Energy from biomass


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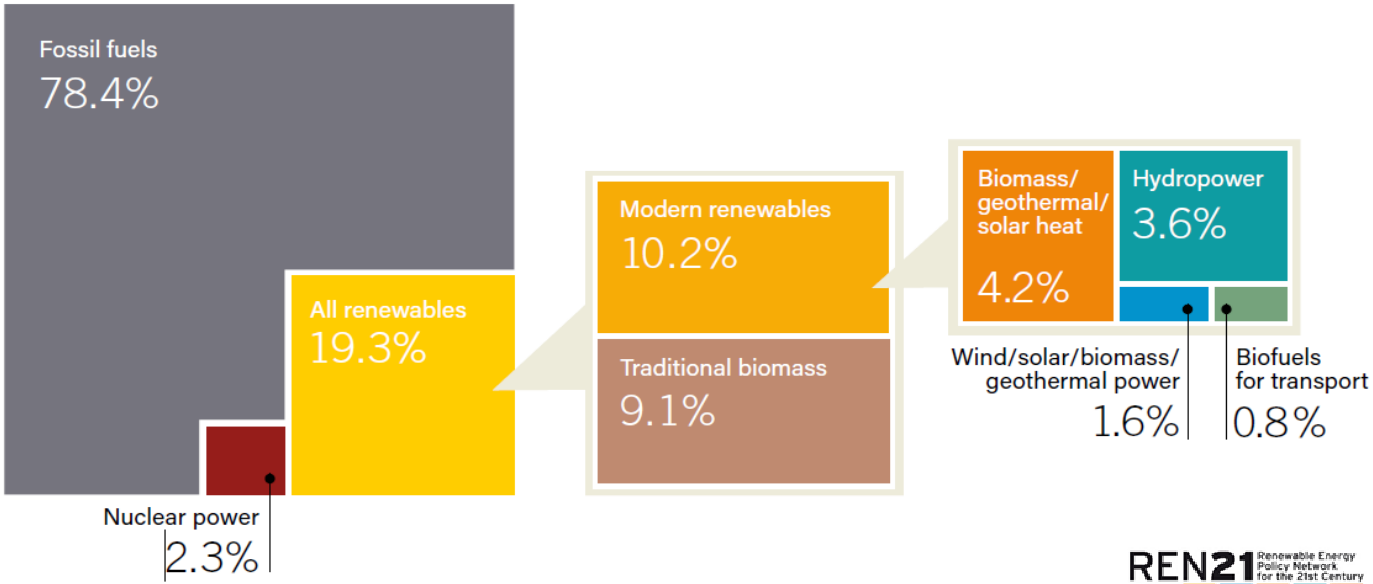
1. Biomass
2. Energy generation from biomass
3. Bioenergy provision today
4. Integration into renewable energy systems: smart bioenergy
5. Expectation

What are we talking about?

Estimated Renewable Energy Share of Total Final Energy Consumption, 2015



REN21 Renewable Energy Policy Network for the 21st Century

Biomass is raw material of biological origin excluding material embedded in geological formations or transformed to fossilized material. Biomass can be processed into solid, liquid or gaseous fuels or stored energy in biomass can be directly converted into other forms of energy (e.g. heat, light) (ISO 13065:2015).

The energy content of biomass

Energy provision from biomass is based on a chemical reaction:

Binding energy: C-C: 350 kJ/ mol C=C: 615 kJ/ mol C-H: 415 kJ/ mol

Oxidation of organic bindings (examples):

$C + O_2 \rightarrow 2\ CO_2 \quad \Delta H = -394$ kJ/ mol

$CH_4 + 2\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O \quad \Delta H = -889$ kJ/mol

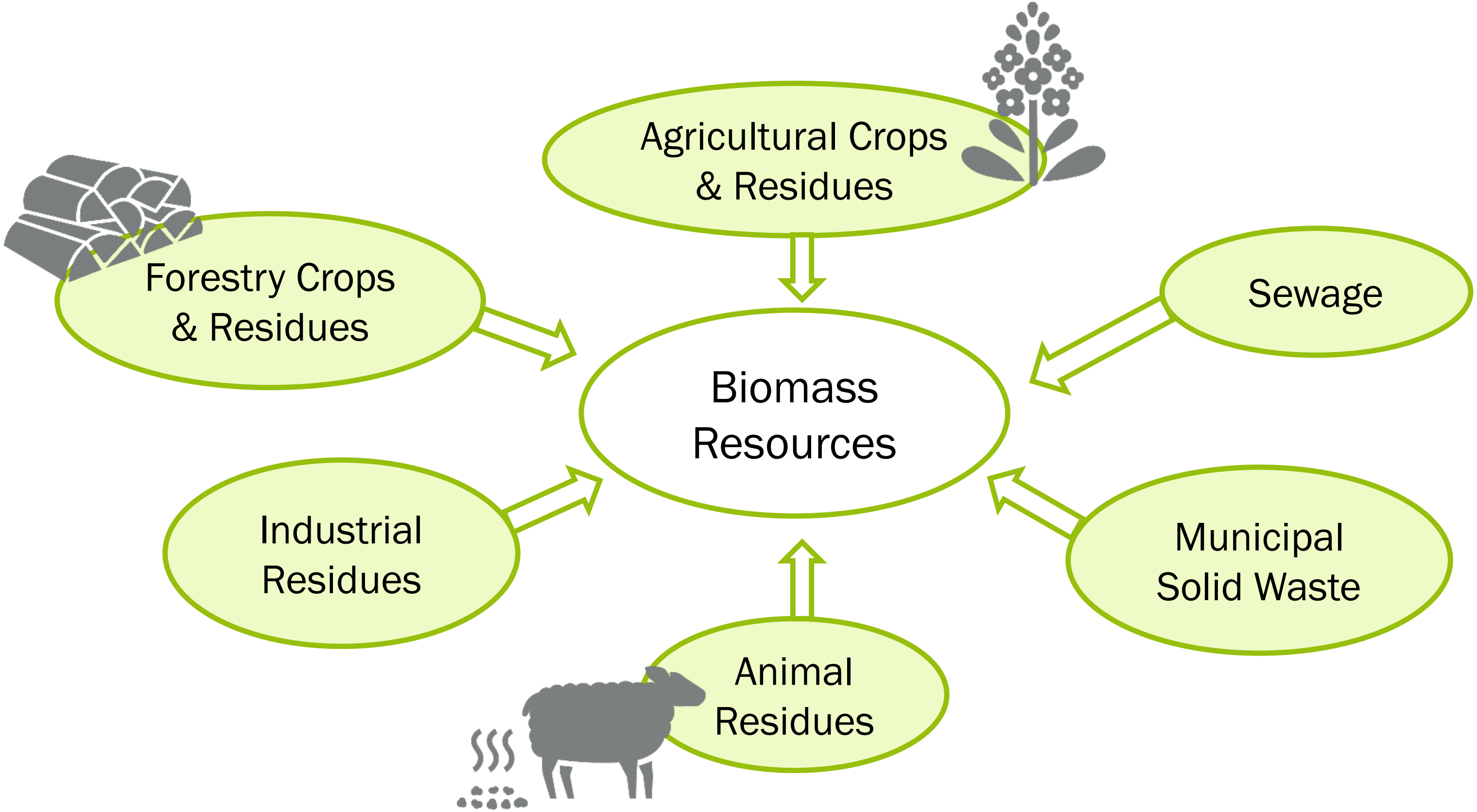
Carbon is sequested from CO_2 by Photosynthesis

