# Biofuels – Which One is the Most Economic One?

## Production Costs and Market Opportunities

Scientific Forum at ILMAC 2007 "Energy and Raw Materials - Contributions of Chemistry and Biochemistry in the Future“

Basel, September 26, 2007

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# Abbreviations

- BTL Biomass-to-Liquid
- CNG Compressed Natural Gas
- CTL Coal-to-Liquid
- DME Dimethyl Ether
- FAME Fatty Acid Methly Ester
- FT Fischer-Tropsch
- GHG Greenhouse Gas
- GTL Gas-to-Liquid
- $H_2$ Hydrogen
- l Litre
- kt Kilotonne
- LNG Liquified Natural Gas
- LPG Liquified Petroleum Gas
- MeOH Methanol
- RME Rape Seed Methyl Ester
- SNG Synthetic Natural Gas

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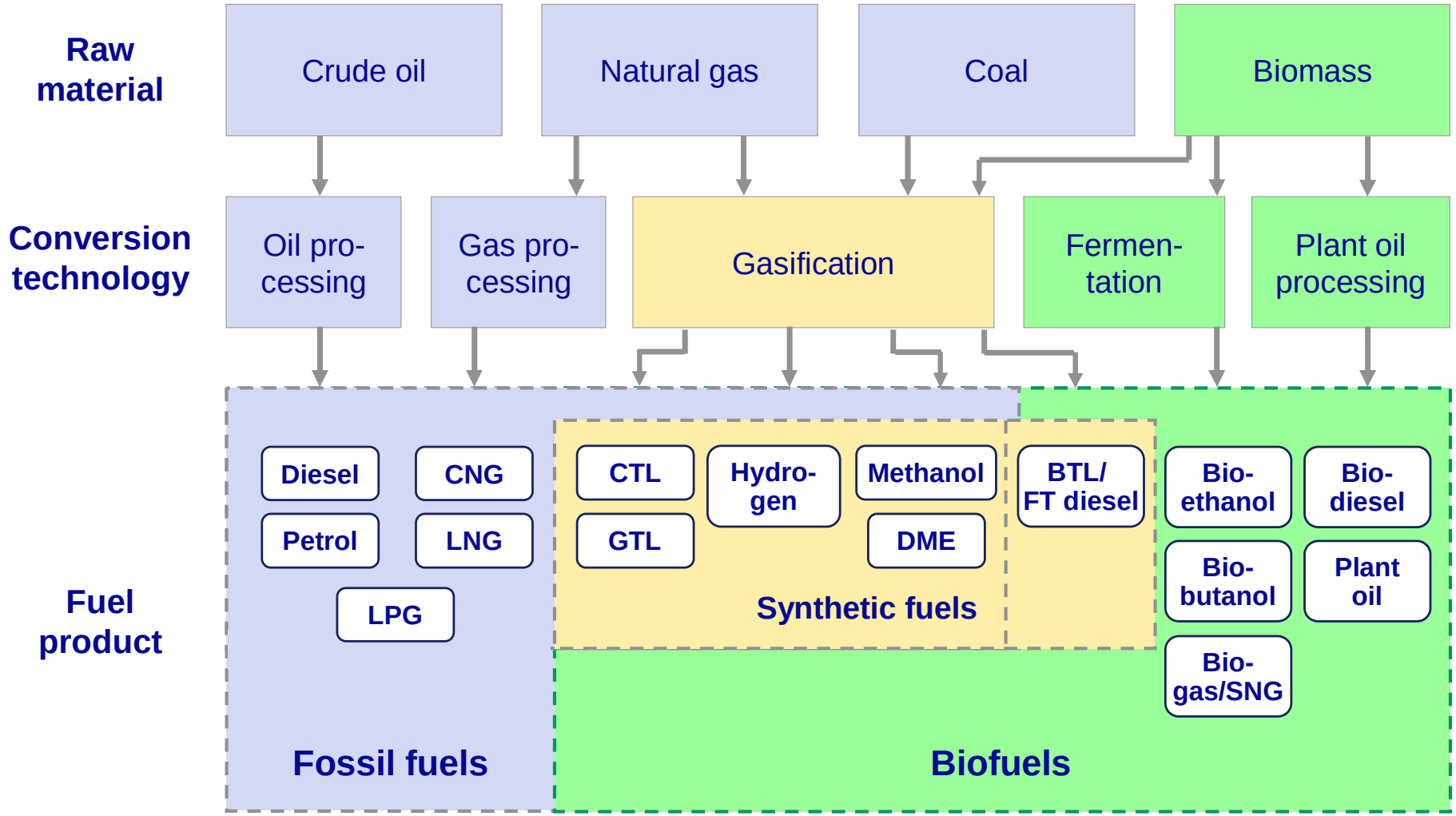
# Fuel types can be categorized based on raw materials and main conversion technologies



