Biomass for energy fuels & chemicals

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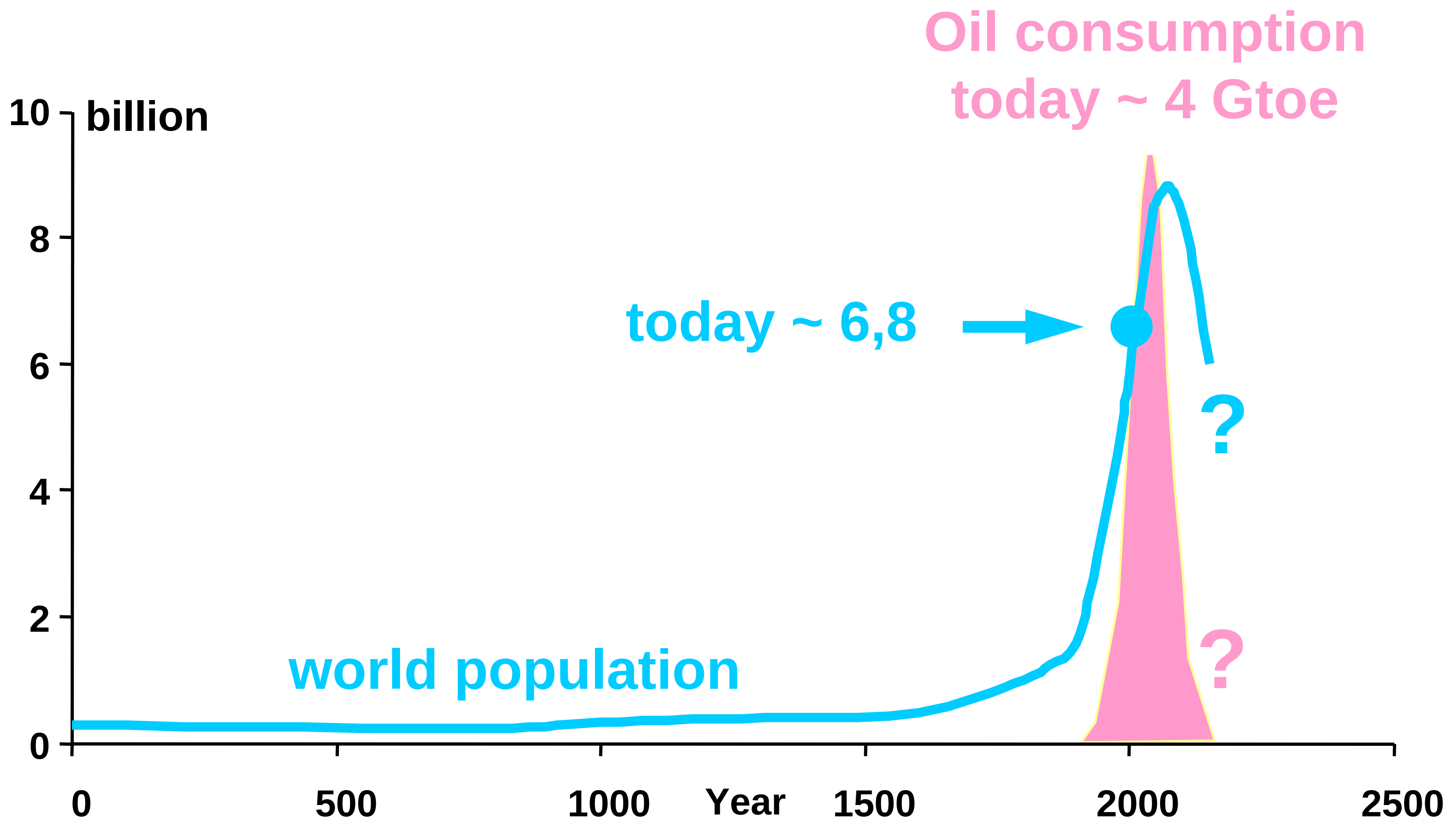
ITC-CPV

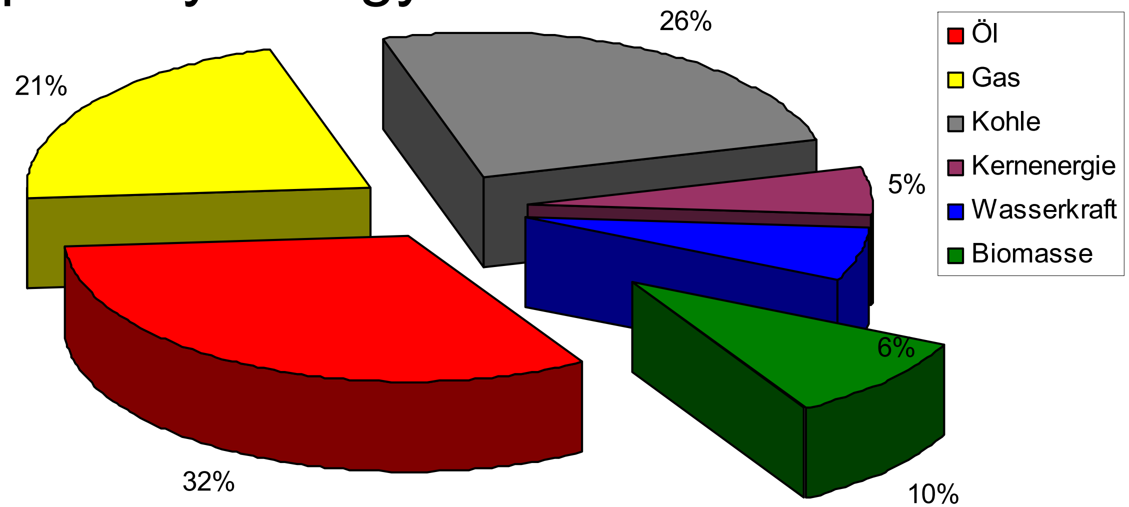
Oil era –2500 years time window



Quelle:BGR

World-wide energy system

Total: about 12 Gtoe primary energy



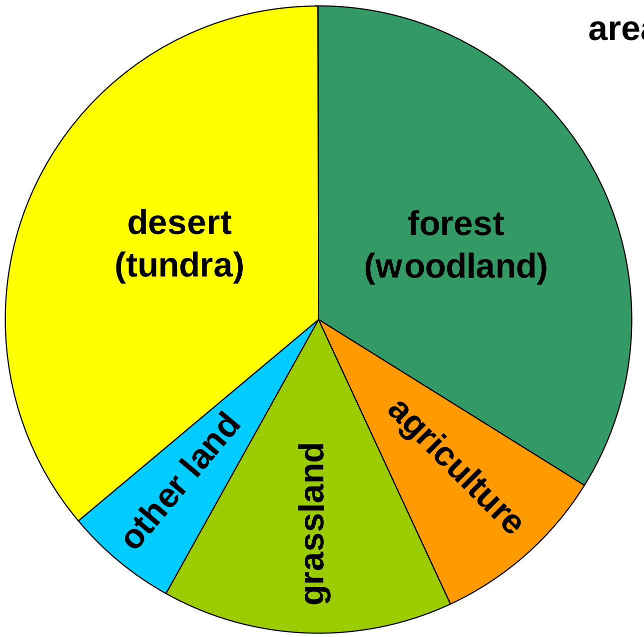
100 % primary energy → Transport conversion → 63 % end energy → Efficiency of use → 29 % effective energy

End energy:

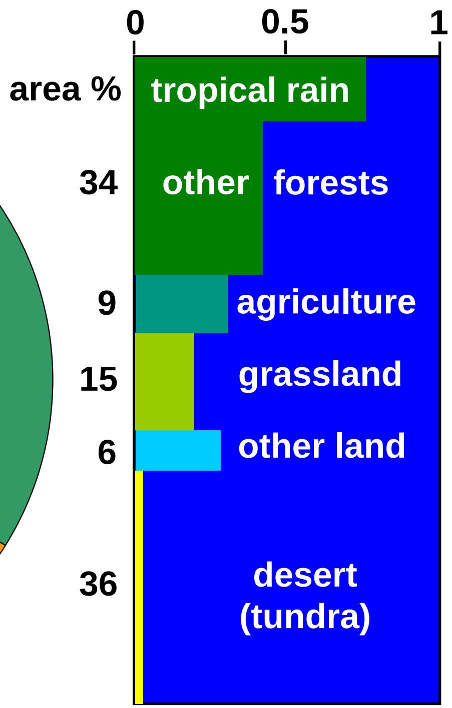
- Transport 19 %
- residential 10 %
- industry 29 %
- commerce 5 %

Global biomass production

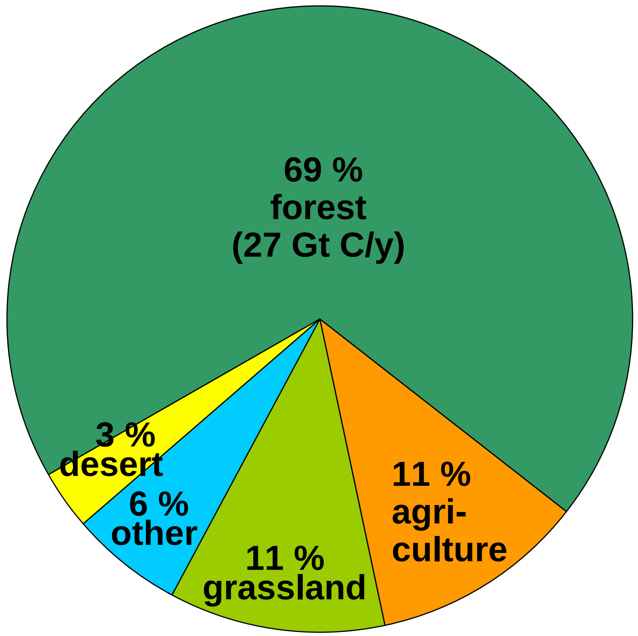
ecosystems
oceans 351 million km² (71 %)
land 149 million km² (29 %)



net biomass
productivity
kg C per m²



net biomass production
ocean ~ 25 Gt C/y, land ~ 40 Gt C/y
total ~ 65 Gt C per year

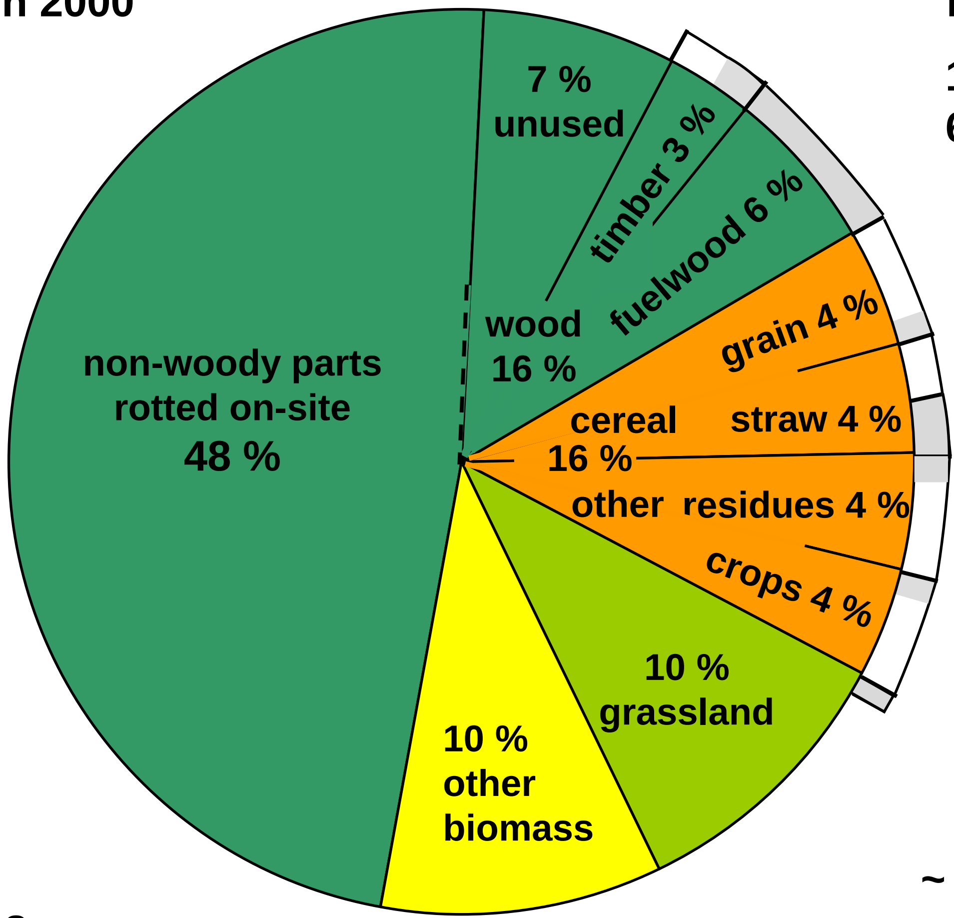


energy conversion factors: 1 tC carbon ≈ 1.12 tce coal ≈ 0.77 toe oil ≈ ca. 2 t dry biomass

Production and use of land biomass

30 Gtoe land biomass in 2000
(32 Gtoe in 2100)

69 % forests, ¼ wood
11 % agriculture
10 % grassland
10 % other biomass



year 2100 percentage

1 Gtoe biofuel in 2000
4 Gtoe biofuel in 2100

- ~ 50 % fuelwood
- ~ 25 % agroresidues
- ~ 25 % biowastes

forestry:

1.5 % "timber" waste
6 % fuelwood

agriculture:

0.7 % "grain“ waste
2 % cereal straw
0.6 % other residues
0.7 % "crop“ waste
0.4 % unsuited hay

~ 9 % wood and ´straw´
~ 3 % biowaste

Maximum bioenergy scenario

crude estimate for 150 Mkm² global land area

		Gt/a upgrowth		Gt/a bioenergy
	forests 1 kg/m²*a			
50 Mkm²:	*average upgrowth*	50	→	5
	grassland 0,5 kg/m²*a			
20 Mkm²:	*for animal food, business as usual*	10	→	0
	agriculture 2 kg/m²*a (harvest)			
10 Mkm²:	*for food and feed, SCP and irrigation*	20	25 % residues →	5
10 Mkm²:	*energy plantations, organic material*	20	→	20
sum: 90 Mkm²:	without ca. 60 Mkm² desert, tundra,…	100	→	30