(example) $6\ CO_2 + 6\ H_2O$ –(light)→ $C_6H_{12}O_6 + 6O_2$

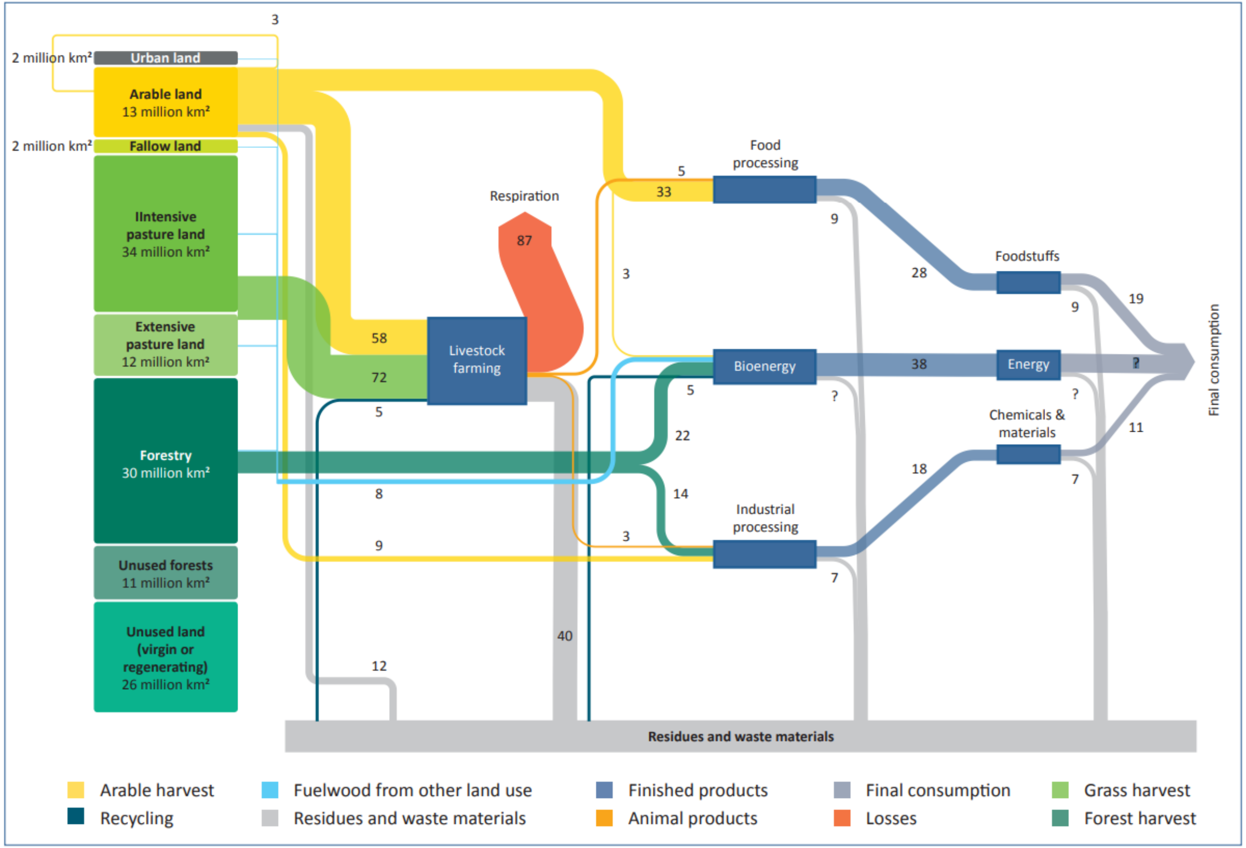
The Hydrocarbons can be used directly (biomass)
or after their fossilation (coal, oil, gas)

Numbers from (Kaltschmitt et al 2001)

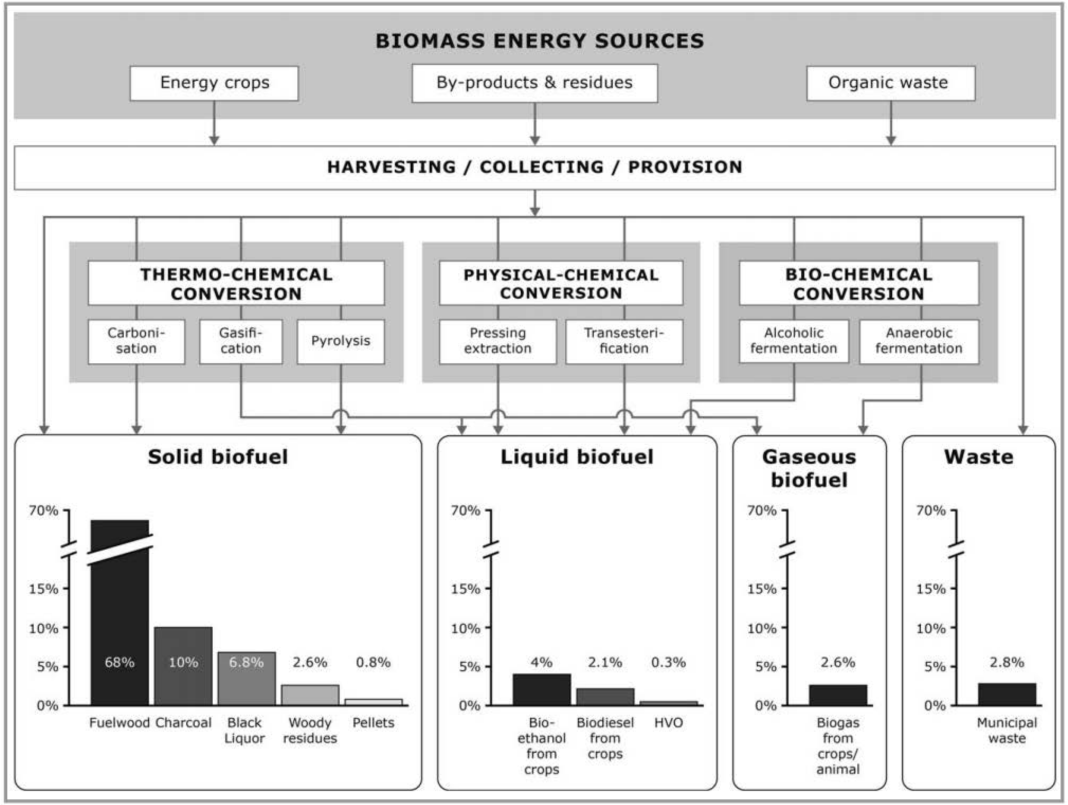
Biomass resources



Biomass
Global biomass flows

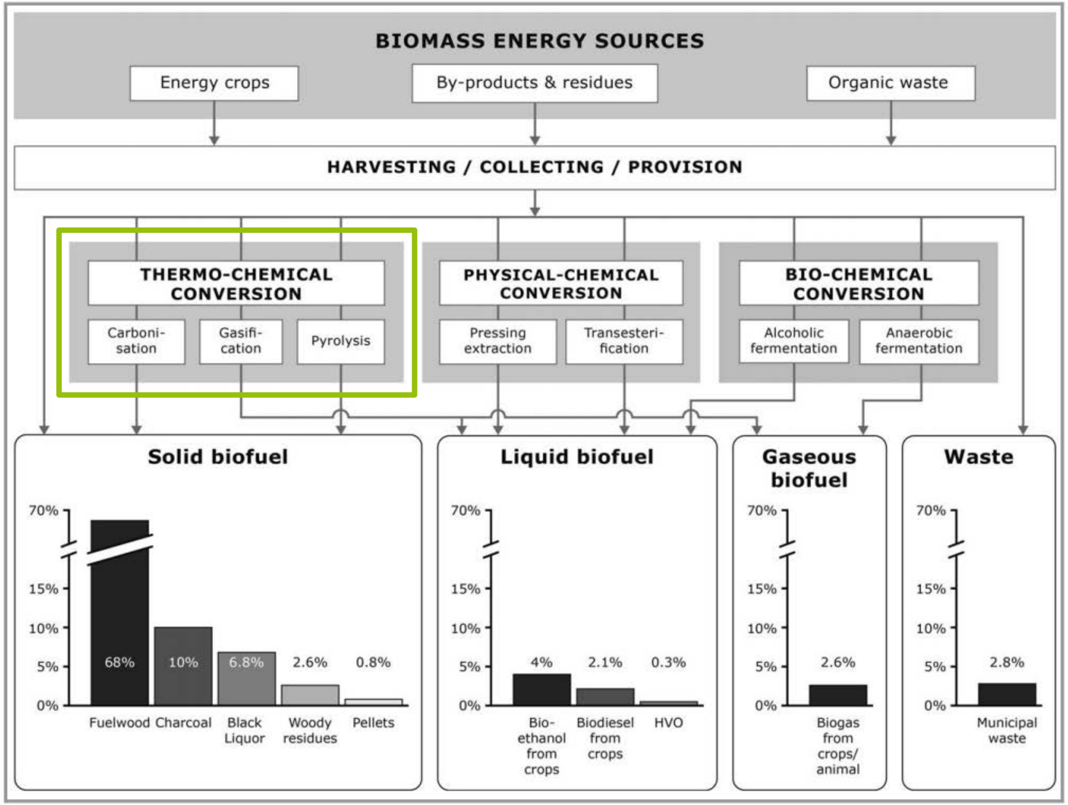


Energy generation from biomass
Pathways



Source: Thrän et al (2017); DOI: 10.1002/cite.201700083

Energy generation from biomass
Pathways



Source: Thrän et al (2017); DOI: 10.1002/cite.201700083

Combustion (of wood)

Combustion stages:

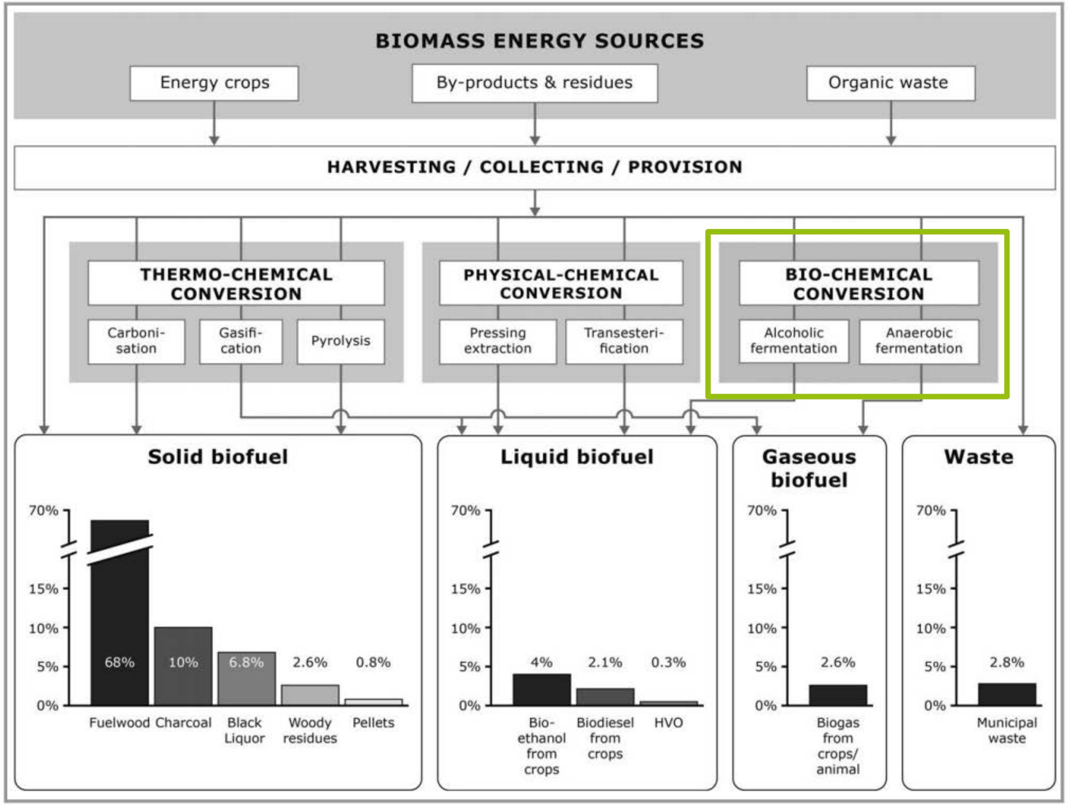
1. at a temperature of 150 °C the fuel is dried
2. a temperature of 150 - 600°C pyrolytic decomposition of the fuels to product gas, pyrolsis oil and charcoal
3. at a temperature of 500 - 1000 °C further gasification (i.e. of charcoal in the firebed)
4. at a temperature of 400 - 1300 °C the gas is burned

At high temperatures, 80 - 85 % of the wood is converted to gas and burns afterwards (complete combustion)

Intermediates can be used for further product processing (synthetic natural gas, methanol, Fischer-Tropsch-Fuels etc.)

The design and optimisation of this system is a huge area

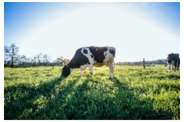
Energy generation from biomass
Pathways

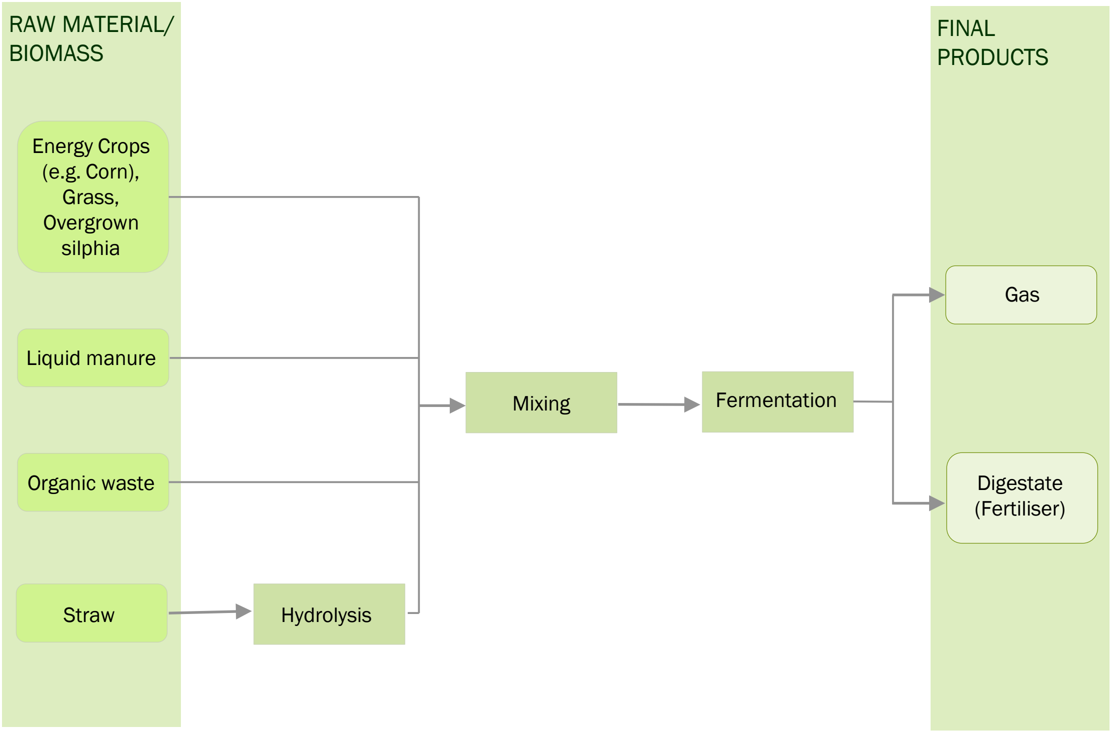


Source: Thrän et al (2017); DOI: 10.1002/cite.201700083

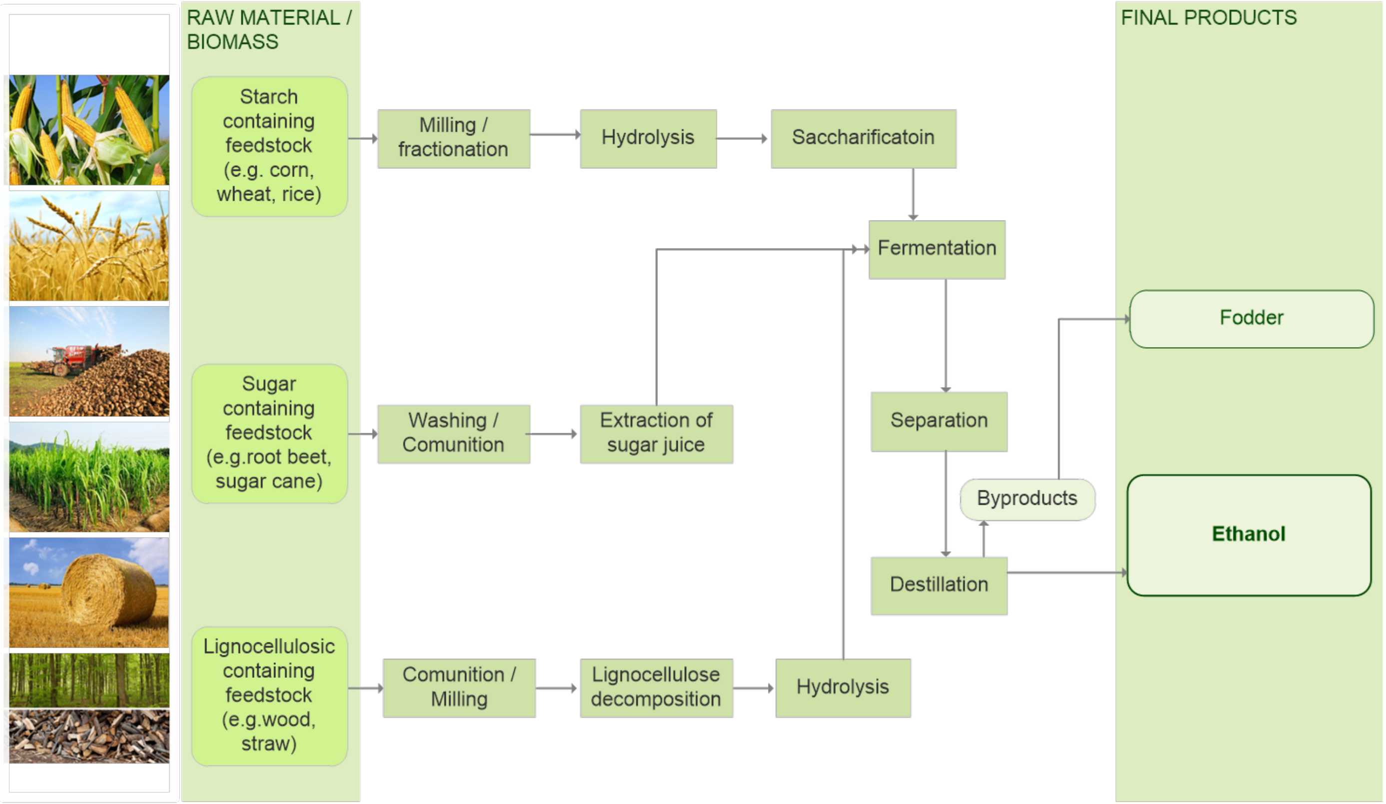
Energy generation from biomass
Biochemical conversion – Biogas