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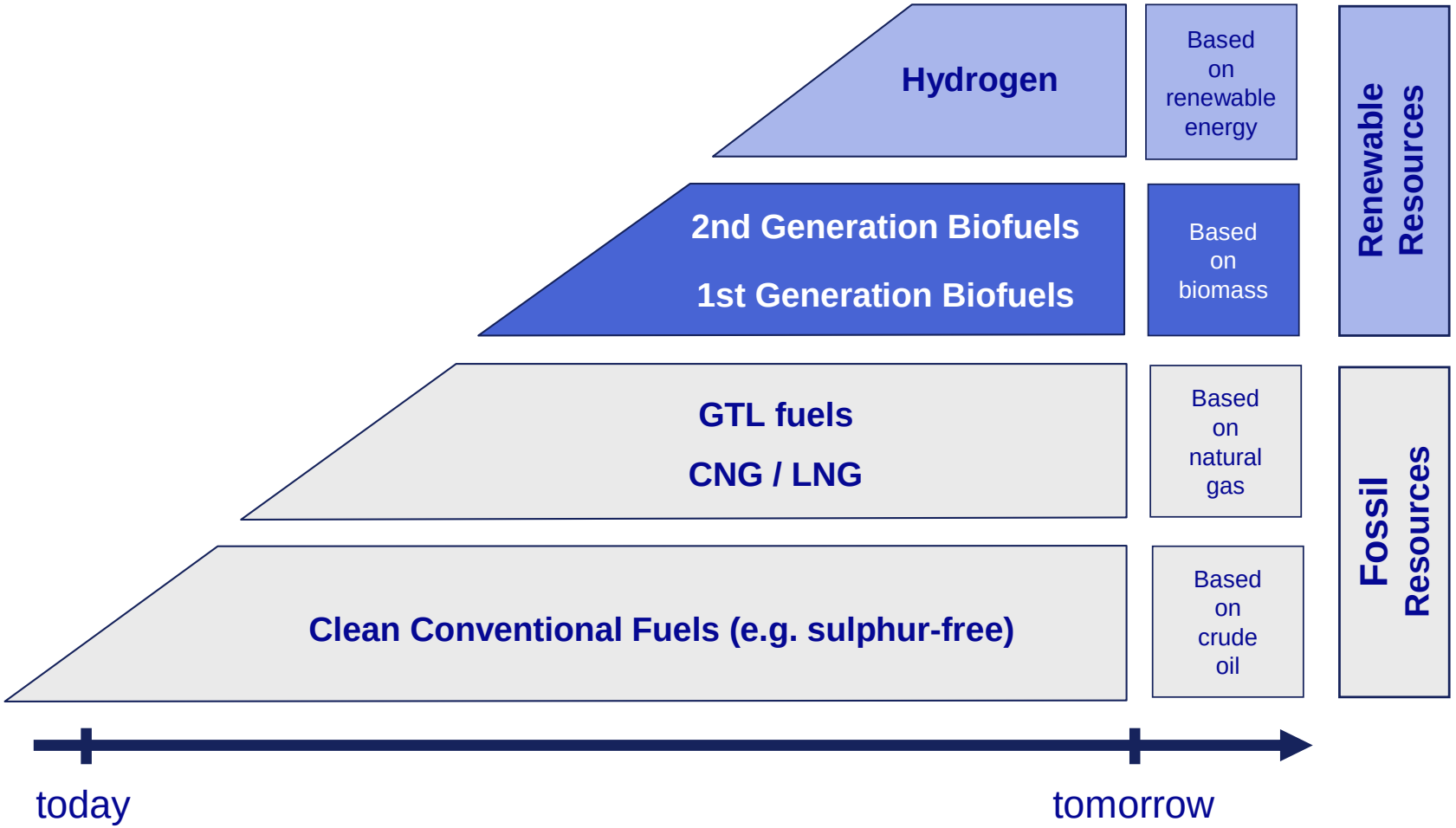