30 Gt/a dry lignocellulose correspond to 12 Gtoe/a, the present primary energy need

Competitive use of biomass

human and animal food → decreasing priority → bioenergy

- wood (construction material)
- organic raw materials

  (cellulose, paper, cotton, rubber latex…)

- biorefinery:
  BtC (carbon products)

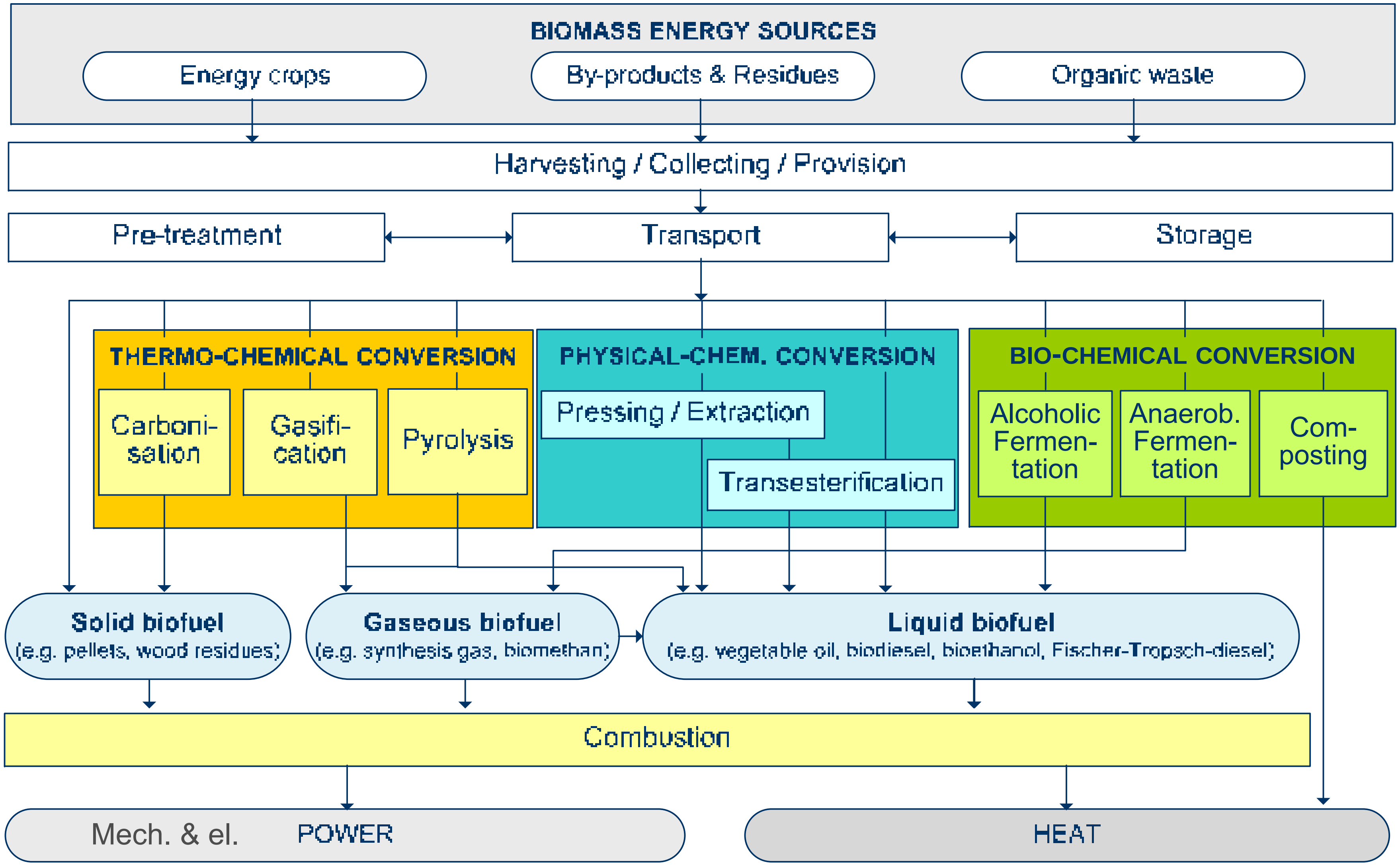
  The organic chemical industry of the future are

  bio-chemical, thermo-chemical, physico-chemical conversion processes

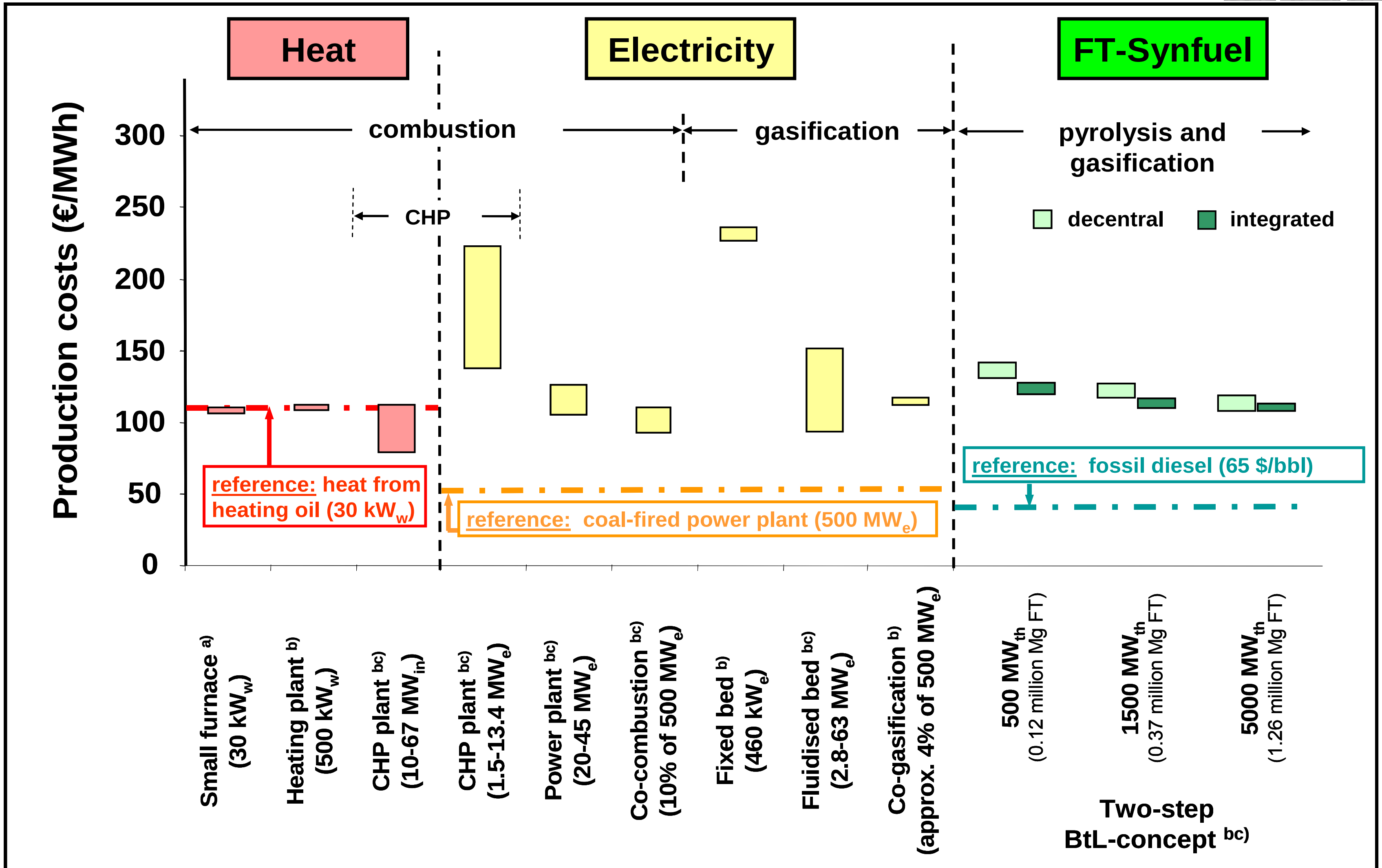
- ore reductant (iron)
- high T process heat (cement, lime, ceramic…)

- residential fuel
- CHP
- Co-firing

Utilization options of biomass for energy



Production costs of heat, electricity and FT-Synfuel from wood residues and cereal straw (basis 2006)



a) Industrial wood (pellets, 92% DM) b) Wood residues (chips, 50% DM) c) Straw (bales, 86% DM)

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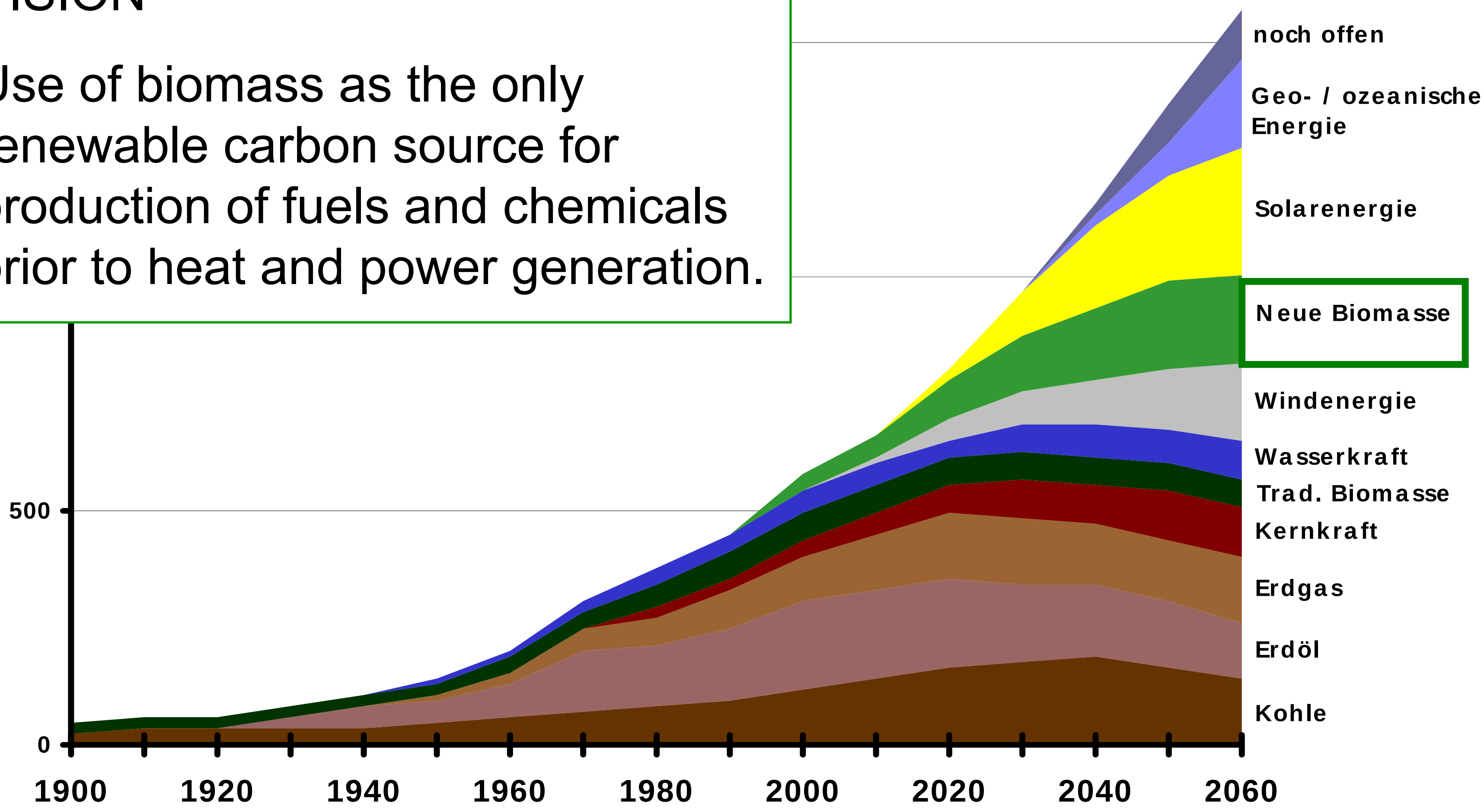
World primary energy demand 2060

VISION

Use of biomass as the only renewable carbon source for production of fuels and chemicals prior to heat and power generation.