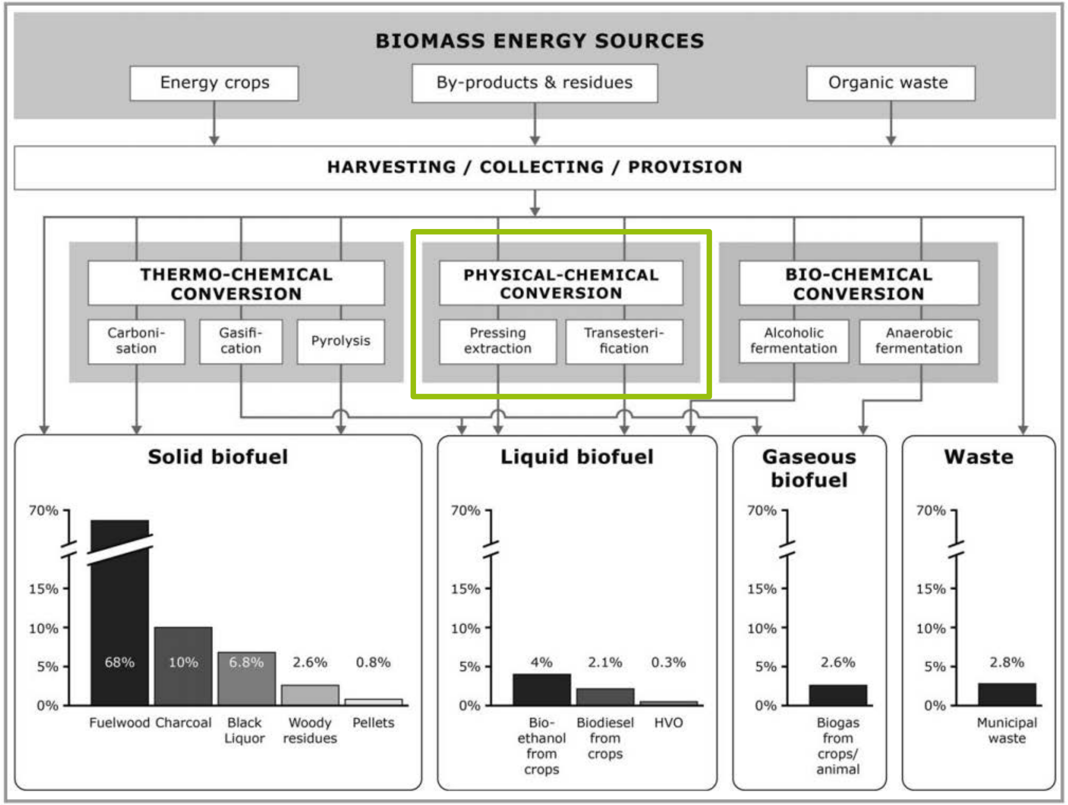




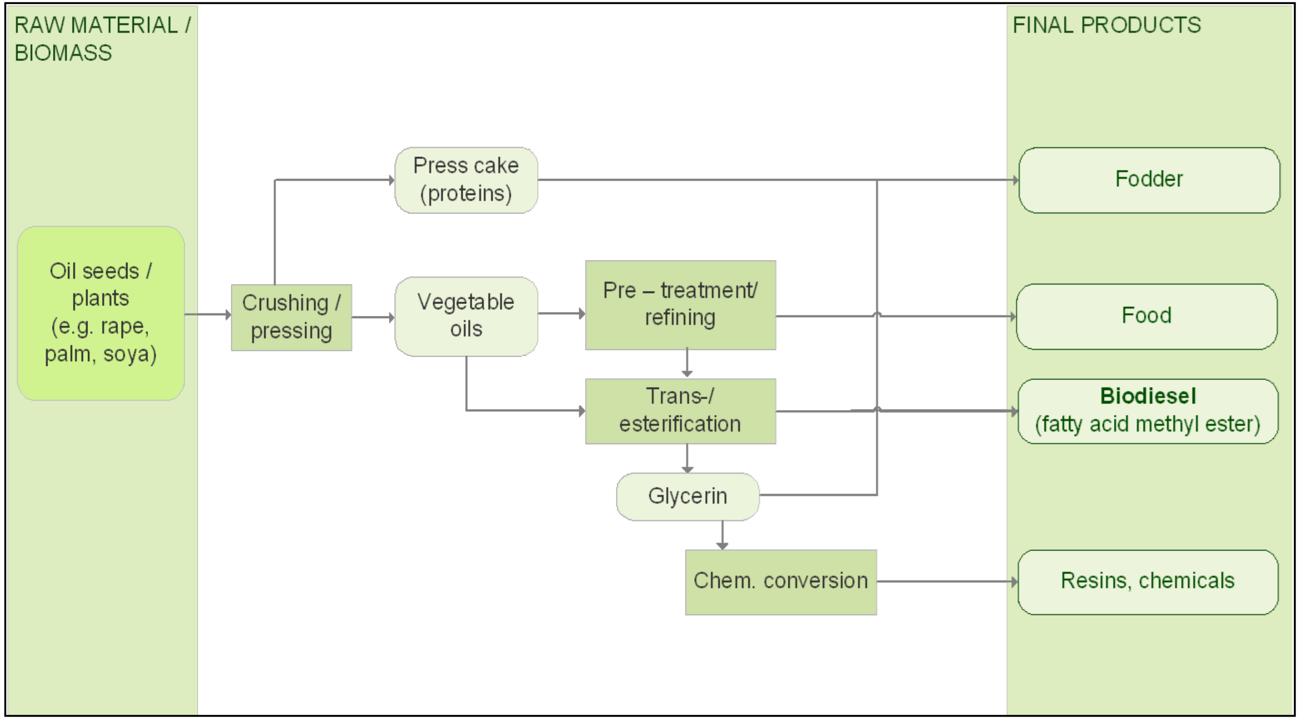
Energy generation from biomass
Biochemical conversion – Bioethanol



Energy generation from biomass
Pathways



Source: Thrän et al (2017); DOI: 10.1002/cite.201700083



RAW MATERIAL / BIOMASS
FINAL PRODUCTS
Oil seeds / plants (e.g. rape, palm, soya)
Crushing / pressing
Press cake (proteins)
Vegetable oils
Pre – treatment/ refining
Trans-/ esterification
Glycerin
Chem. conversion
Fodder
Food
Biodiesel (fatty acid methyl ester)
Resins, chemicals

Fuels for aviation

Aviation:

Strong increase in transport loads and fuel demand is expected for the future (>2% per year)

Long lifetime of aeroplanes (more than 30 years)

Global fuel supply system

Biojet fuels:

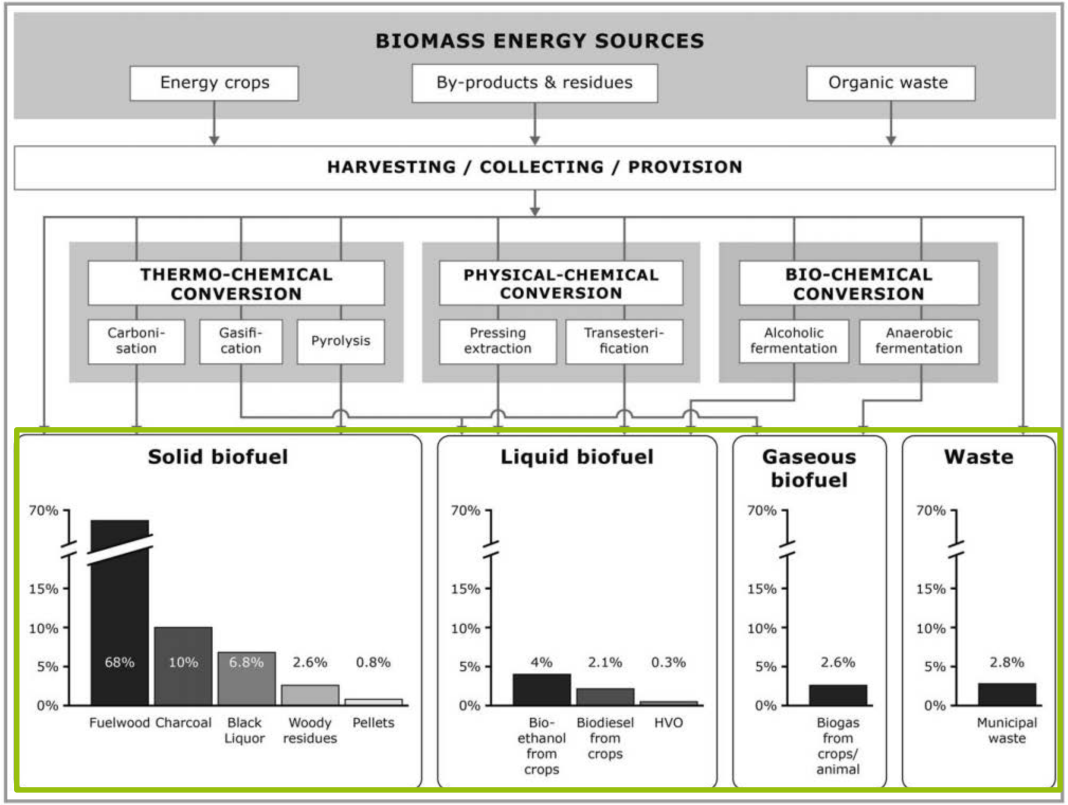
A wide range of biojet fuels have been tested successfully

Technical standards/Certification for five biojet fuels have been established:

- HVO
- FT-diesel
- SIP fuels (Renewable Synthesized Iso-Paraffinic fuel; renewable farnesane hydrocarbon)
- ATJ fuels (Alcohol to Jet Fuel)

They can be applied as drop-in fuels without major changes in infrastructure or aircraft engines.

Bioenergy provision today
World



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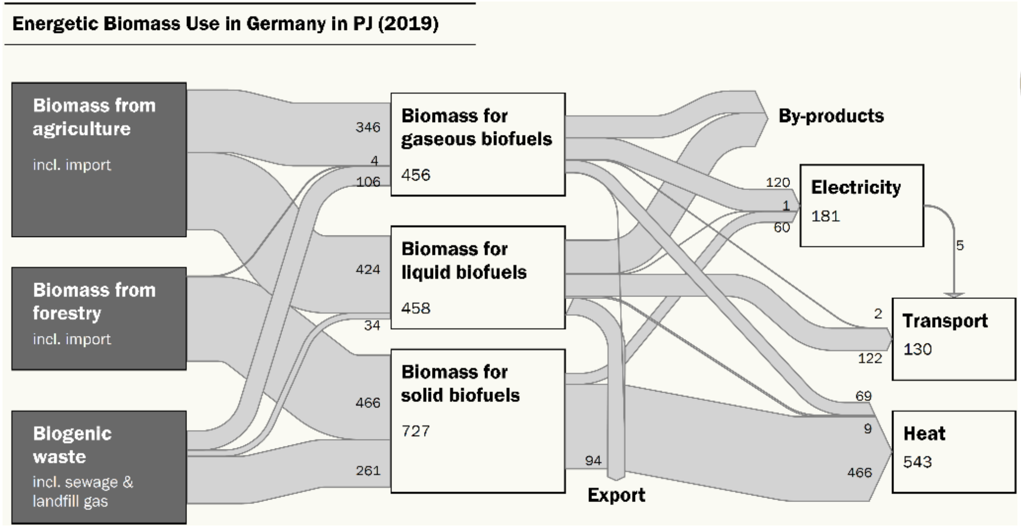
Agricultural residues & forest residues

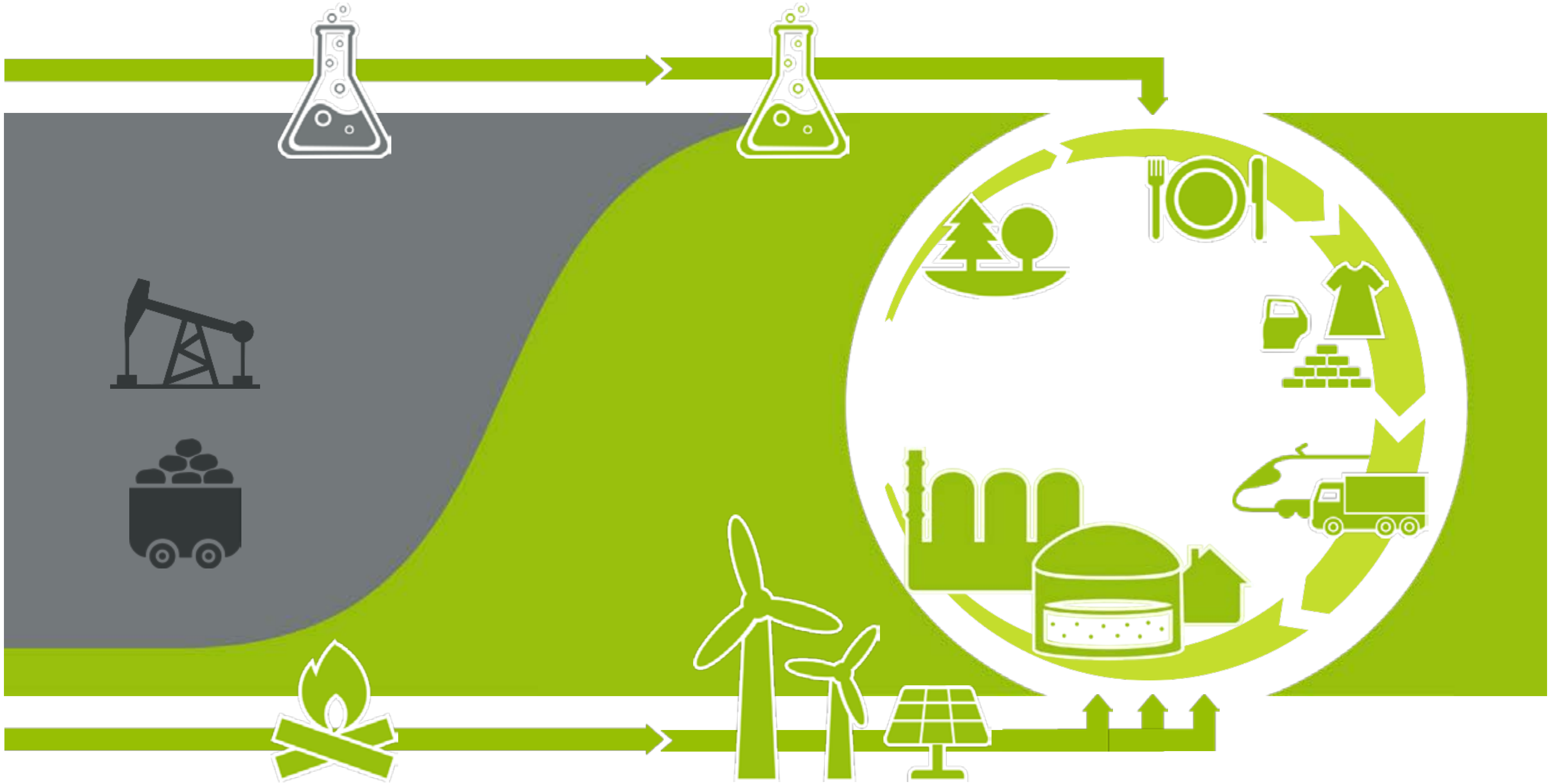
Biomass CHP, biogas plant, Bioethanol (electricity and mobility energy)



Residual and waste materials (waste wood, organic waste, production waste)

Heating systems (from pellet stoves to high temperature use)