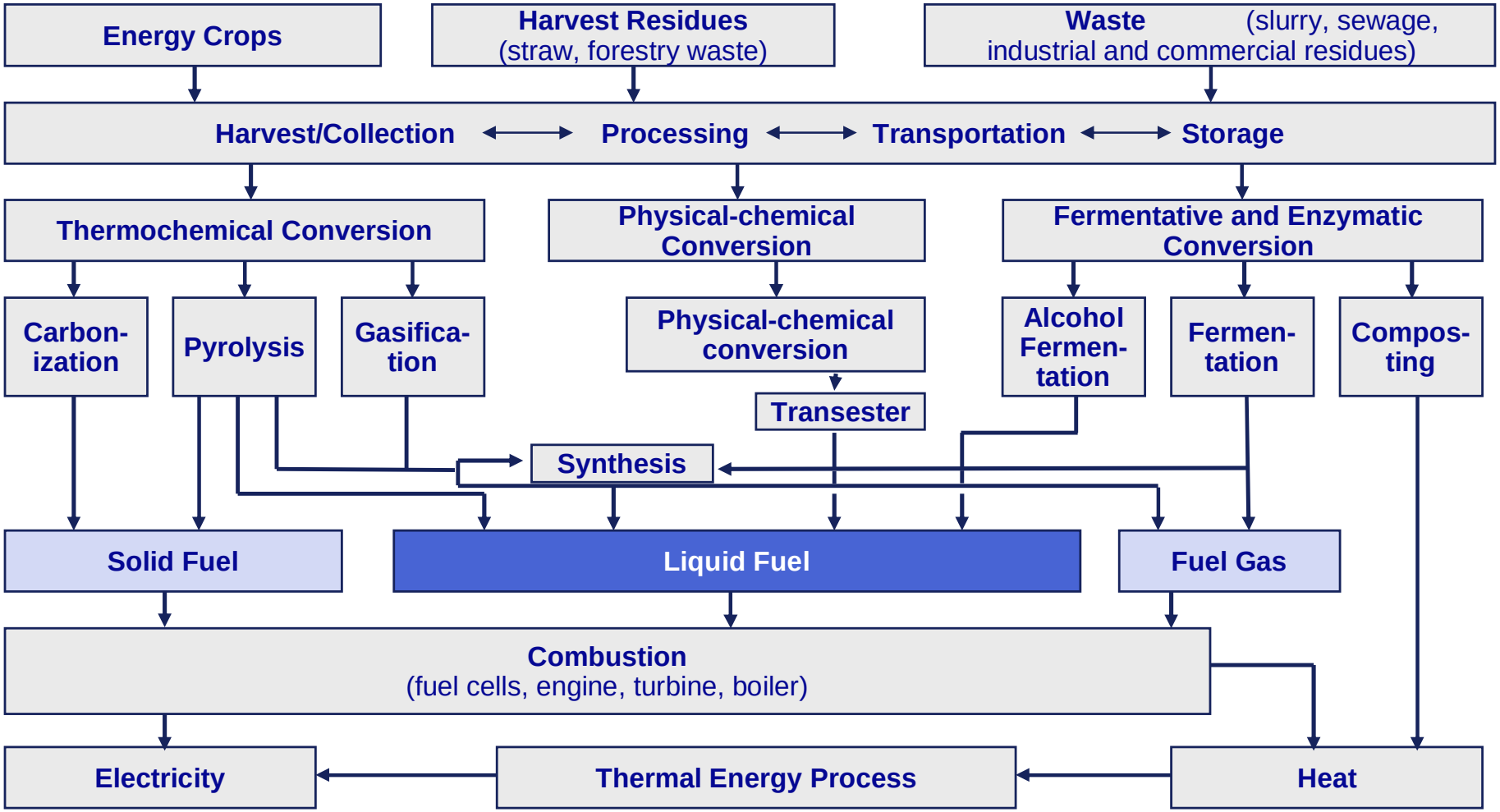
# Different generations of modern fuels deriving from fossil and renewable resources exist