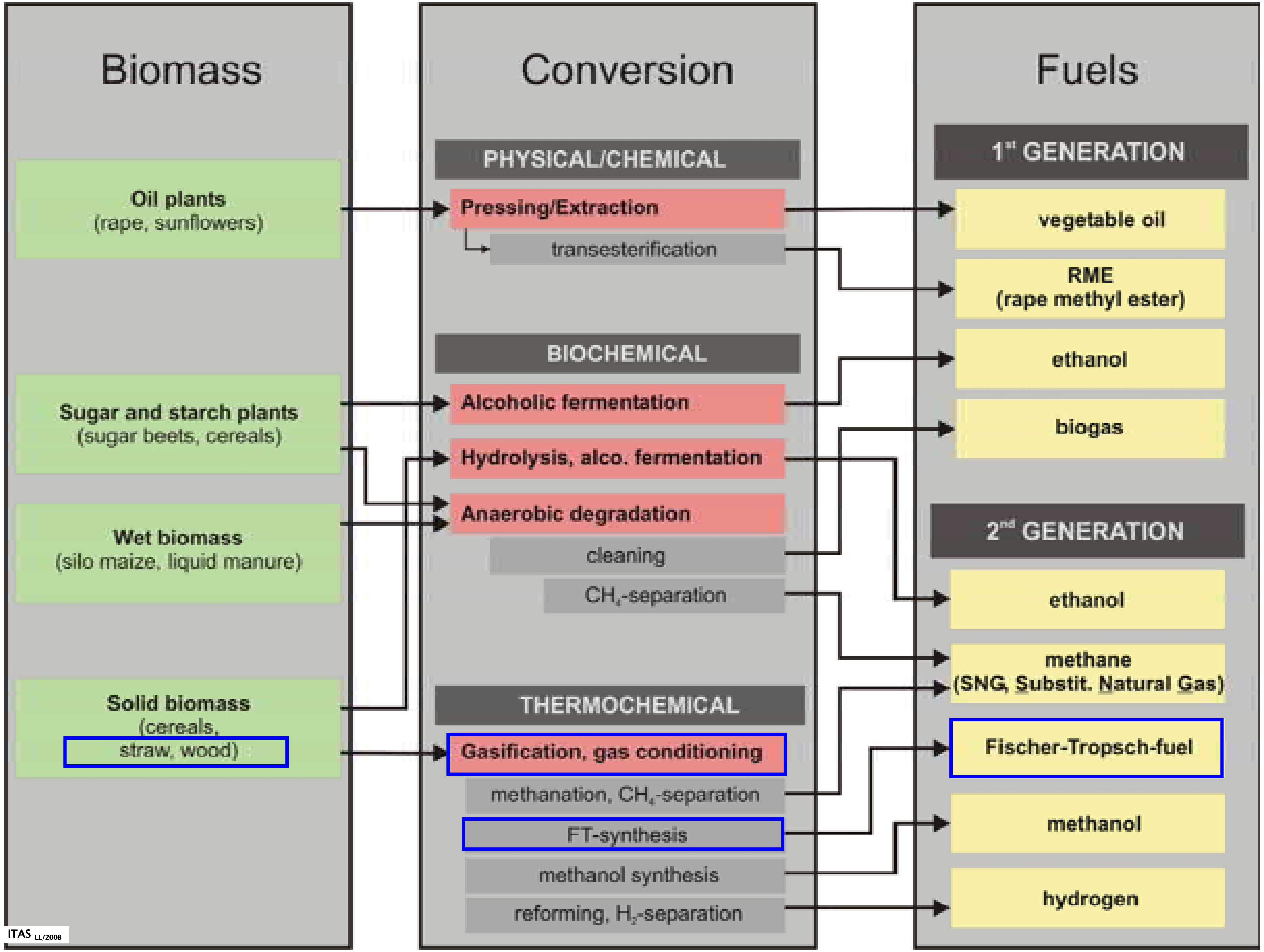


Quelle: Deutsche Shell AG

Opening statements to the use of Biomass

- Biomass is the only renewable carbon source!
- Biomass should be used favourably for organic chemicals and fuel production instead of electrical power and heat generation!
- Syngas and its main constituent, Hydrogen, are key intermediates for synthetic chemistry!
- Synthetic fuels are promising products to begin with!
- Technologies already proved for other applications should be utilized!
- Technologies used have to suitable for high capacities!
- New structures of agricultural production are required!
- Biomass stems from our biosphere – sustainable use!

Routes for the production of fuels from biomass



Biofuels - comparison

	Energy harvest GJ/ha	Fuel yield l/ha	Netto energy yield GJ/ha	GHG reduction t/ha
Biodiesel Rape seed	52	1450	38	3
Palm oil	144	4000 (6000)	75	9
HVO	98	2730	35	5.5
BTL	135	3910	114	10
Bioethanol Sugar cain/beet	135	4160	116	10
Maize	79	2440	40	1.9
Biogas	178	4980	130	7.4

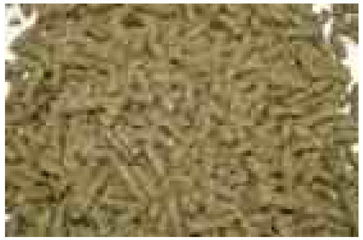
Source: FNR

BtL synthetic fuels (biomass to liquids)

- Synthetic fuels are chemically identical and full compatible to conventional diesel- or gasoline
- Due to their high quality they improve emissions e.g. of CO, particles, or hydrocarbons already by adding small amounts to conventional fuels
- They can be tailored towards new demands e.g. in regard to emission standards or new combustion engine concepts
- BtL fuels are based on a broad feed stock range…
- …exhibiting a large CO_2- reduction potential

Feedstock – dry lignocellulose“

- Agriculture
  - Straw, hay, ….
  - Energy crops
- Forestry
  - Residual wood
  - Short rotation plantation
- Land cultivation residues
  - Cultivation wood
  - Cultivation hay



Feedstock requirements

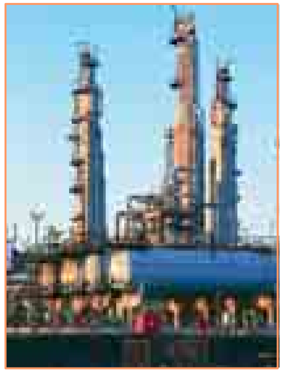
- Humidity/water content
  is not critical to the process, but reduces its effiiciency
  Drying on the field (storability)
  Initial water content < 15 % (air dried)
  Process internal further drying
- Composition
  any ratio of cellulose, hemicellulose and lignin possible
- Mineral content/Contaminants
  low contents of chlorine and sulfur desirable
- Delivery in form of bales, grinded and loose material,
  transportation costs are determining

Chemical pathways to synthetic fuels

CH_3-$(CH_2)_n$-CH_3

Fischer-Tropsch-Synthesis → **Refining** →

- ⇒ **Wax**
- ⇒ **Diesel**
- ⇒ **Gasoline**
- ⇒ **LPG**
- ⇒ **Gas**
- ⇒ ………..



$C_6H_9O_4$

Biomass → **Syngas**

H_2 CO

- ⇒ **Hydrogen**
- ⇒ **Methane (SNG)**

Direct use (Fuel cell, PME-production)

Methanol-Synthesis → **Further Processing** →

CH_3OH

- ⇒ **DME**
- ⇒ **Propylen**
- ⇒ **Ethylen**
- ⇒ **Diesel**
- ⇒ **Gasoline**
- ⇒ …….

Hurdles in large scale biomass utilization

- Low volumetric energy density
- Widely distributed and periodical occurrence
- Heterogeneous solid fuels
- High competition in biomass use
- High ash and salt contents
- Direct gasification is problematic
- Downstream syntheses require high pressures

Syngas and Synfuel production from dry biomass

Dry Biomass

CO, H_2

Fischer-Tropsch

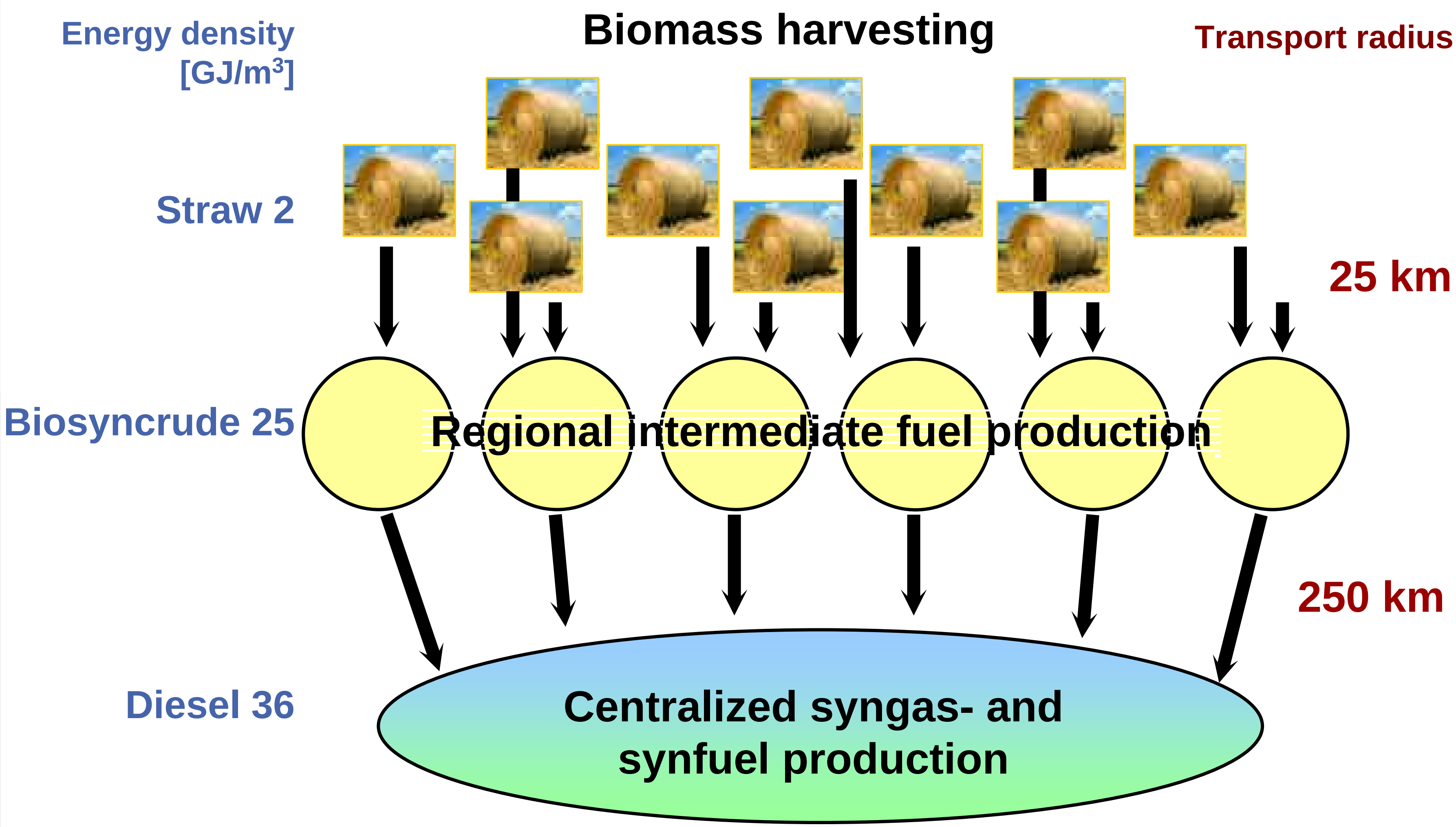
Methanol

DME .....

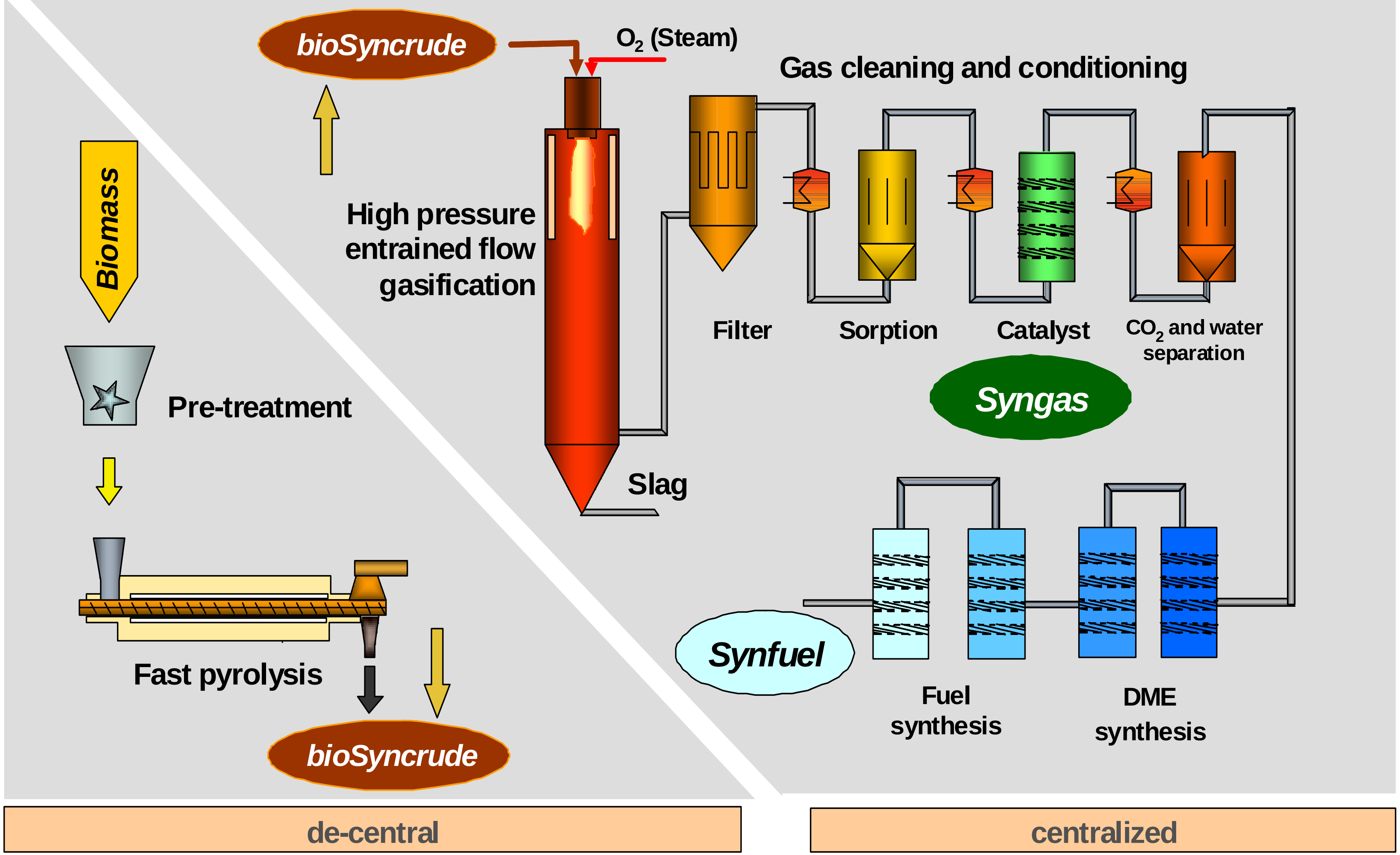
$C_6H_{12}O_6 \rightarrow 6\ CO + 6\ H_2$

