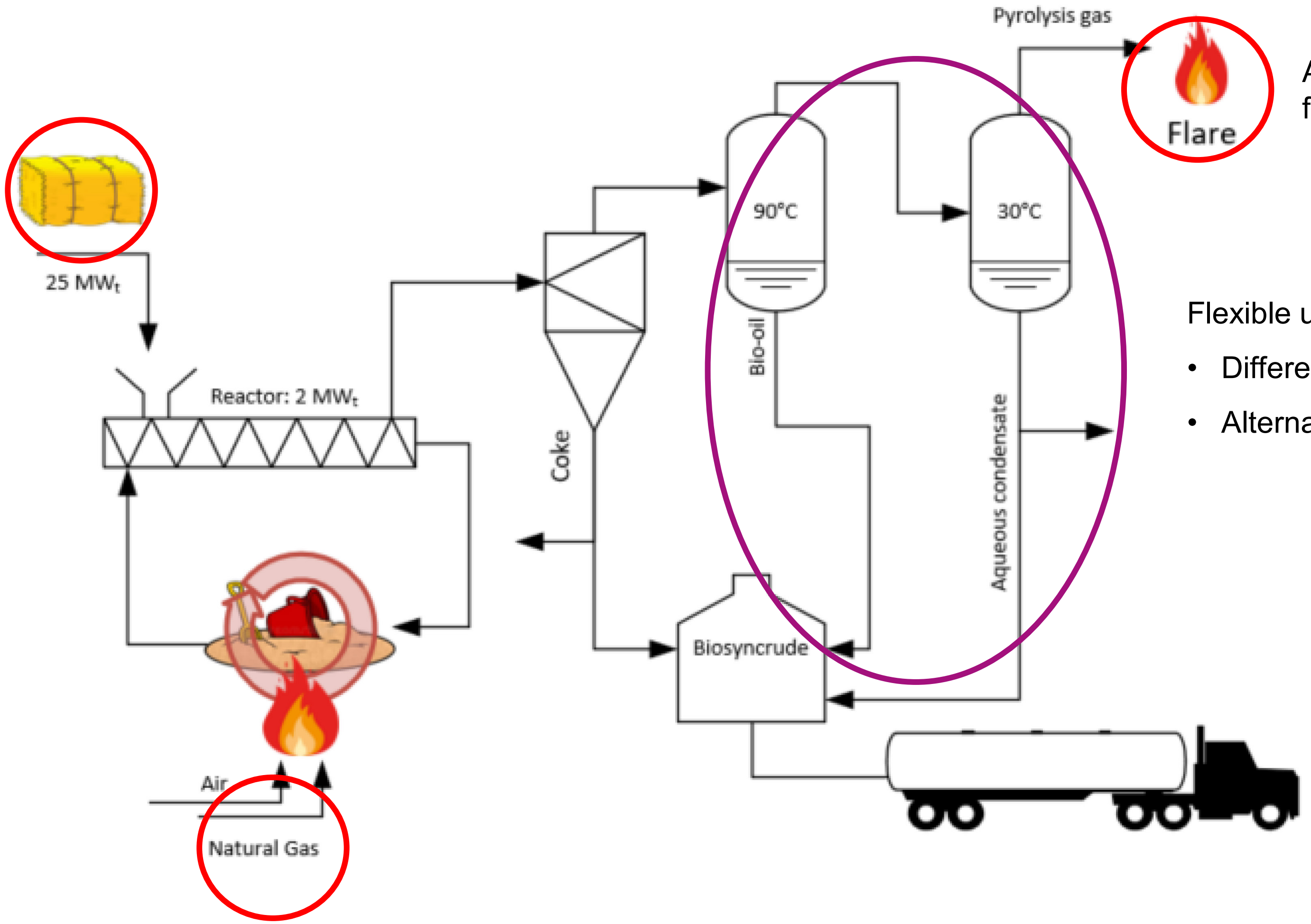
Social acceptance through **decentralized** solutions for biomass **residues** to produce tradeable commodities

Overview

- Process Simulation

Fast pyrolysis @ bioliq: research in IKFT

Data based on: Pfitzer, C.et al. "Fast Pyrolysis of Wheat Straw in the Bioliq Pilot Plant." Energy & Fuels 30 (2016): 6b01412.