# There are many pathways for the energetic utilisation of the different kinds of biomass




Source: Fraunhofer Institute for Environmental, Safety and Energy Technology

# There are numerous evaluation systems for the comparison of the different fuel types

| Kind / Criteria | Biofuel production | | Biofuel suitability concerning | |
|---|---|---|---|---|
| | Overall thermal effciency[a] | Technical effort[b] | Current fuel distribution | Current vehicle fleet |
| FT diesel | → | ↘ | ↗ | ↗ |
| MeOH | → | → | ↘ | ↘ |
| DME | → | ↘ | → | → |
| SNG | ↗ | ↗ | → | → |
| $H_2$ | ↗ | ↗ | ↘ | ↘ |

Legend: ↗ very promising → promising ↘ less promising

Evaluation of biofuels in relation to each other in context of present frame conditions
[a] based on selected refererences
[b] in terms of system complexity

Source: Institute for Energy and Environment Leipzig

# Biofuels are a complex topic due to the high number of different influencing factors

## Biofuels influencing factors

### Technical factors

- Raw material supply
- Conversion technologies
- Engine / powertrain technologies
- Infrastructure requirements / investments

### Economical factors

- Fuel costs (incl. subsidy and tax aspects)
- Engine modification costs
- Infrastructure / availability costs
- Trade balance impact

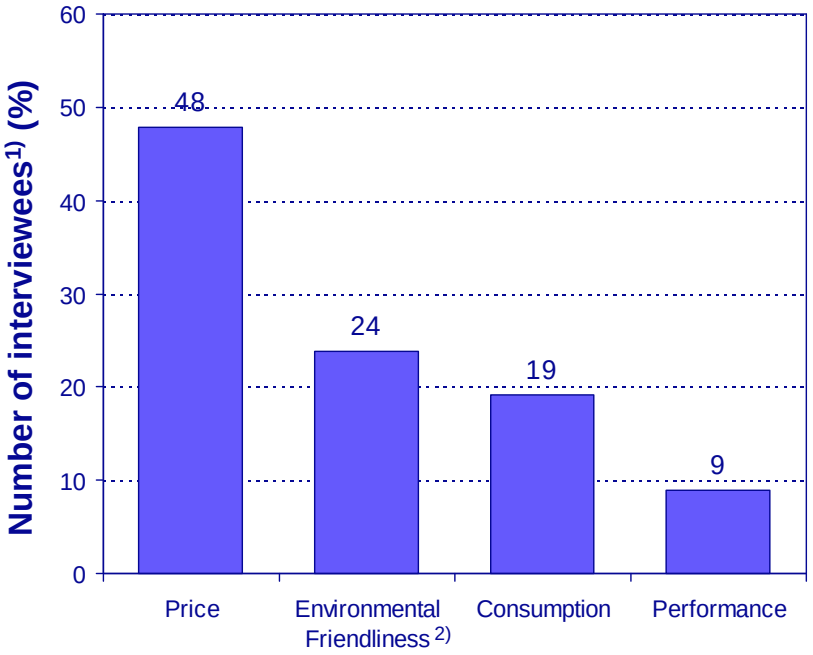
### Ecological / political factors

- GHG emissions and reduction costs
- Support of local farmers
- Efficient land use / food vs. fuel usage
- Reduced dependency on crude oil

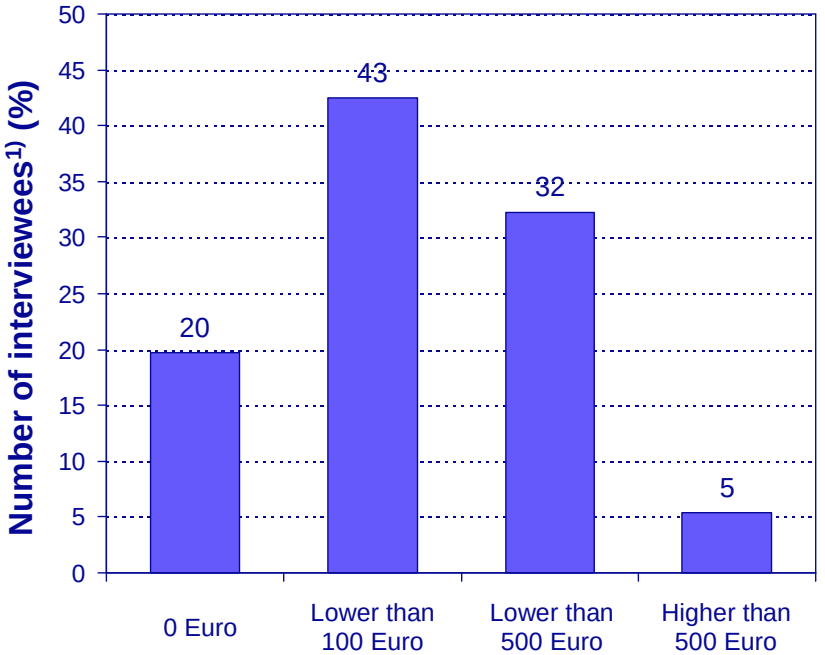
**How can interesting technological opportunities be identified without getting lost in these details?**