$6\ CO + 6\ H_2O \rightarrow 6\ CO_2 + 6\ H_2$

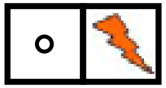
The bioliq- slurry gasification concept



The bioliq - process chain

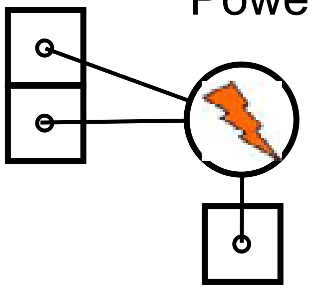


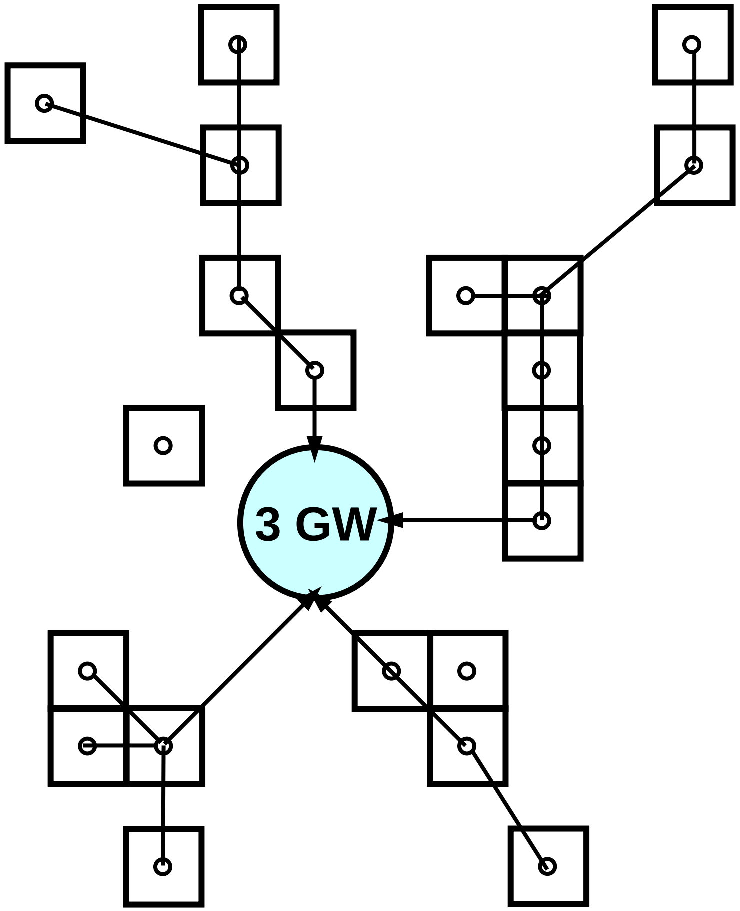
Stepwise implementation plan



First plant
(demonstration,
CHP)

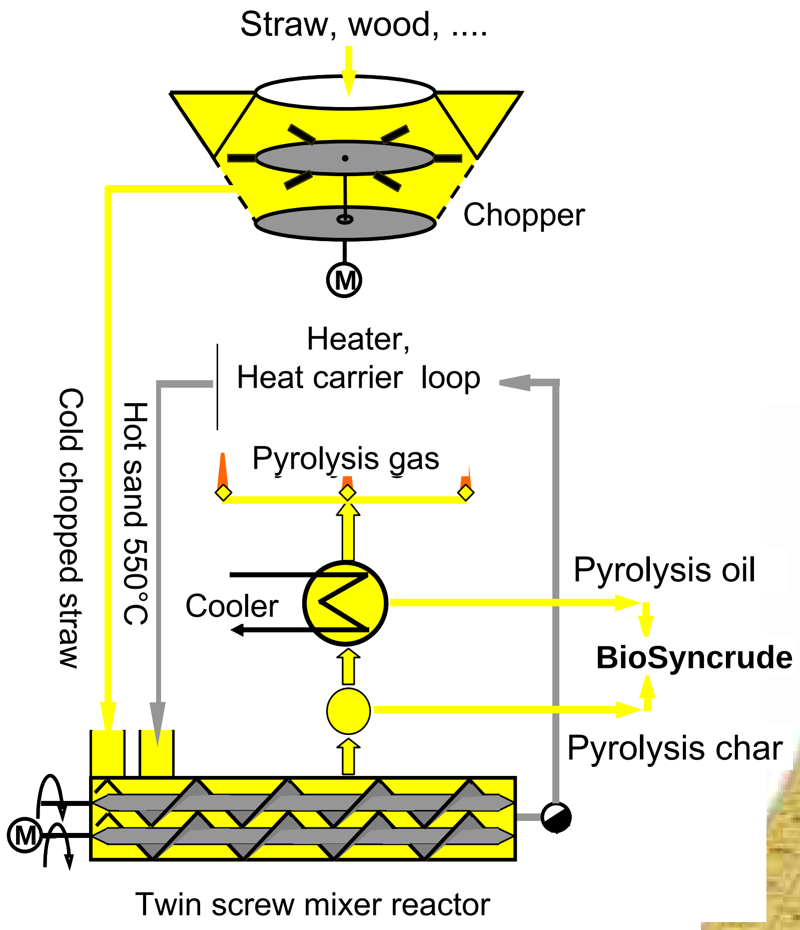
Power plant network



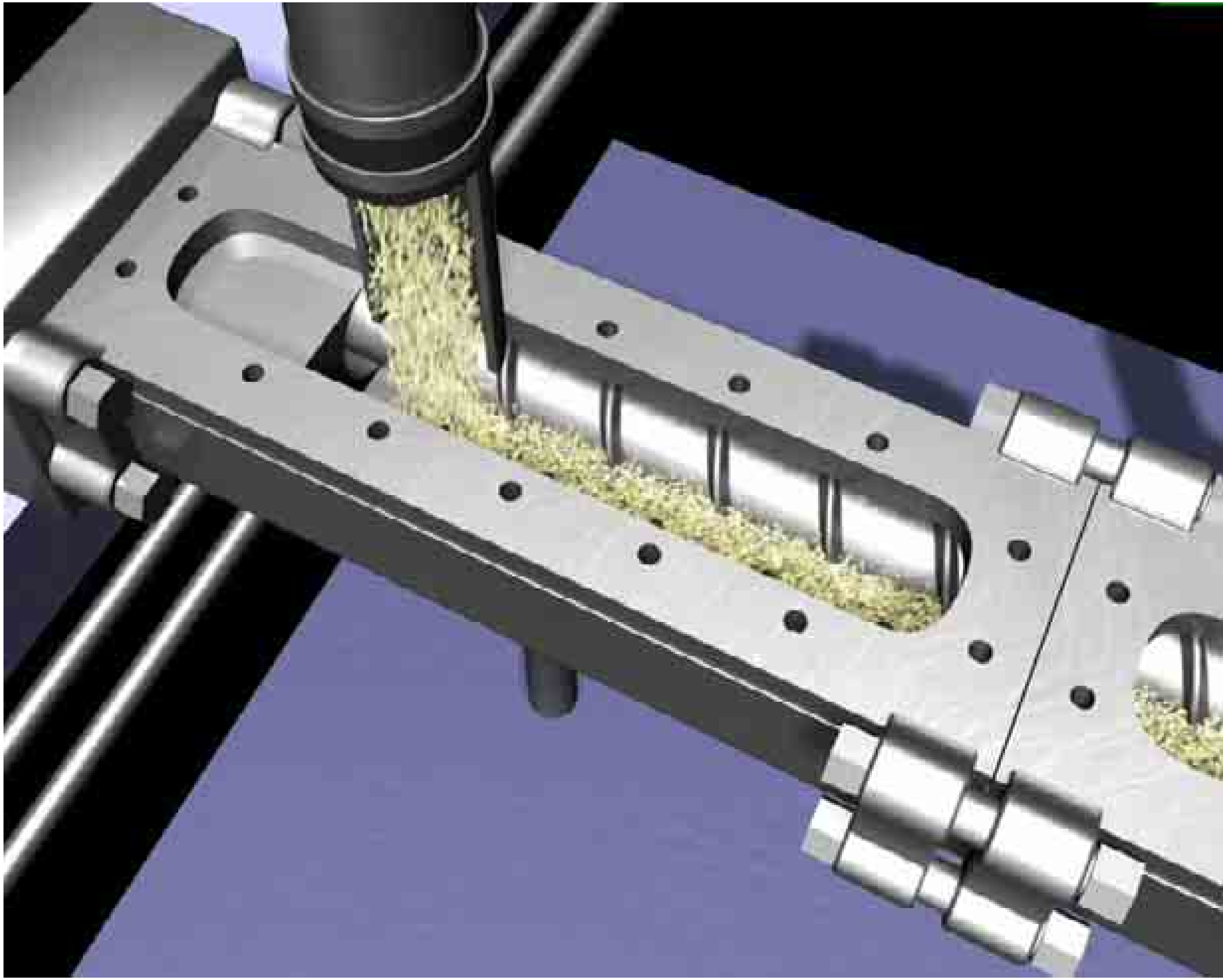


Synfuel network

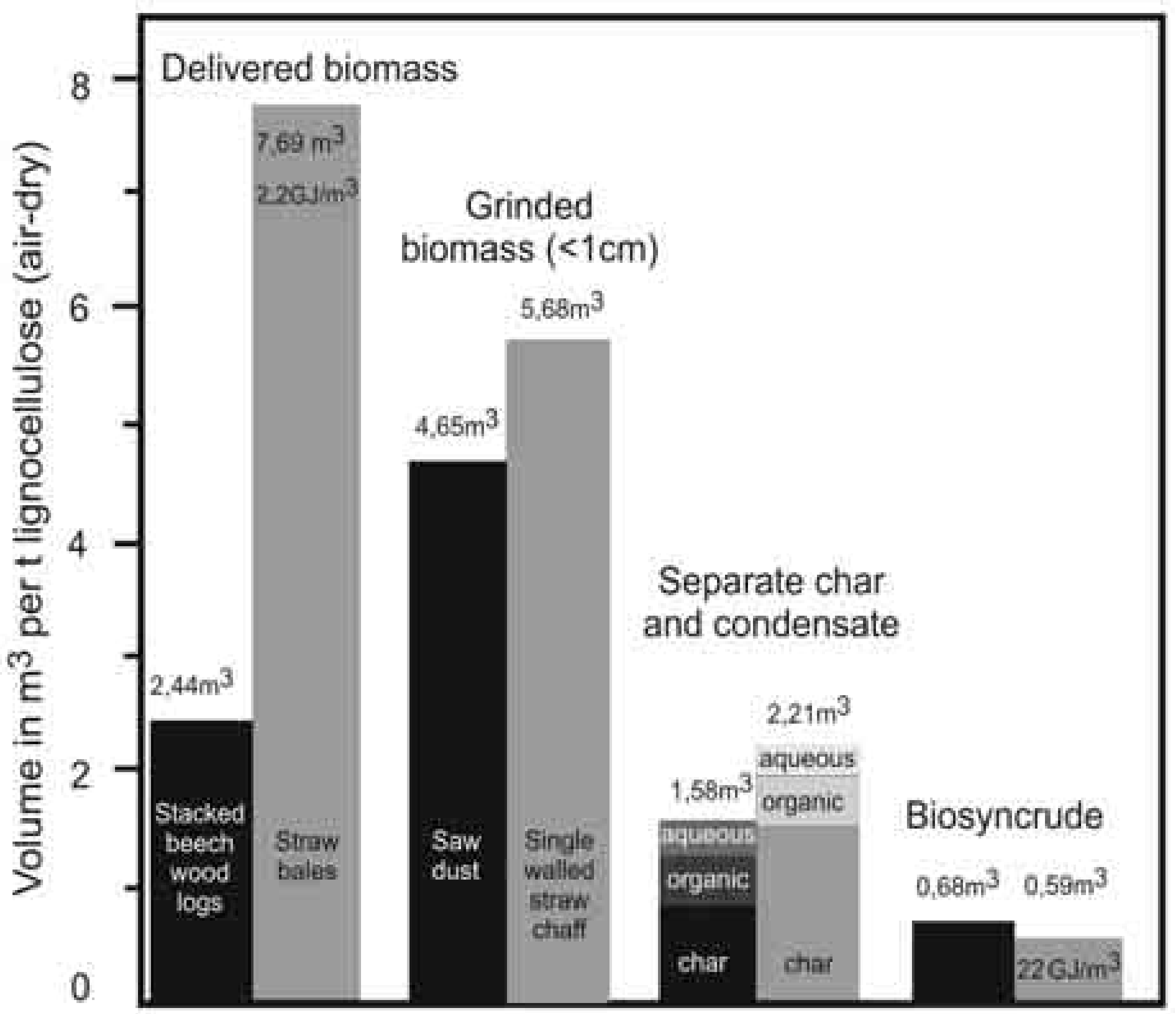
Fast pyrolysis using a twin screw mixer reactor



- Mechanical fluidized sand at 500°C
- Rapid transport, good radial mixing
- Fast heat transfer gas retention time ca. 2 sec