Bioenergy provision in the future
Sustainable and smart



Comprehensive integration for an efficient energy transition

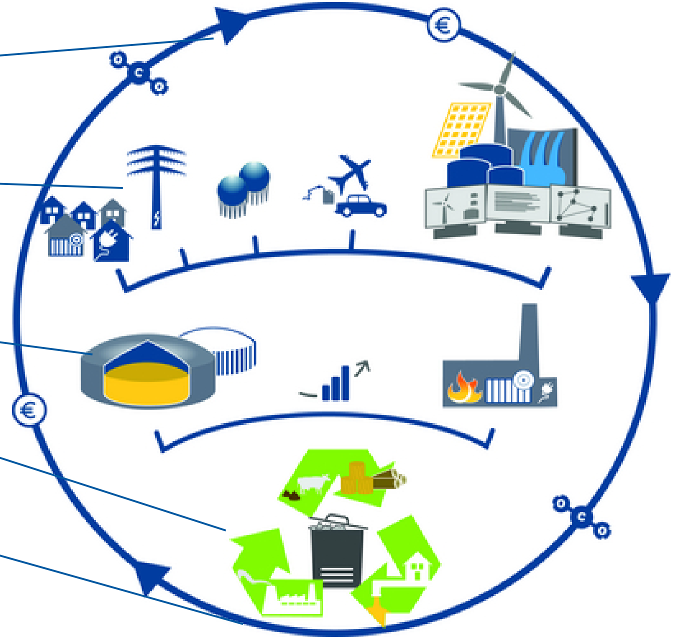
Focus: System effect with hydrogen

Focus: Hybrid concepts

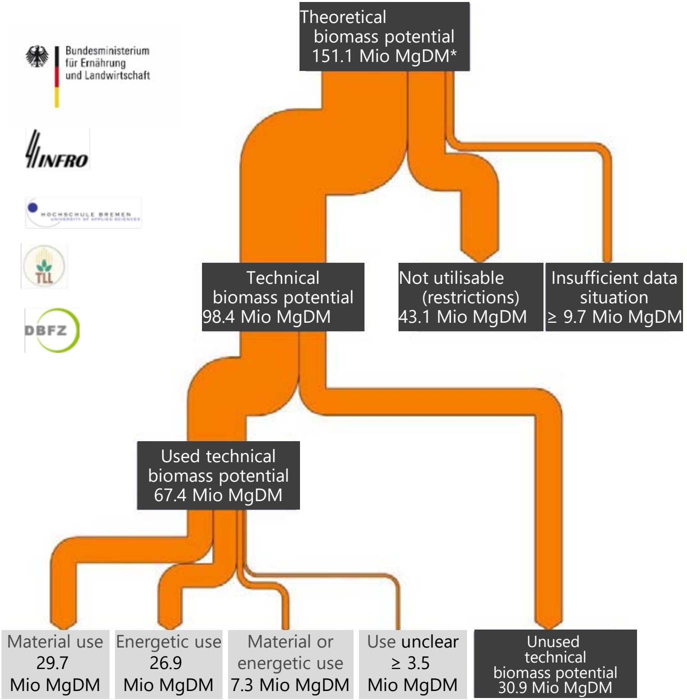
Focus: Flexible concepts

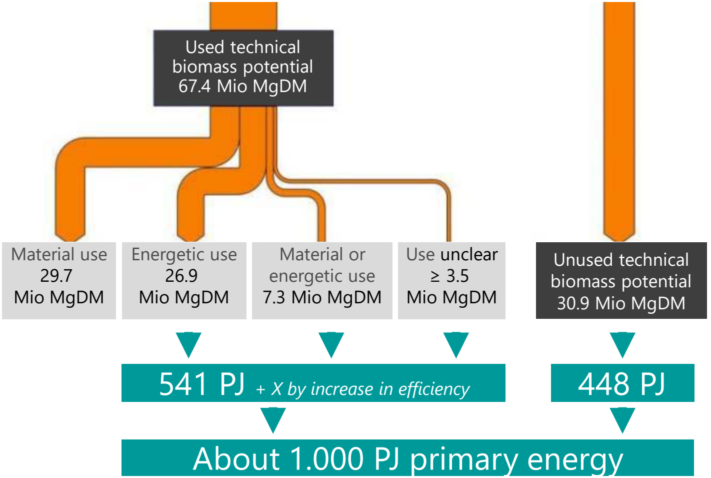
Focus: Residual and waste materials

Focus: Negative emissions from 2030



Focus on residual and waste materials
Potential and use in Germany





Source: Brosowski et al (2016)

*MgDM: Megagram (metric ton) dry mass

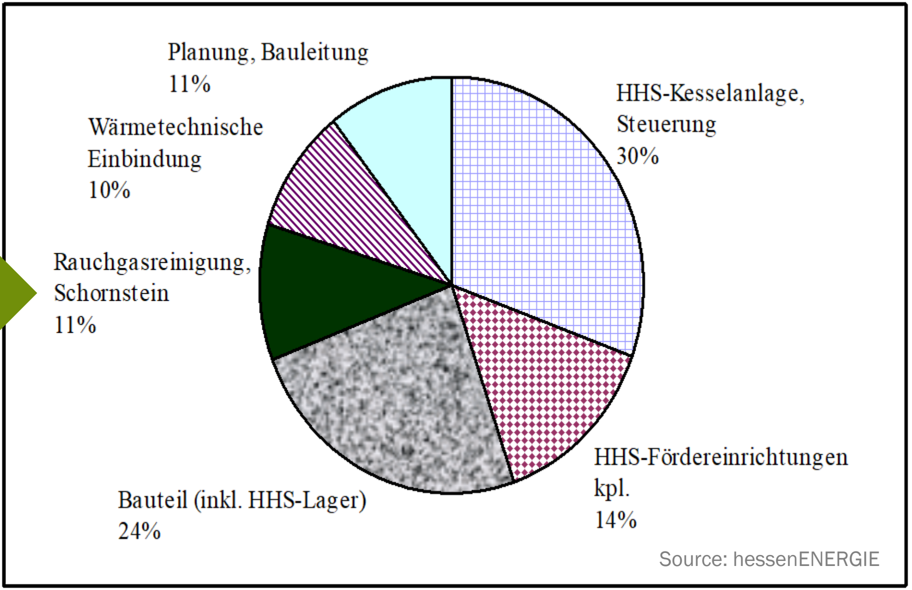
→ Residues and waste arise at the end of different value chains
→ Constant availability can be expected

Focus on residual and waste materials
Requirements for clean conversion

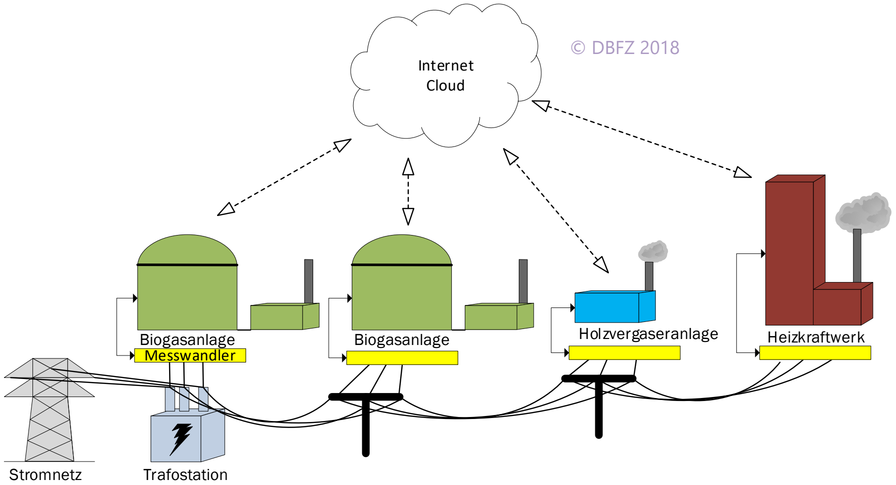
Background: In addition to local air pollution control, absolute particu-late matter emissions in Germany must also be reduced (EU requirement).

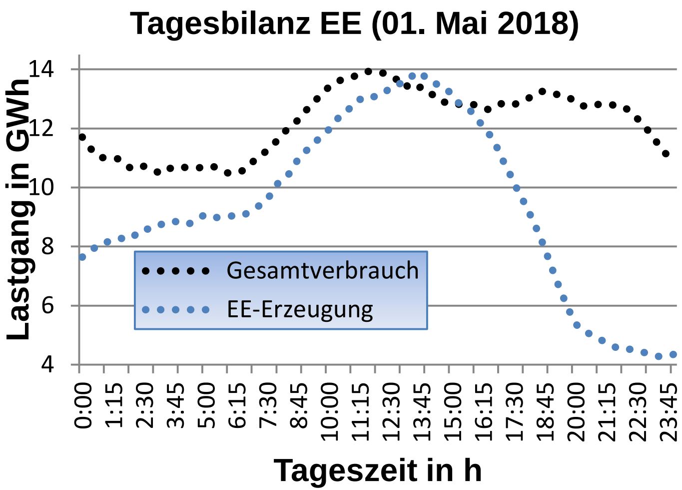
For larger boilers from 300 kW(th), the following applies roughly:

- 10% more costs reduce particulate matter by a factor of 10;
- Non-wood fuels always need a secondary separator for limit value compliance (+10% costs), as higher emissions are produced during combustion.