# An analysis of the customer preferences shows clearly the importance of price and low modification costs

## Buying criteria for car drivers




## Acceptance of modification costs




1) Multiple answers were not possible
2) At the same fuel price
Source: Interviews with approx. 200 car drivers conducted by the Hochschule Reutlingen on behalf of FESTEL CAPITAL

# Fundamental aspects of customer acceptance will define the requirements for short- to mid-term biofuel usage

## Hypotheses regarding biofuel usage

### Customer acceptance

- Lower prices compared to fossil fuels (without tax subsidy!)
- Normal usage of existing cars
  - No loss of power and range
  - No modification costs
- High availability and easy handling (similar to existing fuels)

### Biofuel requirements

- Low raw material and production costs
- No additional distrubution / infrastructure costs
- Problem-free mixing with existing fuel types
- Same chemical/physical properties as existing fuels (e.g. energy content)

**Important are economical factors and not ecological aspects - the deciding factor for market success are the costs for the car owner at the filling stations**

## Due to these requirements the high complexity of biofuels can be reduced significantly

### Biofuels influencing factors

| Technical factors | Economical factors | Ecological / political factors |
|---|---|---|
| • **Raw material supply** | • **Fuel costs** (incl. subsidy and tax aspects) | • GHG emissions and reduction costs |
| • **Conversion technologies** | • Engine modification costs | • Support of local farmers |
| • Engine / powertrain technologies | • Infrastructur bility costs | se / food |
| • Infrastructure requirements / investments | • Trade balance impact | ndency on crude oil |

**View of investors!**

**Regarding success probability only fuel costs based on raw material supply and conversion technologies are of importance**

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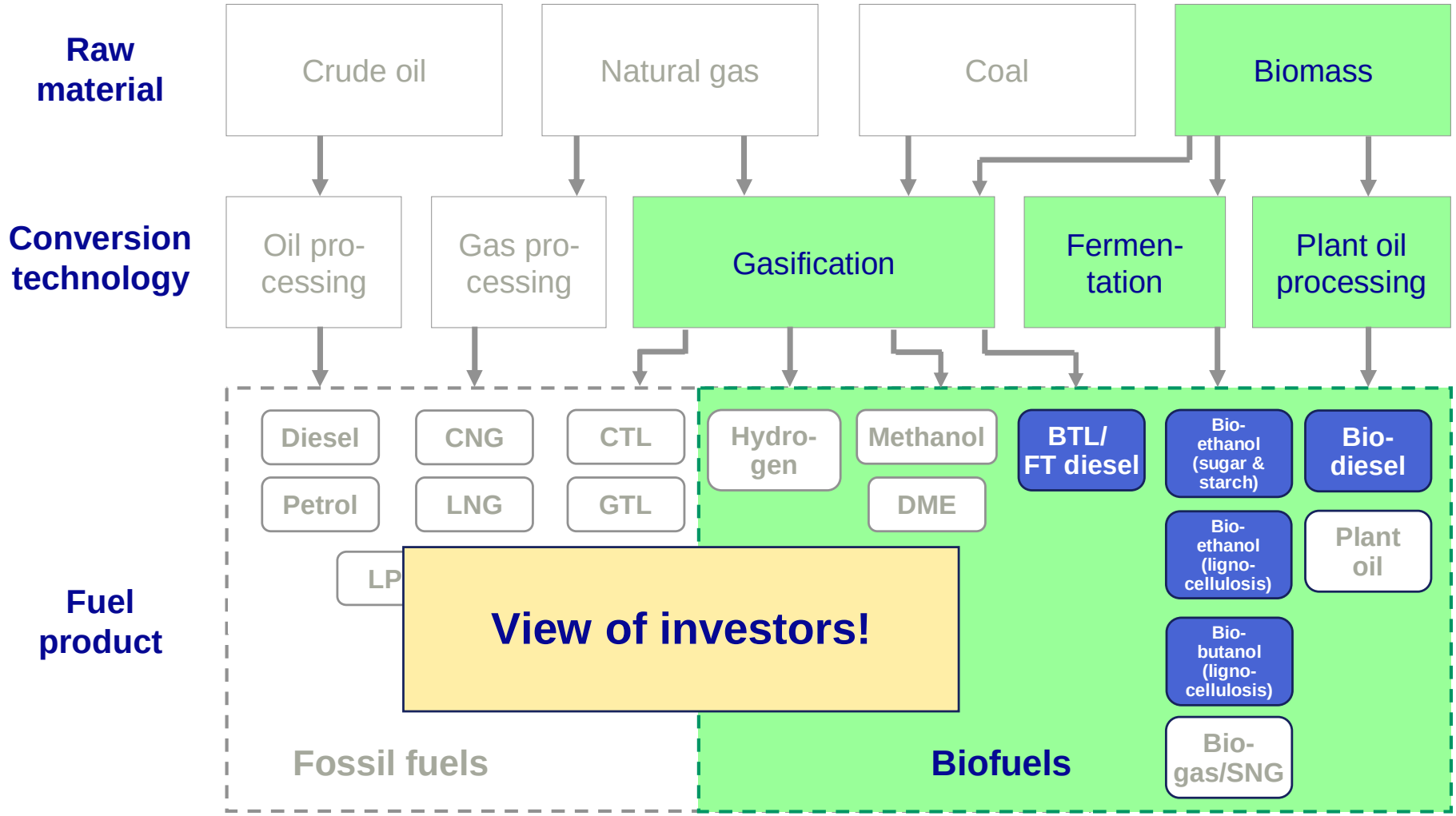
# Based on these requirements only BTL fuel, bioethanol, biobutanol and biodiesel were analysed in detail with regard to production costs