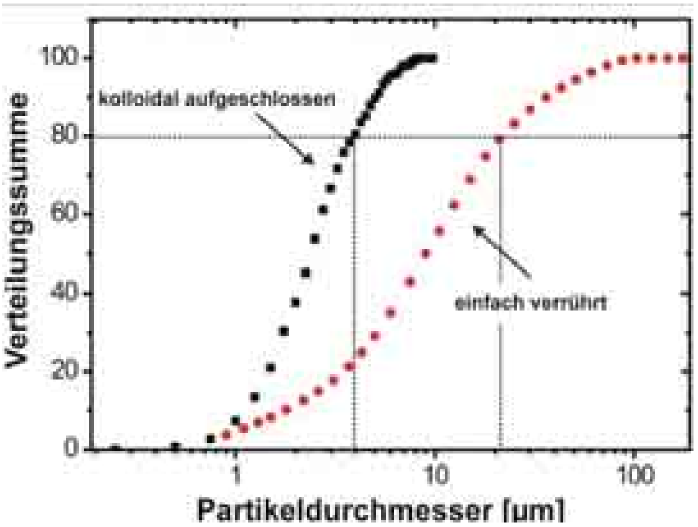


Relative volumes of pyrolysis products



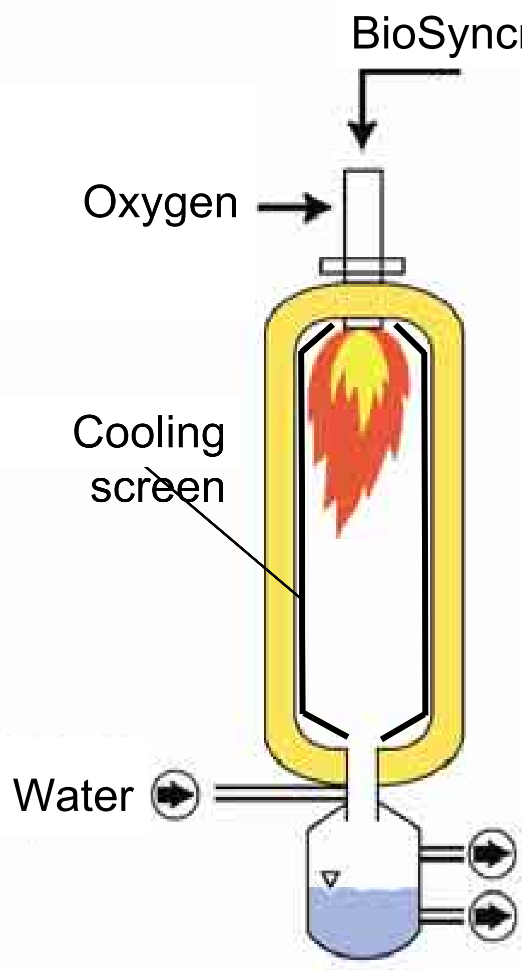
Key issue: BioSyncrude preparation

- Free flowing suspension
- High particle content up to 40wt.%
- Stable for storage and transport
- Easy to produce by mixing



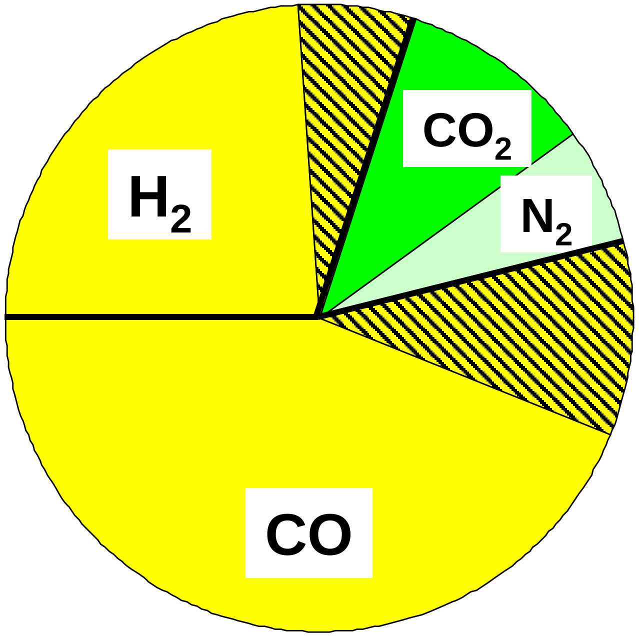
High pressure entrained flow gasification

- Suitable for feeds rich of ash
- Gasification with pure O_2
- Temperatures around 1200 °C
- High pressures up to 80 bar
- Tar free synthesis gas
- Residence time of seconds, complete C-conversion
- 4 gasification campaigns with different feed materials at the 2-5 MW_{th} pilot-gasifier of Future Energy, Freiberg
- further development based on Lurgi MPG technology



Results of biosyncrude gasification

Gas composition



- no tar, < 0.1 vol.% methane
- C-conversion ≥ 99 %
- operation without problems

Feeds:

Solids: 0 – 39 wt.%
Ash: 3 %
Heating value: 10 – 25 MJ/kg
Density: 1250 kg/m³

Operation conditions:

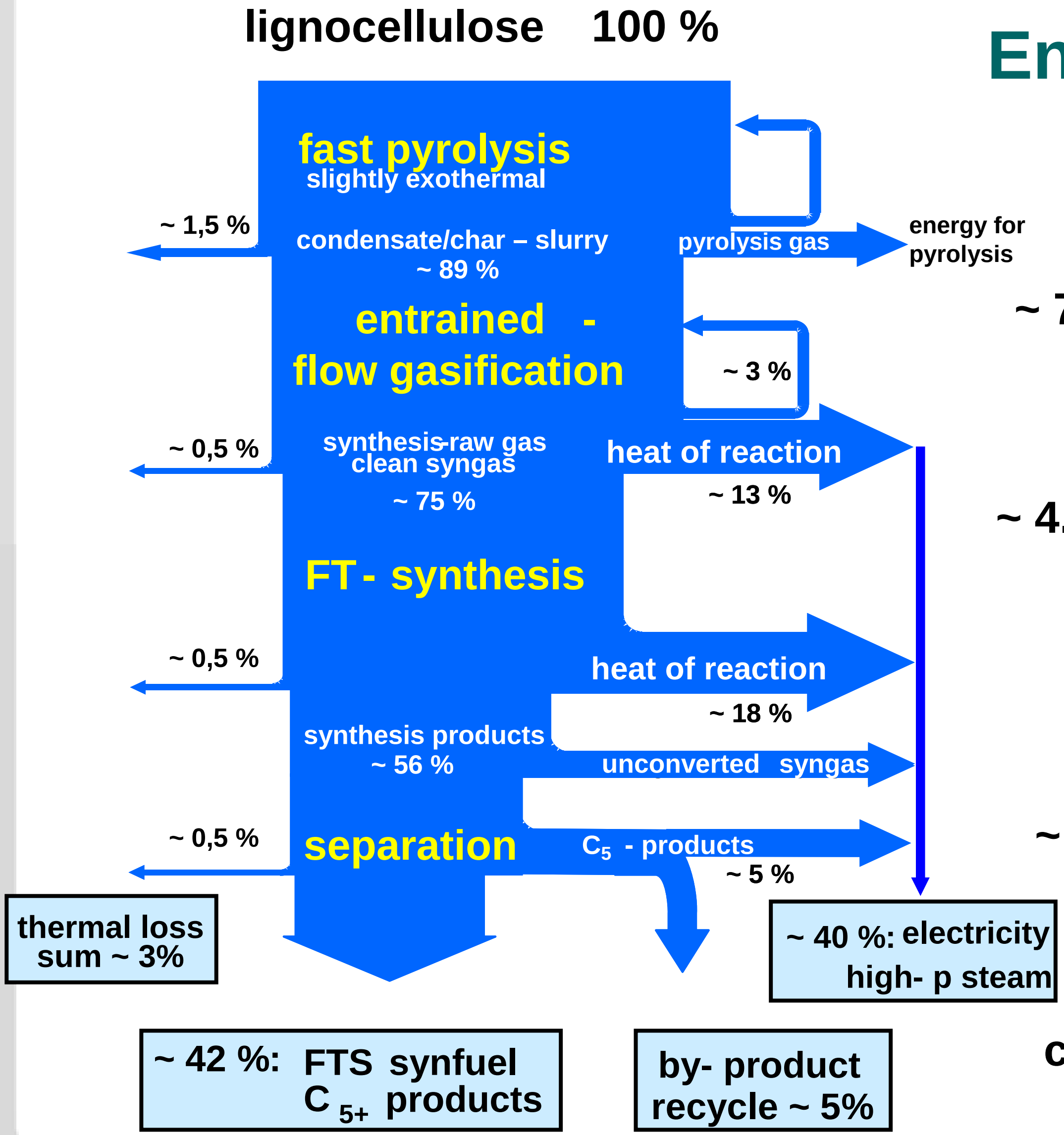
Throughput: 0.35 – 0.5 t/h
Pressure: 26 bar
Temperature: 1200 – 1600 °C
Feed-Temperature: 40, 80 °C

Sasol, South Africa
ca. 6 Mio. t/a

Synfuels from Fischer-Tropsch- and Methanol synthesis

Titan, Trinidad
ca. 0.8 Mio. t/a

Energy and mass balance



~ 7 t airdry (15 % H_2O) wood or straw

~ 6 t dry wood or straw

~ 4.7 t condensate/char - slurry or paste
plus ~ 2.7 t technical O_2

~ 1.2 t FT-synthesis raw products

~ 1 t synfuel
~ 10 % more with by-product recycle

inevitable by-products:
chemicals, electricity and HT-steam

Alternative use

Energetic efficiency in % of energy initially contained in the biomass (related to HHV)

Biomass, $C_6H_9O_4$, 100 %

Bio-Slurry $C_5H_{5,4}O_{1,1}$, 88 %

Power production

Synthesis gas 72 %

4,3 CO + 3,1 H_2

Hydrogen 72 %

Methane 56 %

Methanol 61,1 %

FT-Products 55 %

Platform chemicals

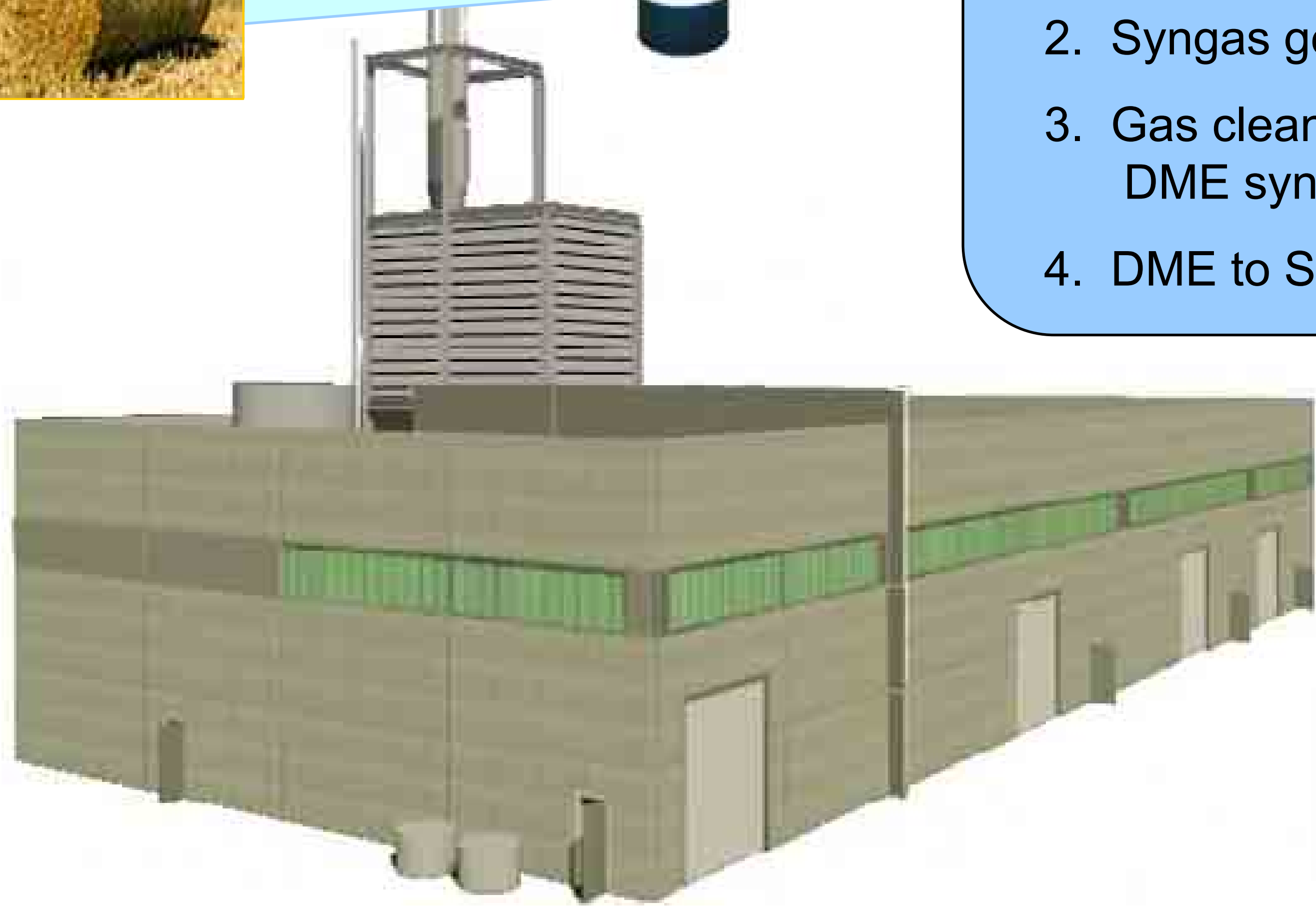
FT-Diesel 44 %

bioliq - Pilot plant

500 kg/h

100 L Synfuel

1. Biomass pretreatment
   Fast pyrolysis,
   Biosyncrude preparation
2. Syngas generation
3. Gas cleaning
   DME synthesis
4. DME to Synfuel



Lurgi

FACHAGENTUR NACHWACHSENDE ROHSTOFFE e.V.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