Reduction of particulate matter is primarily a question of cost

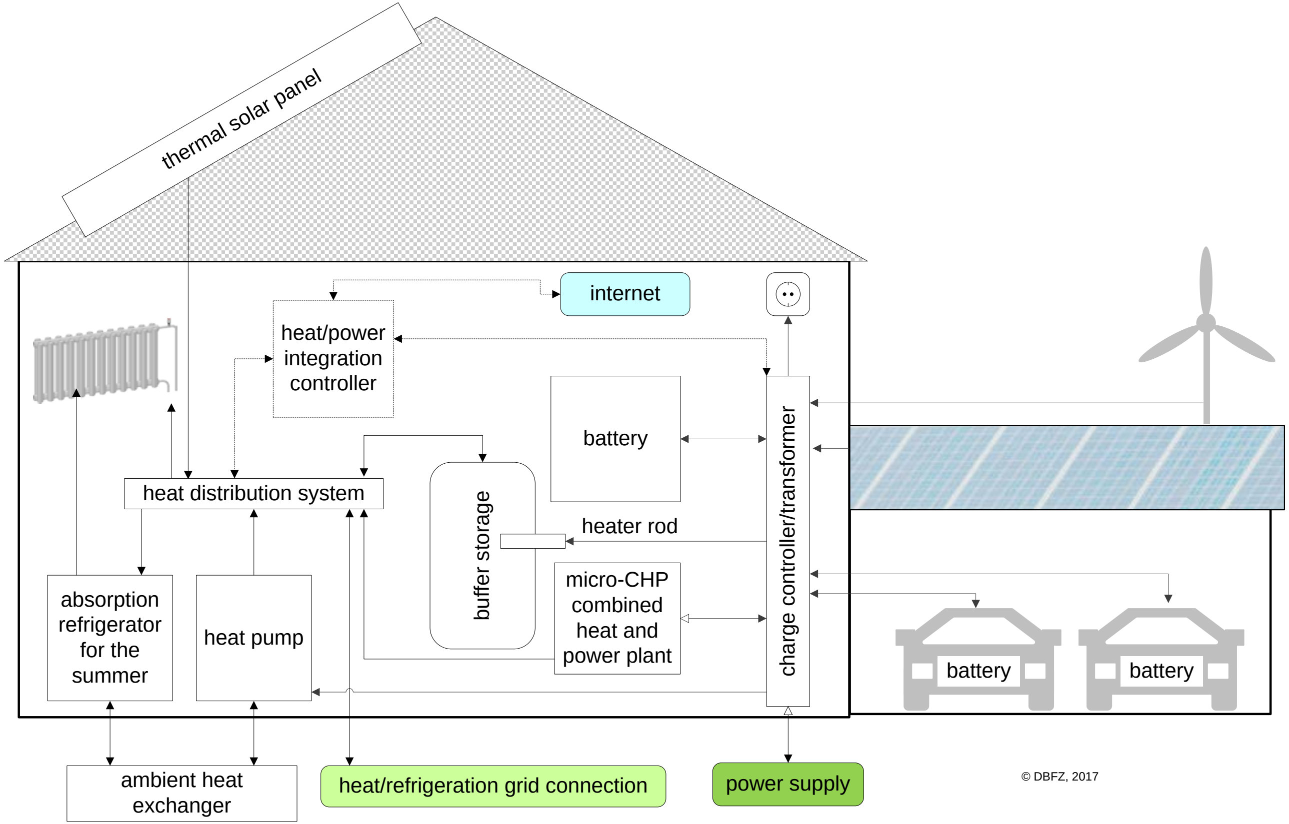




Source:: UFZ modelliert mit Daten der Bundesnetzagentur - www.smard.de, abgefragt am 08.10.2018

Flexibilisation offers:
- System services
- Electricity market revenues
- Hybrid heat supply

Flexibilisation requires:
- Maintaining capacities
- Controllability and concepts
- Intersections



Components for a renewable energy supply in a building area or housing quarter – not all used at the same single house.

Example for hybid systems in 100 RE solutions:
- Heat has peak demand in winter, when PV has minimum electricity supply.
- Heat pumps have to make the biggest contribution

(in Germany: Peak power demand up to 400 GW; peak power demand today 70-80 GW; RE capacity: 132 GW)

UFZ DBFZ

Options or areas of application, as well as challenges and research needs in the context of RE and bioenergy in particular.

Digitalisation

- Interfaces (management)
- Regional energy & climate data
- Forecast of energy demand
- Automated systematic data collection
- Merging simulation tools
- Communication of added value to users

Flexibilisation

- Input material flexibility (broad raw material spectrum vs. quality requirements)
- Flexible operating strategies (bioenergy production in complementarity with volatile RE; heat: flexible temperature levels through biomass)
- Product flexibility (flexible electricity/heat/fuel production; biobased gases as intermediates)

Technology combinations

- Network control of district heating networks in sub-networks and coupling of electricity, gas and heat
- Micro-satellite CHP for biogas plants (biogas in the gas grid)
- Central high-temperature heat pumps in combination with heat grids
- Seasonal storage and solar thermal

Focus: System effect with hydrogen
On the way to a climate-neutral circular economy

Climate-friendly hydrogen can be be produced from biomass
(Hydrogen from biomass)

Hydrogen can be used in bioenergy processes to increase efficiency
(Hydrogen with biomass)

Hydrogen can produce climate-friendly PtX products with biogenic CO2
(Hydrogen with bioenergy)

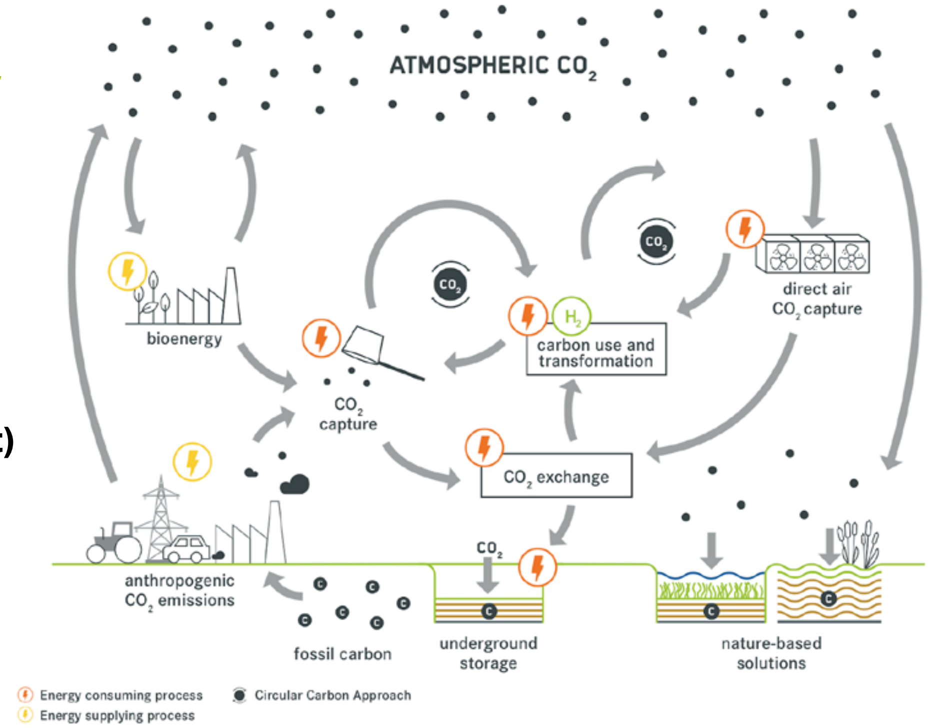
Hybrid concepts for hydrogen and Bioenergy are particularly useful
(Hydrogen and bioenergy)

More information coming soon:
https://task44.ieabioenergy.com/publications

Statement Hydrogen
www.energetische-biomassenutzung.de/
publikationen/stellungnahmen

All climate scenarios expect negative emissions and give bioenergy a high priority because:

- **technically available in a wide range**
- **Potential for real CO2 removal**
- **Energy as a by-product**
- **Combination with industrial processes (e.g. cement)**



Source: Helmholtz Klimainitiative (HI-CAM)

Focus on bioenergy options for negative emissions from 2030 onwards
Example: CO2 removal from bioenergy plants in Germany

How can 1 million tonnes of bio-CO2 be provided?