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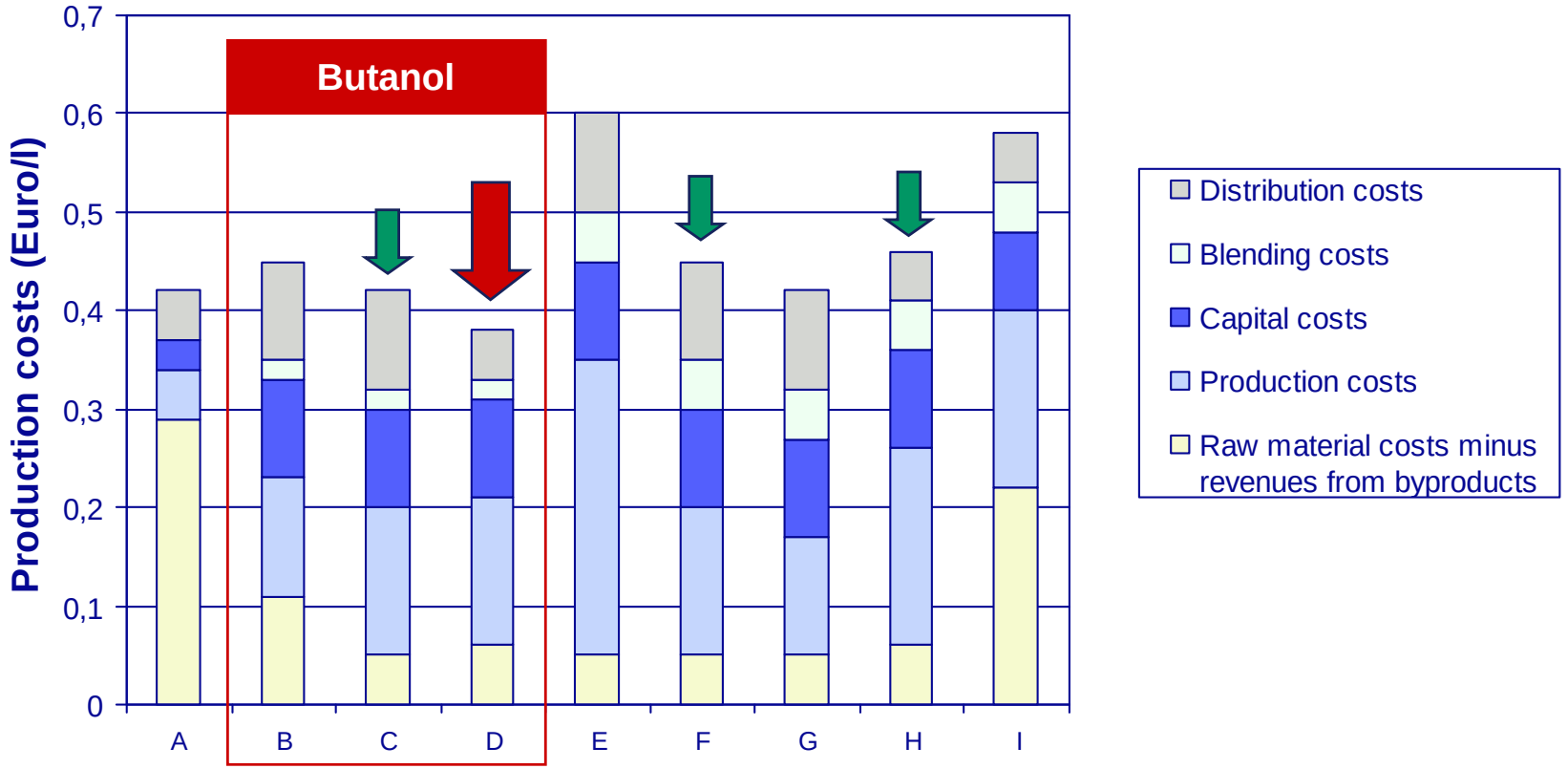
# A model calculation for Germany shows the competitiveness of the different petrol substitutes (1/2)