Stage 1: Fast pyrolysis and Biosyncrude preparation

Biomass preparation

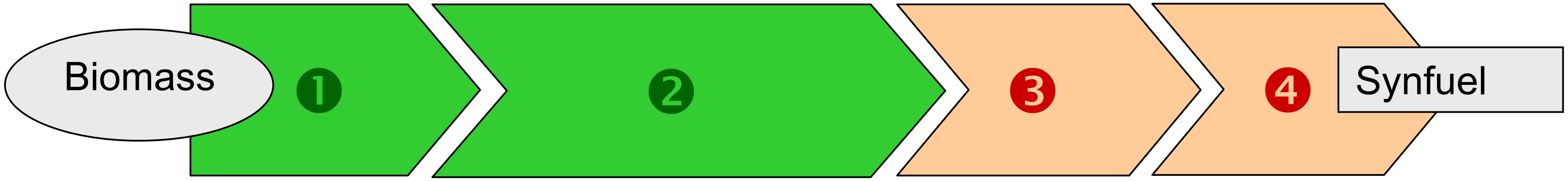
Fast pyrolysis

Pyrolysis product recovery

Feed stock storage

Biosyncrude preparation

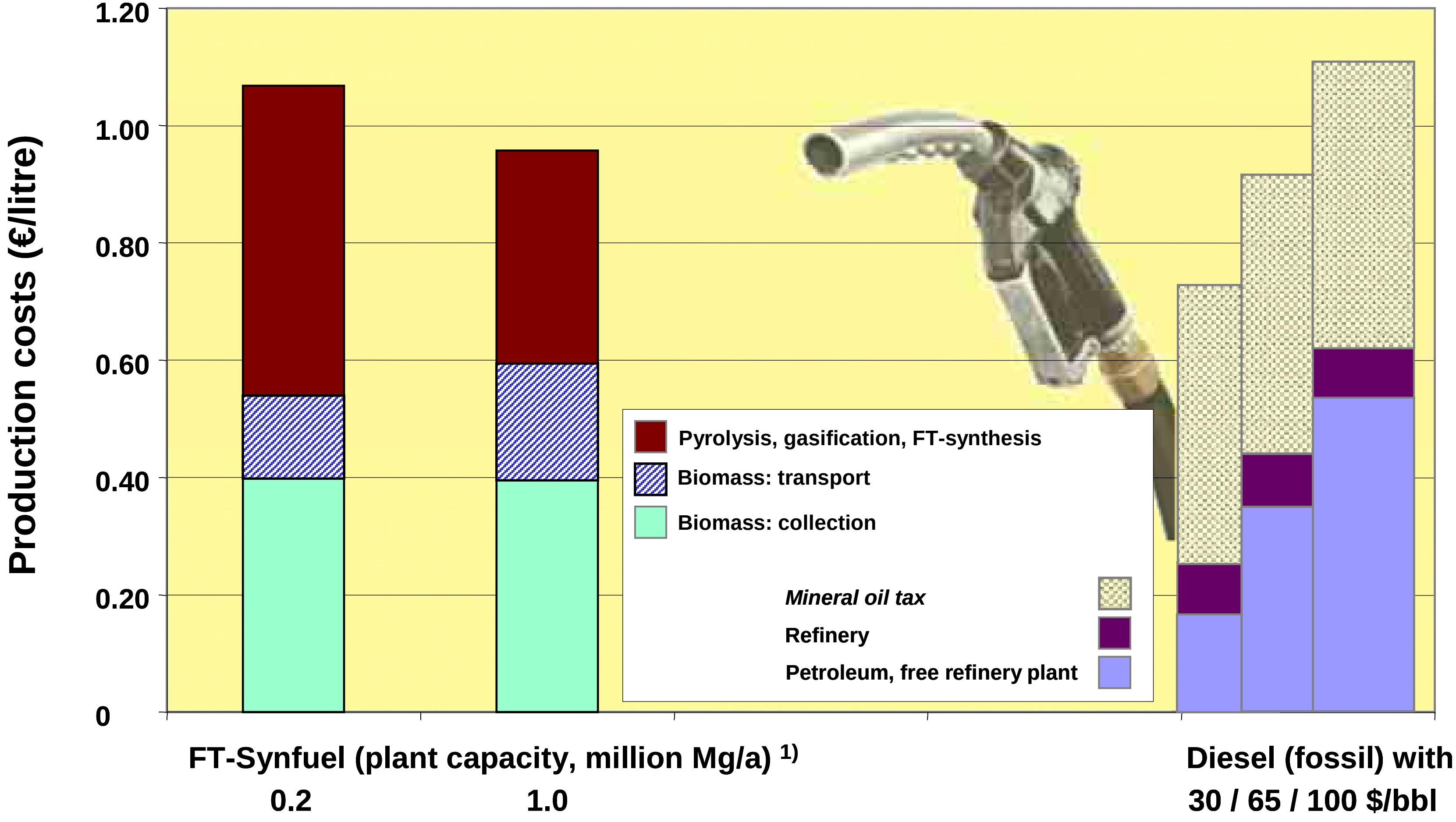
Bioliq pilot plant – actual state



	Stage 1	Stage 2	Stage 3	Stage 4
Process	Fast pyrolysis	HP Entrained flow gasification	Gas cleaning + Synthesis I	Synthesis II
Product	BioSyncrude	Synthesis gas	DME	Synfuel
Capacity	500 kg/h (2 MW)	1 t/h (5 MW)	150 kg/h	80 kg/h
Realization	2008	2011	2012	2012
Costs	8.2 Mio.€	24.8 Mio.€	22.5 Mio.€*	

*applied for

Production costs of FT-synfuel from straw <u>and</u> wood residues



[1] FT-Synfuel from straw and wood residues, central plant; production costs quoted free plant, without tax; basis 2006

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International interests

- Request and contacts:

China	Straw and other residues
Chile	Wood- residues
India	Residues from sugar cane
Malaysia, Indonesia	Residues from palm oil production
Russia / former USSR	Straw und wood- residues



Conclusion BTL

- Production of high quality synthetic fuels
  ⇨ value added products by innovative technologies
- Use of any kind of dry biomass
  ⇨ huge feedstock potential
- No competition to food and feed production
  ⇨ Use of residues from agricultural and forestry
- De-central/centralized concept
  ⇨ high availability of biomass
- Regionally distributed plant for biomass pretreatment
  ⇨ new income options for farmers
- Process energy is produced as a side product
  ⇨ high CO_2 reduction potential
- Large scale synfuel production
  ⇨ economic industrial plant size

Biomass to Liquid Karlsruhe

Hydrothermal gasification of wet biomass

Wet (waste) Biomass

H_2, CH_4

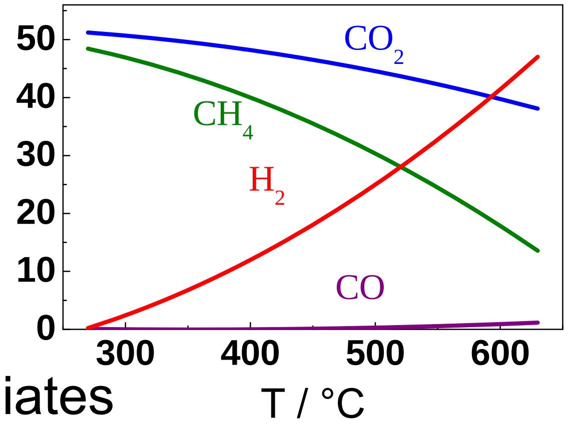
$$2\ C_6H_{12}O_6 + 6\ H_2O \rightarrow 12\ H_2 + 3\ CH_4 + 9\ CO_2$$

Feed materials for hydrothermal gasification

Residual biomass	Organic waste	Fuels	Energy plants
Disposal & energy	Disposal & energy	Decentralized Energy	Enduring energy
Food & beverage Wine trash Agricultural production Liquid manure	Paper & cellulose Pharmaceutical & chemical industry Biotechnology Sewage sludge	Bio-alcohol Rape oil MeOH Hydrocarbons Pyrolysis oil	Suitable ground and aquatic fresh plants Corn silage Mash (bio- ethanol) Sludge (biogas)
Wet	Wet / toxic	Without catalyst	Use of complete plant

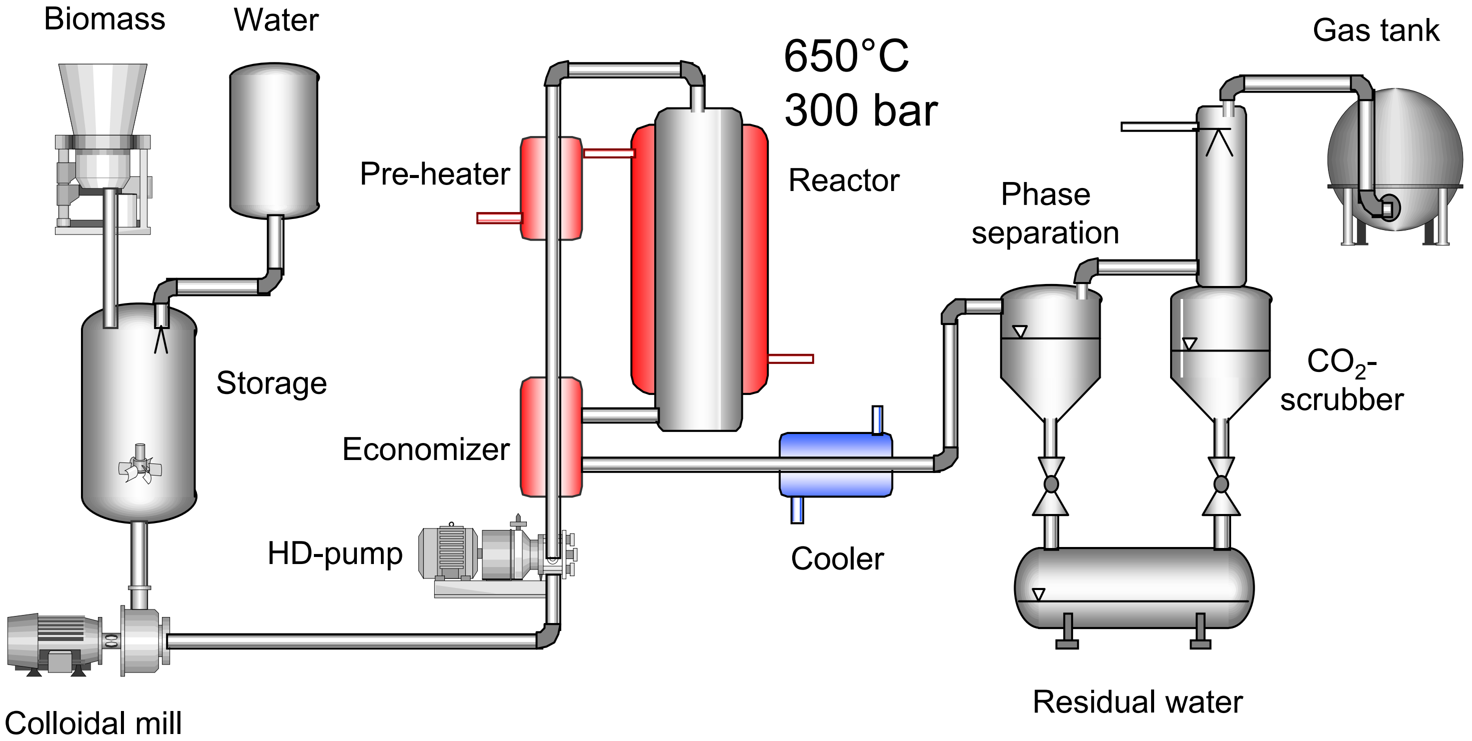
Hydrothermal gasification of biomass

- Gasification in excess water at 700°C, 300bar
- "integrated" water gas shift reaction
- High H_2-yield obtained under pressure
- Short reaction times, high space/time-yields
- No tar and char due to solvation of the intermediates
- Easy CO_2-separation under pressure
- Inorganic components are not volatile



Wood, $CH_{1,44}O_{0,66}$,
25 MPa, 10 wt.%

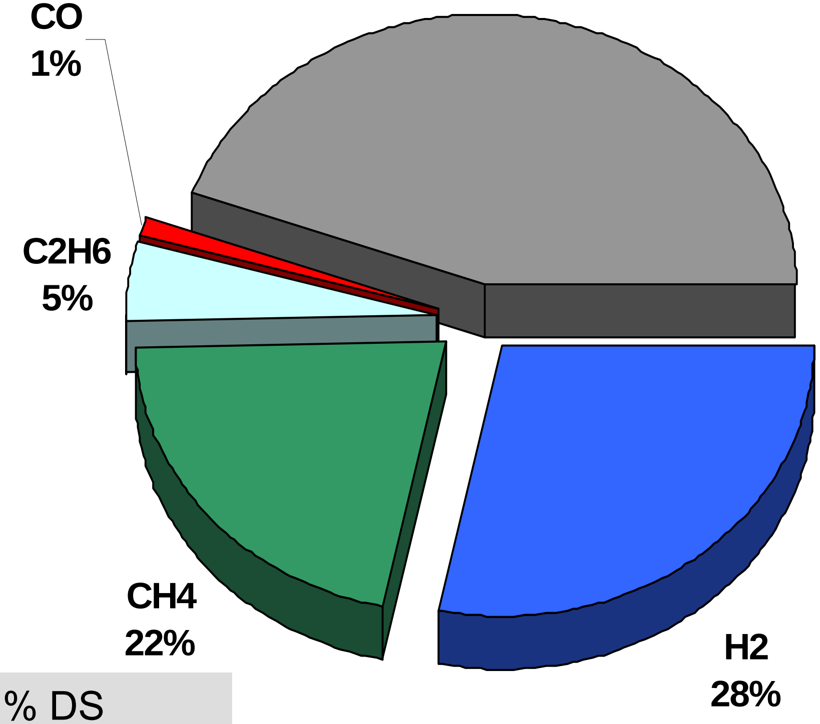
Flow scheme for hydrothermal gasification



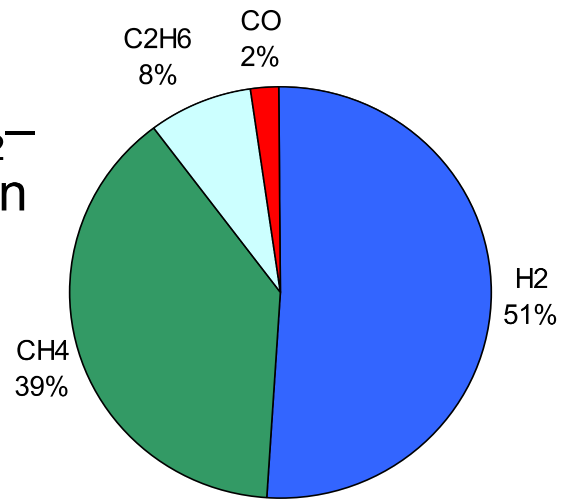
VERENA pilot plant

Hydrothermal gasification of corn silage

Before CO_2–separation



After CO_2–separation



7.5 wt.% DS
700 °C, 250 bar
1.3 – 3.4 min

Conclusions

- Energetic utilisation of biomass already contributes to the reduction of greenhouse gases in Germany and worldwide. Sustainable use of biomass increases this effect.
- The emission of greenhouse gases depends strongly on the biomass and the utilisation (conversion technology and the form of end energy).
  - Waste and residual biomasses show low emission of greenhouse gases
  - Heat generation from biomass shows very low emissions
  - Long term use of biomass as C-carrier necessary
  - Efficient technologies are developed.
- Optimization target for the future is the whole chain of the biomass utilization.