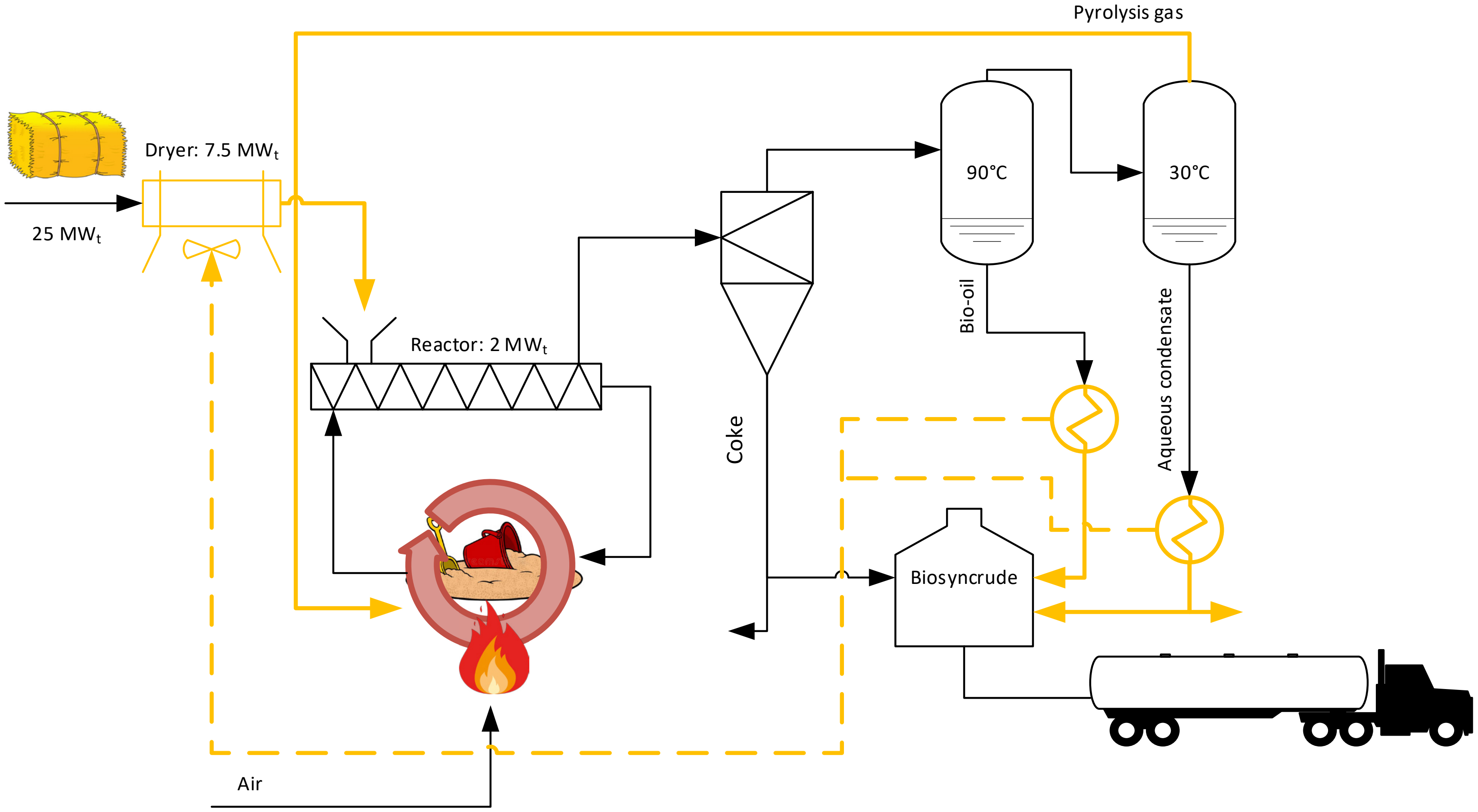


Alternative uses for pyrolysis gas

Flexible use/production of oil

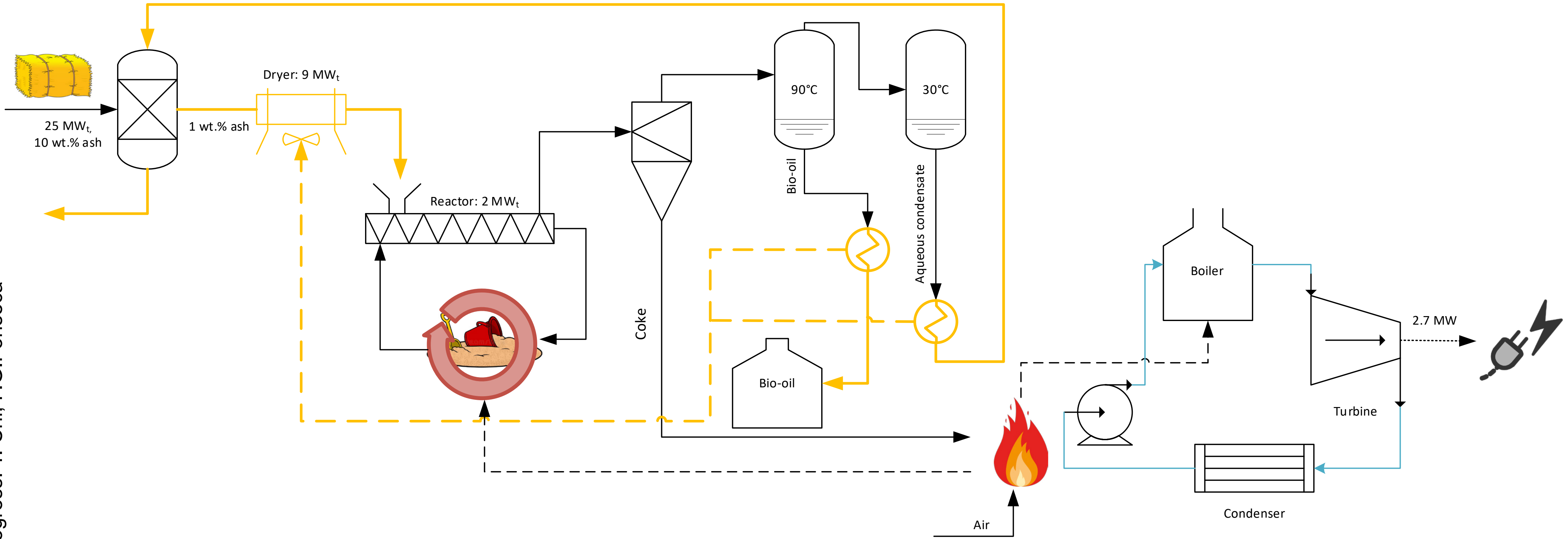
- Different temperature profiles
- Alternative valorization of liquids

Fast pyrolysis in bioliq: alternative process configuration



Data based on: Fonseca, F.G. et al. "Moisture content as a design and operational parameter for fast pyrolysis." JAAP 136 (2019): 01.012.

Fast pyrolysis in bioliq: alternative process configuration



Studies in progress: Y. Chi, F.G.Fonseca

Thank you for your attention!

Dr.-Ing. Axel Funke

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