**Numbers are based on a "bottom-up" calculation model**

| Biofuel | Raw Material | Region | Scenario | Plant Size (kt/year) | Plant Investment (mn Euro) | Production Costs (Euro/l fuel) | Profit Margin (Euro/l) | Price at Filling Station (Euro/l) |
|---|---|---|---|---|---|---|---|---|
| **Petrol** | Crude oil | Europe | **60 USD/barrel** | 10,000 | 2,600 | 0.37 | **0.05** | 1.30 |
| **Biobutanol** | Corn | USA | Large scale 2008 | 200 | 240 | 0.33 | **0.02** | 1.30 |
| **Biobutanol** | Straw | USA | Large scale 2008 | 200 | 240 | 0.30 | **0.05** | 1.30 |
| **Biobutanol** | Straw | Europe | **Large scale 2008** | 200 | 240 | 0.35 | **0.09** | 1.30 |
| **Bioethanol** | Straw | USA | Small scale 2008 | 50 | 90 | 0.45 | **-0.13** | 1.30 |
| **Bioethanol** | Straw | USA | Large scale 2008 | 200 | 240 | 0.30 | **0.02** | 1.30 |
| **Bioethanol** | Straw | USA | Large scale 2012 | 200 | 240 | 0.27 | **0.05** | 1.30 |
| **Bioethanol** | Straw | Europe | Large scale 2008 | 200 | 240 | 0.36 | **0.01** | 1.30 |
| **Bioethanol** | Wheat | Europe | **With tax** | 200 | 200 | 0.48 | **-0.11** | 1.30 |
| **Bioethanol** | Wheat | Europe | **Without tax** | 200 | 200 | 0.48 | **0.54** | 1.30 |

Source: FESTEL CAPITAL analysis

# A model calculation for Germany shows the competitiveness of the different petrol substitutes (2/2)




A - Petrol (crude oil, 60 USD/barrel)
B - Biobutanol (corn, USA, large scale 2008)
**C - Biobutanol (straw, USA, large scale 2008)**
**D - Biobutanol (straw, Europe, large scale 2008)**
E - Bioethanol (straw, USA, small scale 2008)
**F - Bioethanol (straw, USA, large scale 2008)**
G - Bioethanol (straw, USA, large scale 2012)
**H - Bioethanol (straw, Europe, large scale 2008)**
I - Bioethanol (wheat, Europe)

Source: FESTEL CAPITAL analysis

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# A model calculation for Germany shows the competitiveness of the different diesel substitutes (1/2)