„Stone era did not end because a lack of stones, and the oil era will not end up because oil is running out “

Sheich Zaki Yamani, 1974
former minister from Saudi Arab

Supported by….

Forschungszentrum Karlsruhe

Helmholtz-Gemeinschaft HGF

Ministerium für Verbraucherschutz, Ernährung und Landwirtschaft BMELV

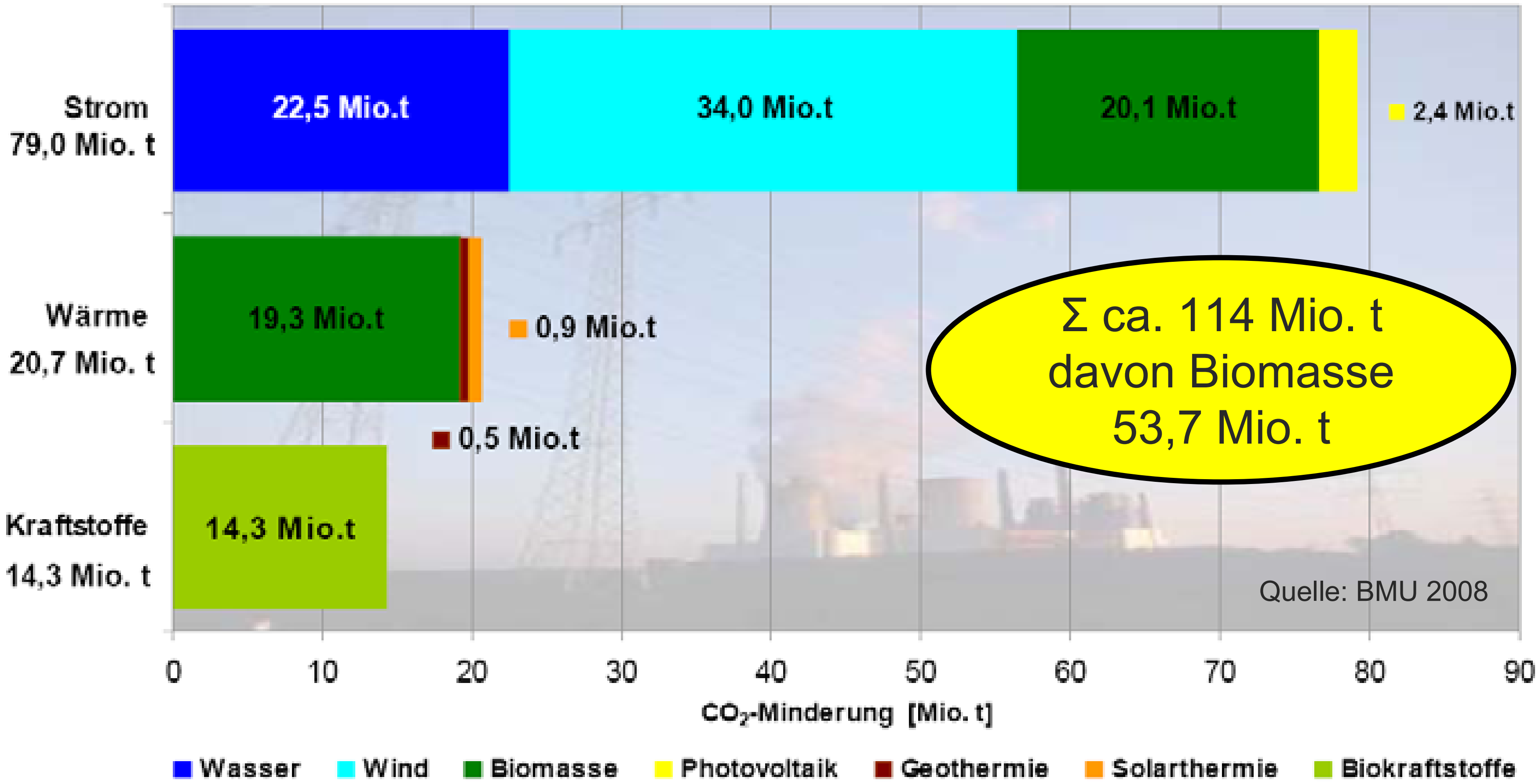
Fachagentur Nachwachsende Rohstoffe

Ministerium für Ernährung und ländlichen Raum Baden-Württemberg MELR

EU Kommission

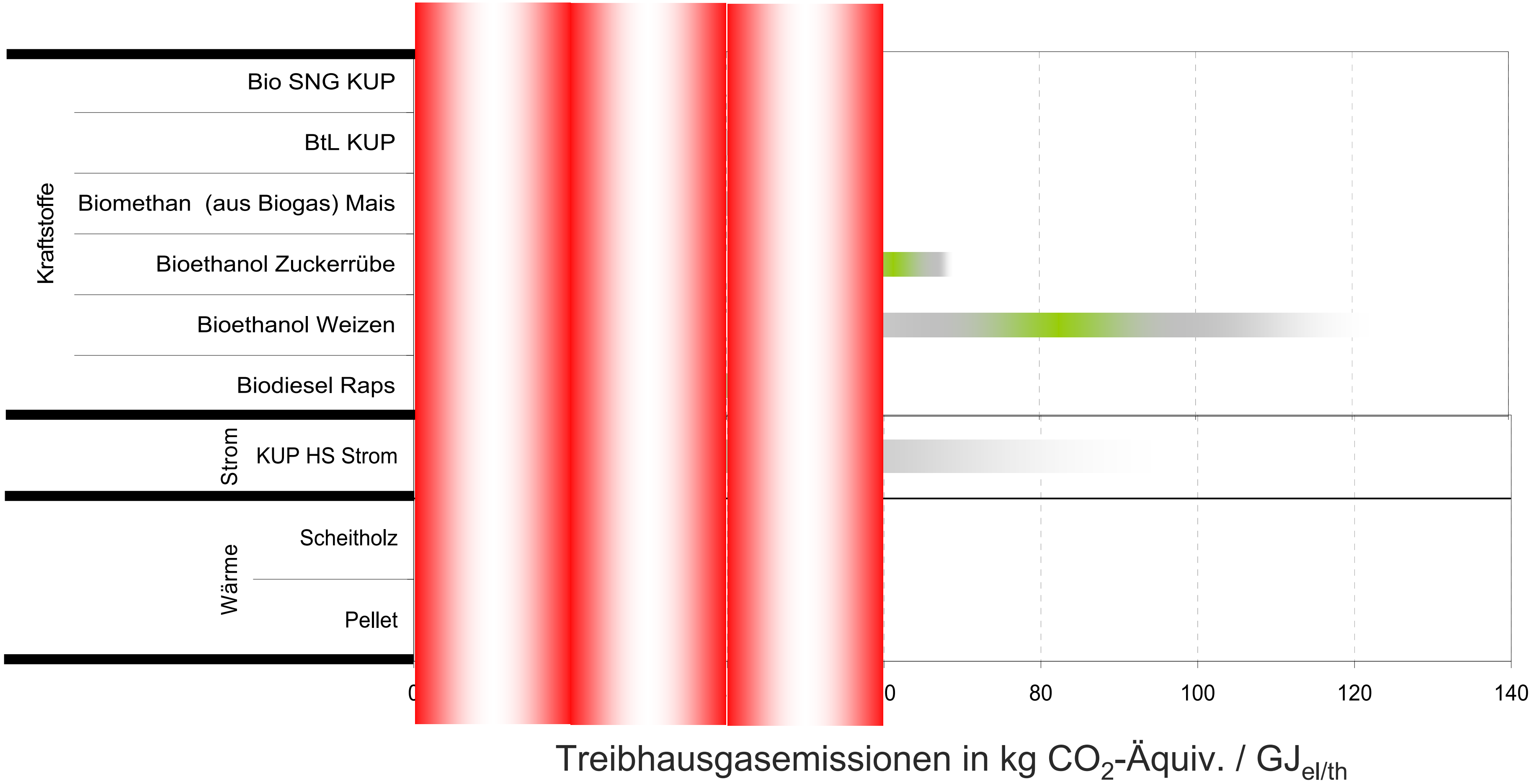
Ministerium für Bildung und Forschung BMBF

Energy system Germany
- Avoided Greenhouse gases -



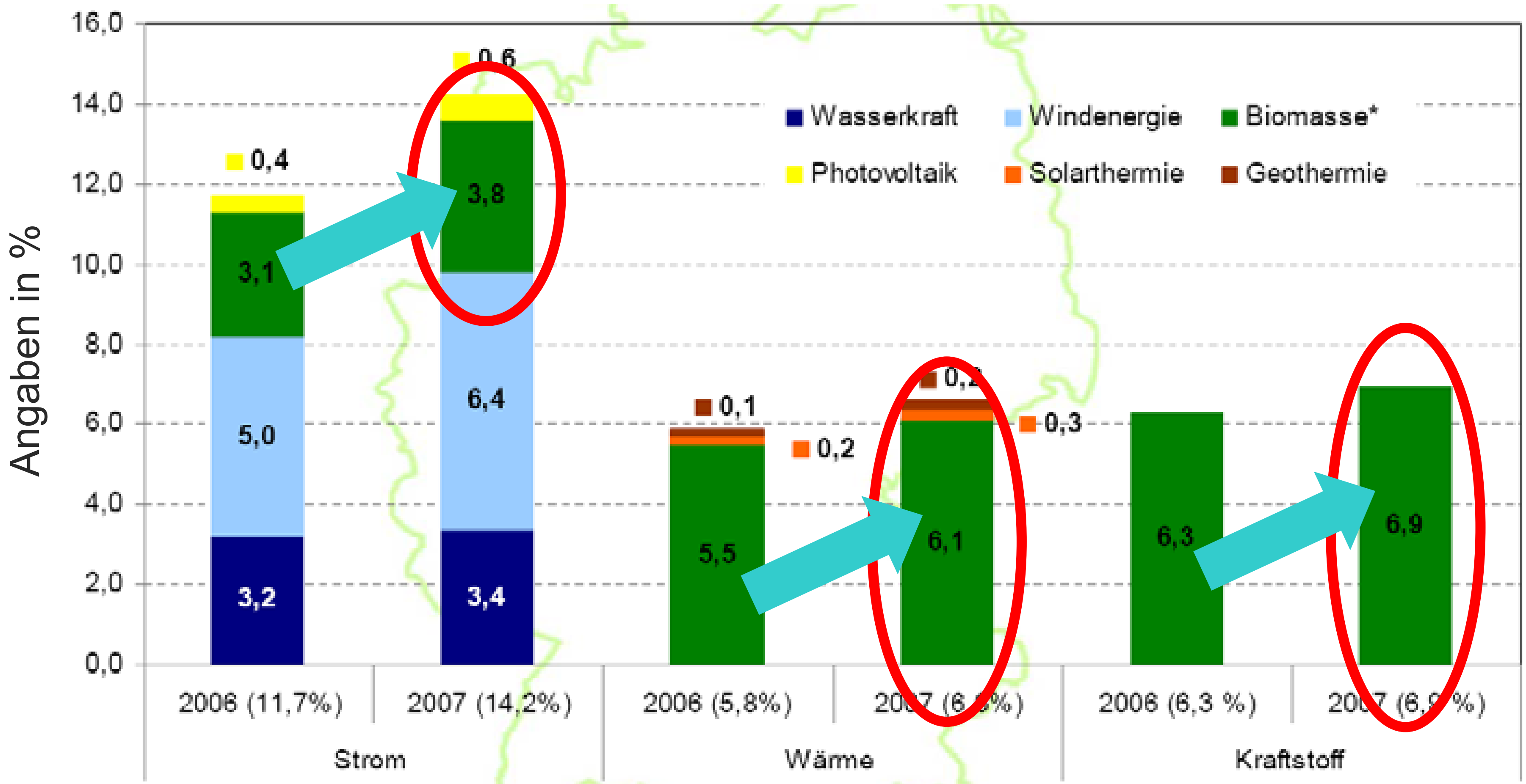
Die durch die Nutzung der Biomasse (reg. Energien) vermiedenen Klimagasmissionen liegen bei 6 bis 7 % (14 bis 15 %) der energiebedingten Klimagasfreisetzungen in Deutschland (2007).