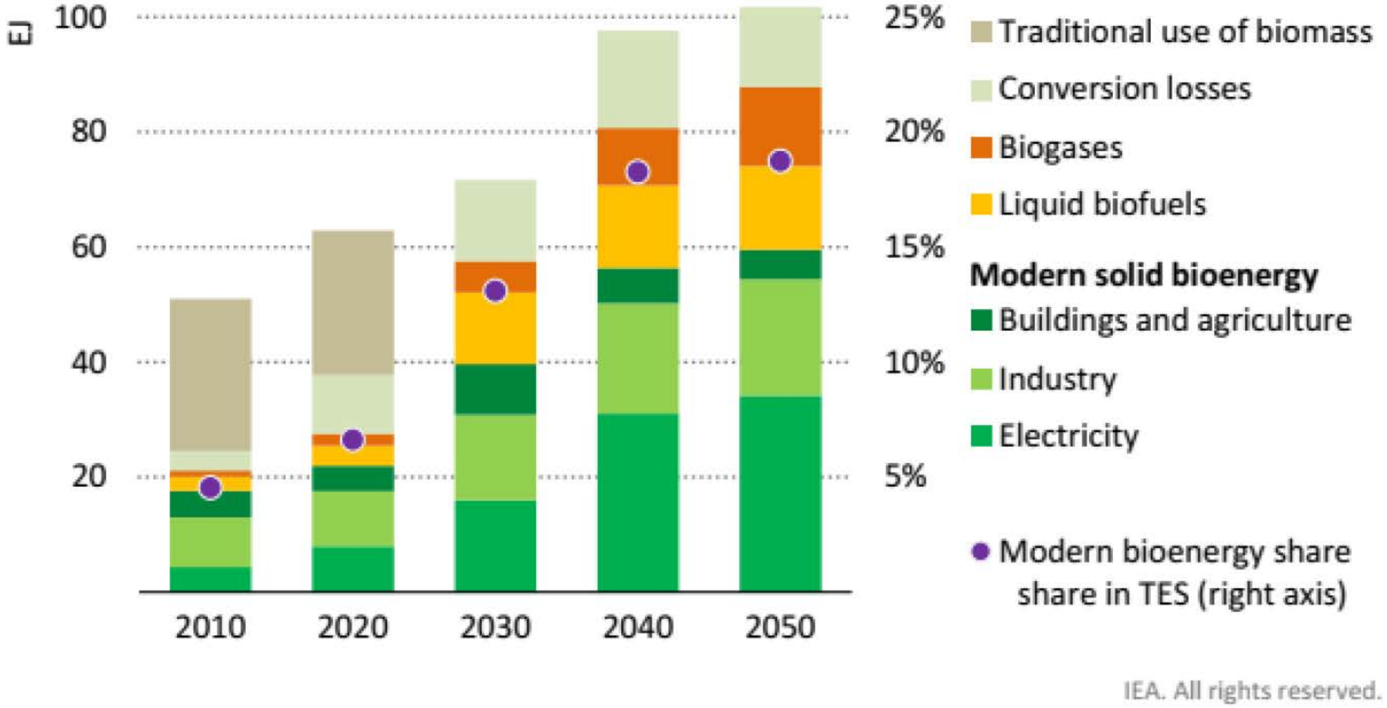
- 8–20 Bioethanol plants
- or 130 biomethane plants
- or 60 biomass cogeneration plants

Costs: 100–200 US$/t$CO_2$
(Fuss et al. 2018)

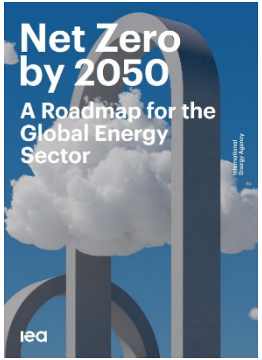
Plant category	Number of plants (status 2019)	Typical CO2 availability per plant	Theoretical CO2 potential of operating plants
BtL- plant	0 (Biodiesel)	up to 900 kt/a (?)	none
Bioethanol	7	48–271 kt/a	665 kt/a
Biomethane	216	7,5–8,5 kt/a	1.500 kt/a
Biomass CHP plant	>600	5–30 kt/a	6.380 kt/a
Biogas (on-site electricity generation)	8.870	2,5–3,5 kt/a	27.000 kt/a
Biomass furnace / boiler	11.123.000	0,0005–1,5 kt/a	40.000 kt/a

Own calculation; data based on DBFZ-Report 11 2019; DBFZ-Report 22 2016, Trost et al 2012, BMUB 2012, NABU 2009, VDZ 2014, VDEh 2014, SMUL 2014, FNR 2021, BNetzA 2021,

Towards net zero
Expectations from IEA



Assuming moderate potential assumptions and distribution across all sectors



Summary

Bioenergy is the most relevant renewable energy source today.
Many technologies and concepts are implemented.

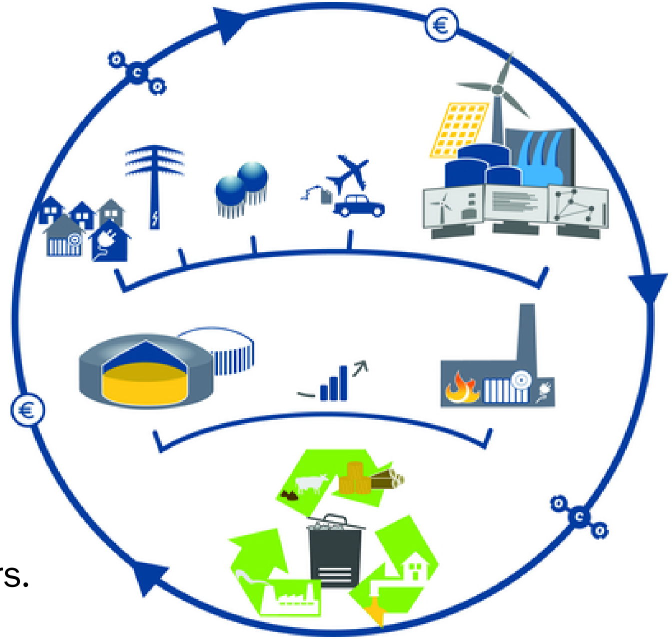
Biomass is a limited resource, so bioenergy provision needs integration, not only in the energy system but also in sustainble supply systems.

The use of residual and waste materials will increase and need mobilisation strategies and utilisation technologies.

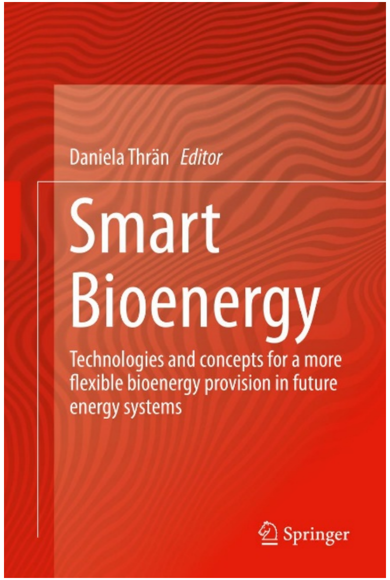
The areas of application remain diverse; however, flexible and hybrid concepts are gaining importance in all energy sectors.

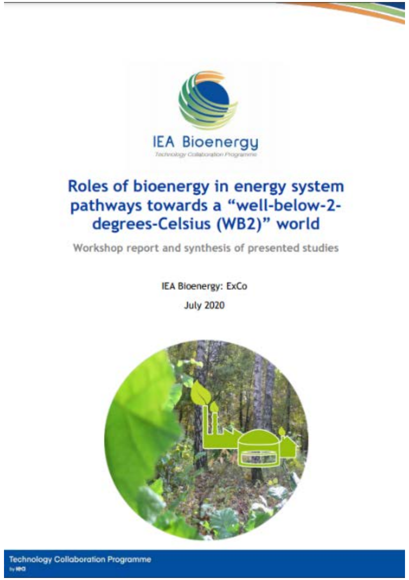
The interaction with hydrogen and negative emissions is relevant in the long term and needs to be researched now.

Further technology development (especially particulate matter) and digitalisation (predictive controls, interface standardisation…) are pioneers.



To read more





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Journal: Energy, Sustainability & Society
https://energsustainsoc.biomedcentral.com/

Energy System of the Future (ESYS)
https://energiesysteme-zukunft.de/en/publications/position-paper/bioenergy

Thank you!

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