Greenhouse gases
balance for bio-energy systems



Energiesystem Deutschland

- Anteil der ern. Energien am EEV -



* feste, flüssige, gasförmige Biomasse, biogener Anteil des Abfalls, Deponie- und Klärgas;
Quelle: BMU nach Arbeitsgruppe Erneuerbare Energien - Statistik (AGEE-Stat); vorläufige Angaben, Stand März 2008

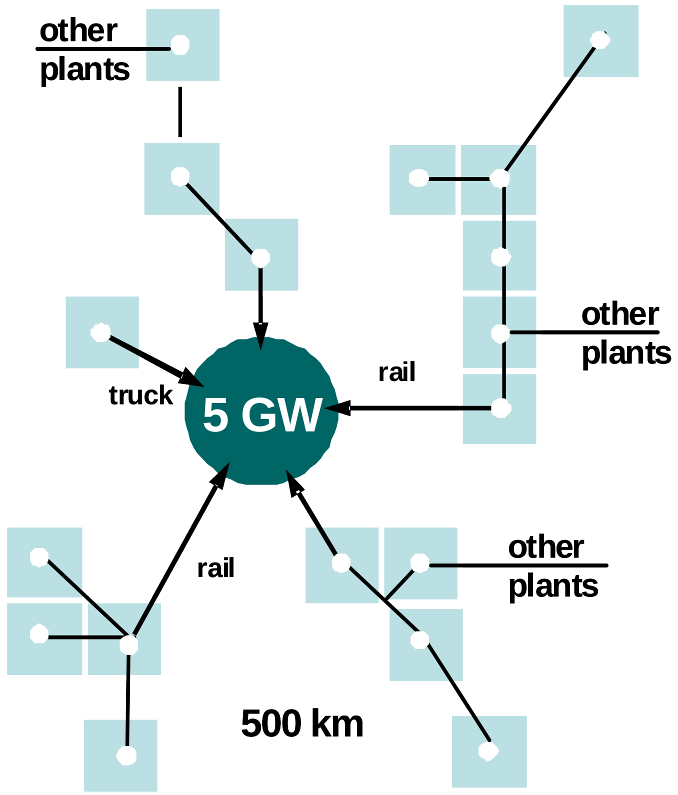
Quelle: BMU 2008

Nutzungsperspektiven für BioSyncrude

- Co-Verbrennung in (Heiz)kraftwerken
  - Co-Verbrennung in (Heiz)Kraftwerken
  - Stadtwerke Hannover, UM Niedersachsen
  - Stadtwerke Halle, UM Thüringen
  - Nordhessen HMULV, eon-mitte, Lurgi (Nordhessen-Studie)
  - Weitere Kontakte mit Vattenfall, EnBW, RWE

- Monoverbrennung (BHKW)
  - AGO (Kulmbach), Agrartechnik (Schleidorf)

Examplary plant configuration



10 trucks (60 m³ straw each)

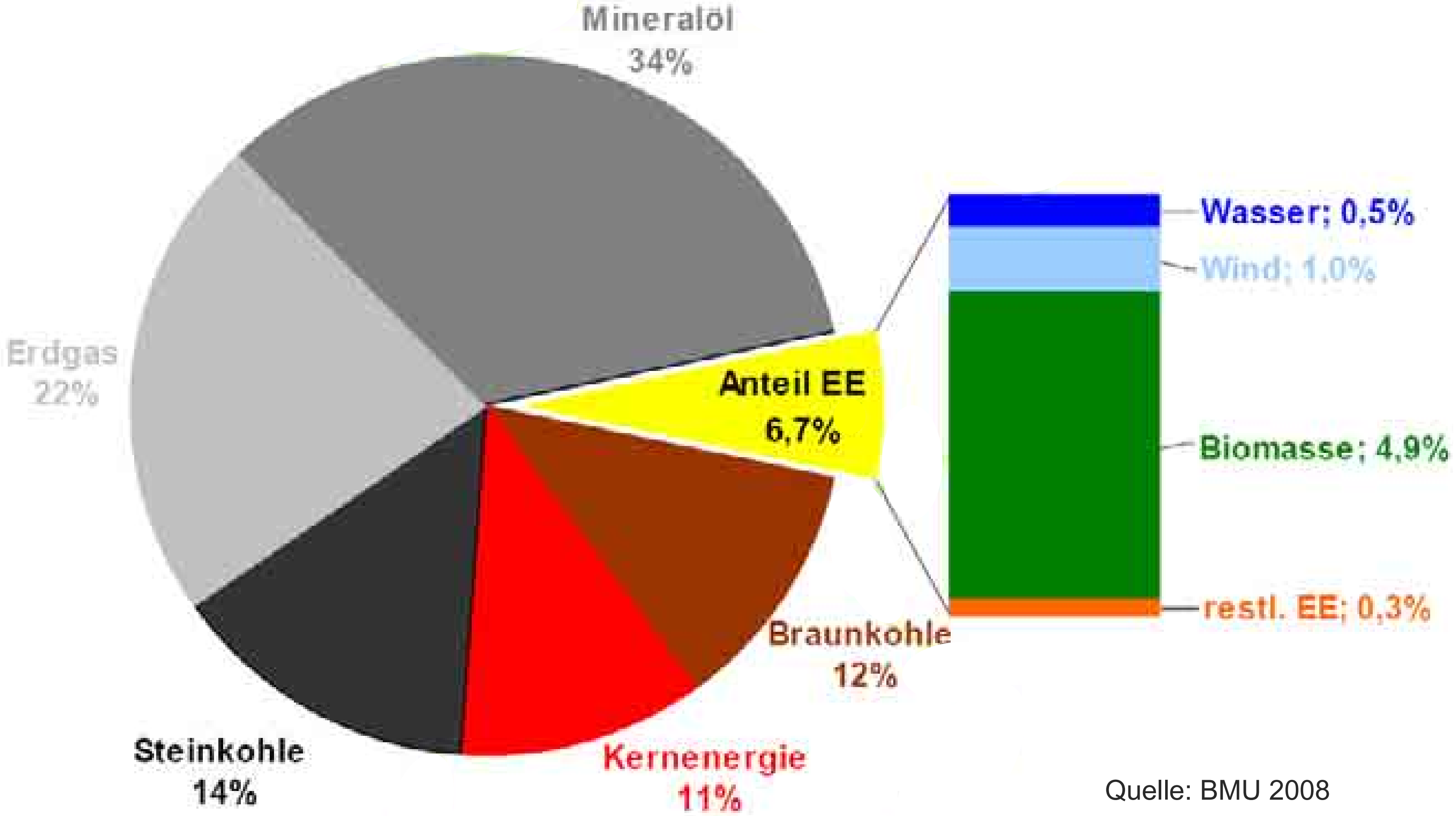
Straw ↓ Transport

40 pyrolysis plants (20 M€)
Capacity ~ 0.2 Mt/a straw each

Slurry ↓ Transport

1 central gasification unit (500 M€)
production capacity ~ 1 Mt/a

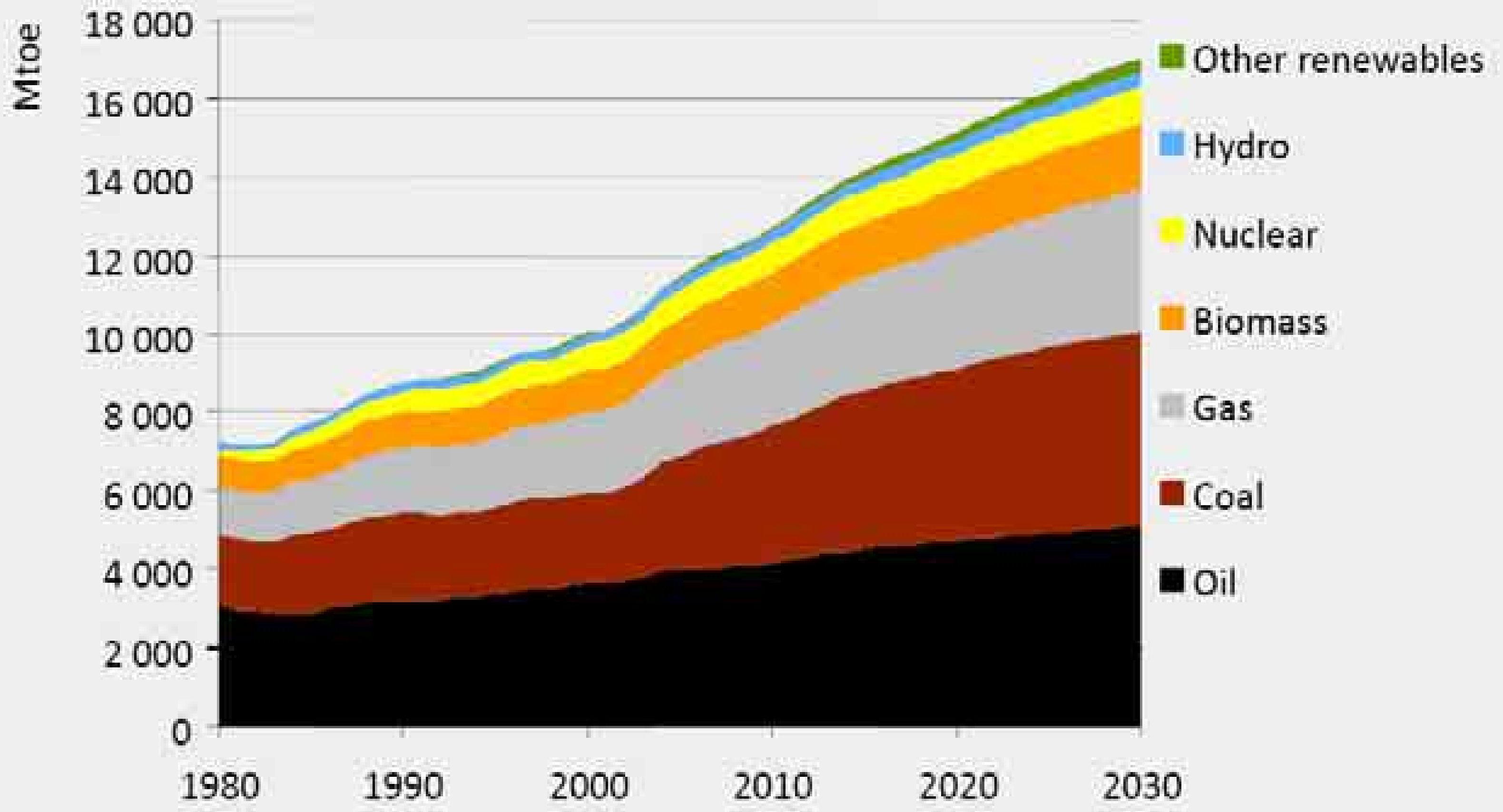
Energy system - Germany
primary energy



Quelle: BMU 2008

PEV 2007: 13,9 EJ (2,7 % bez. auf den Welt-PEV)

Entwicklung des Welt-Primärenergieverbrauchs bis 2030 (IEA-Referenz-Szenario)

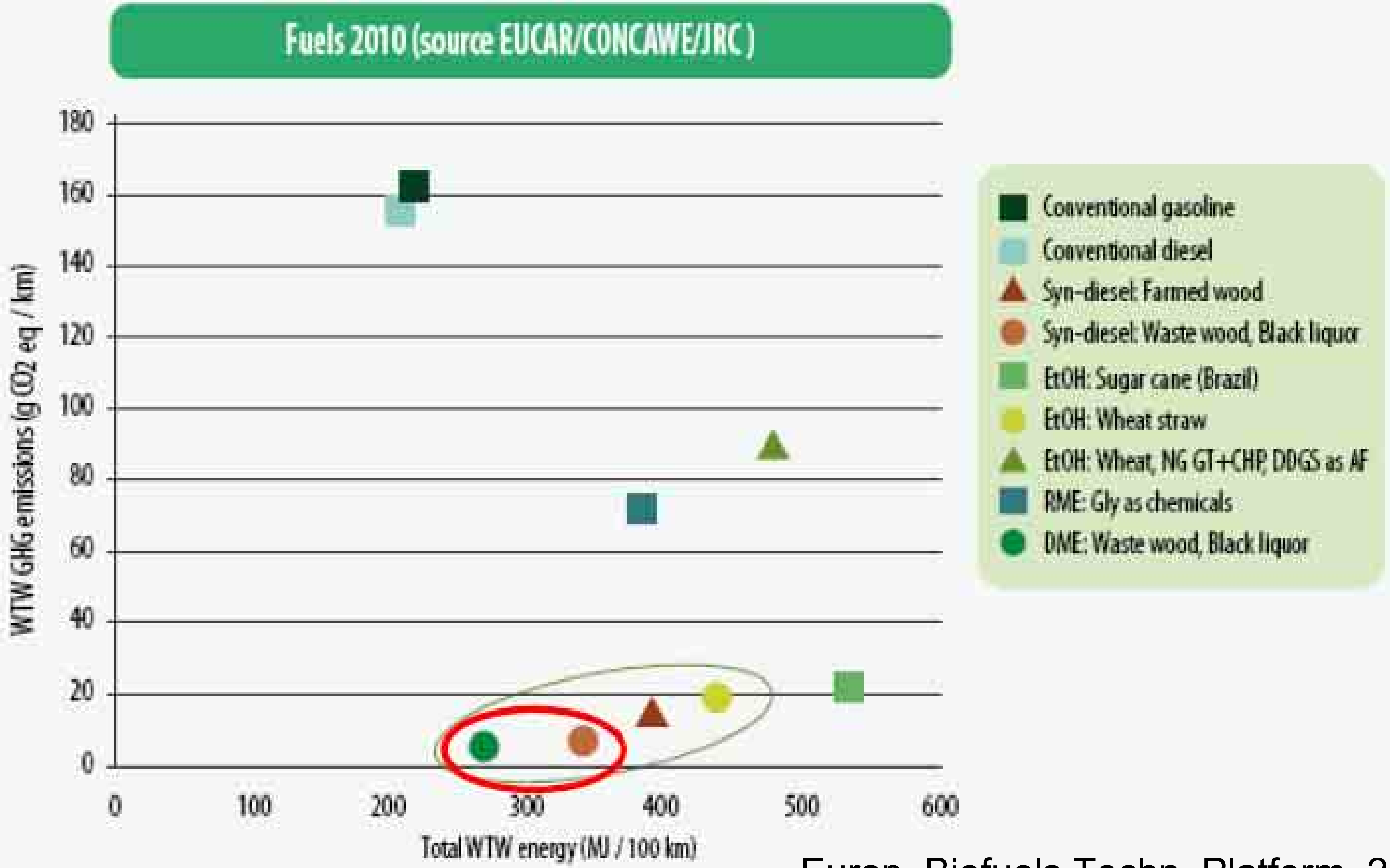


Quelle: IEA (17.11.2008): World Energy Outlook 2008, Key Graphs

Other renewables: Geothermie, Solar, Wind, etc.

Fazit: Bis 2030 wird sich der Primärenergieverbrauch um rd. 45 % erhöhen!

Well to Whell GHG vs. total energy use



Europ. Biofuels Techn. Platform, 2008