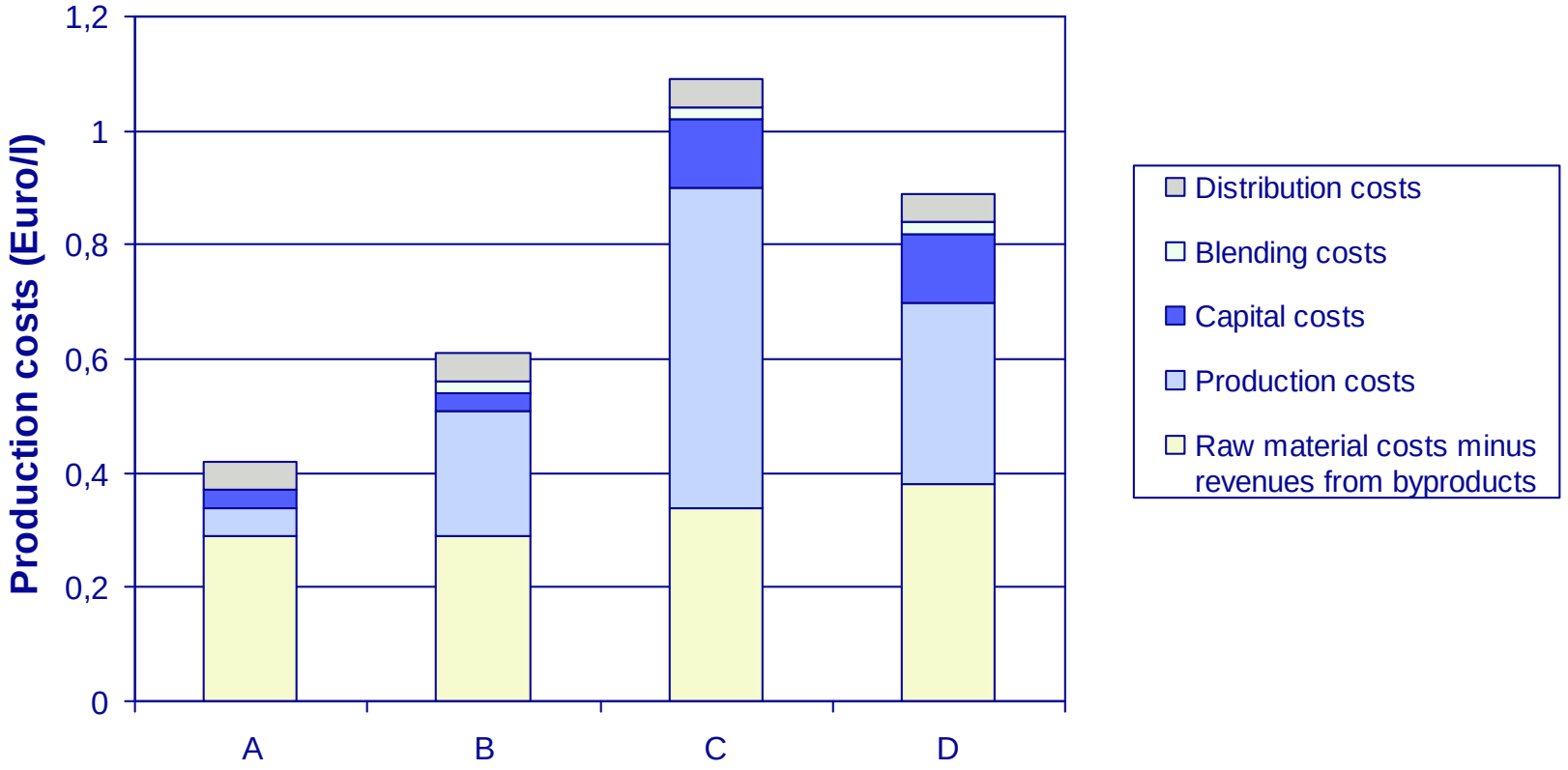
**Numbers are based on a "bottom-up" calculation model**

| Biofuel | Raw Material | Region | Scenario | Plant Size (kt/year) | Plant Investment (mn Euro) | Production Costs (Euro/l fuel) | Profit Margin (Euro/l) | Price at Filling Station (Euro/l) |
|---|---|---|---|---|---|---|---|---|
| **Diesel** | Crude oil | Europe | **60 USD/barrel** | 10,000 | 2,600 | 0.37 | **0.06** | 1.10 |
| **Biodiesel** | Rape seed | Europe | **With tax** | 200 | 40[1)] | 0.54 | **-0.13** | 1.10 |
| **Biodiesel** | Rape seed | Europe | **Without tax** | 200 | 40[1)] | 0.54 | **0.34** | 1.10 |
| **BTL** | Wood | Europe | Small scale with tax | 120 | 200 | 1.02 | **-0.61** | 1.10 |
| **BTL** | Wood | Europe | **Large scale with tax** | 1,200 | 1,600 | 0.82 | **-0.41** | 1.10 |
| **BTL** | Wood | Europe | **Large scale without tax** | 1,200 | 1,600 | 0.82 | **0.06** | 1.10 |

1) Including oil mill

Source: FESTEL CAPITAL analysis

# A model calculation for Germany shows the competitiveness of the different diesel substitutes (2/2)




A - Diesel (crude oil, 60 USD/barrel)
B - Biodiesel (rape seed, Europe)
C - BTL (wood, Europe small scale 120 kt)
D - BTL (wood, Europe large scale 1,200 kt)

Source: FESTEL CAPITAL analysis

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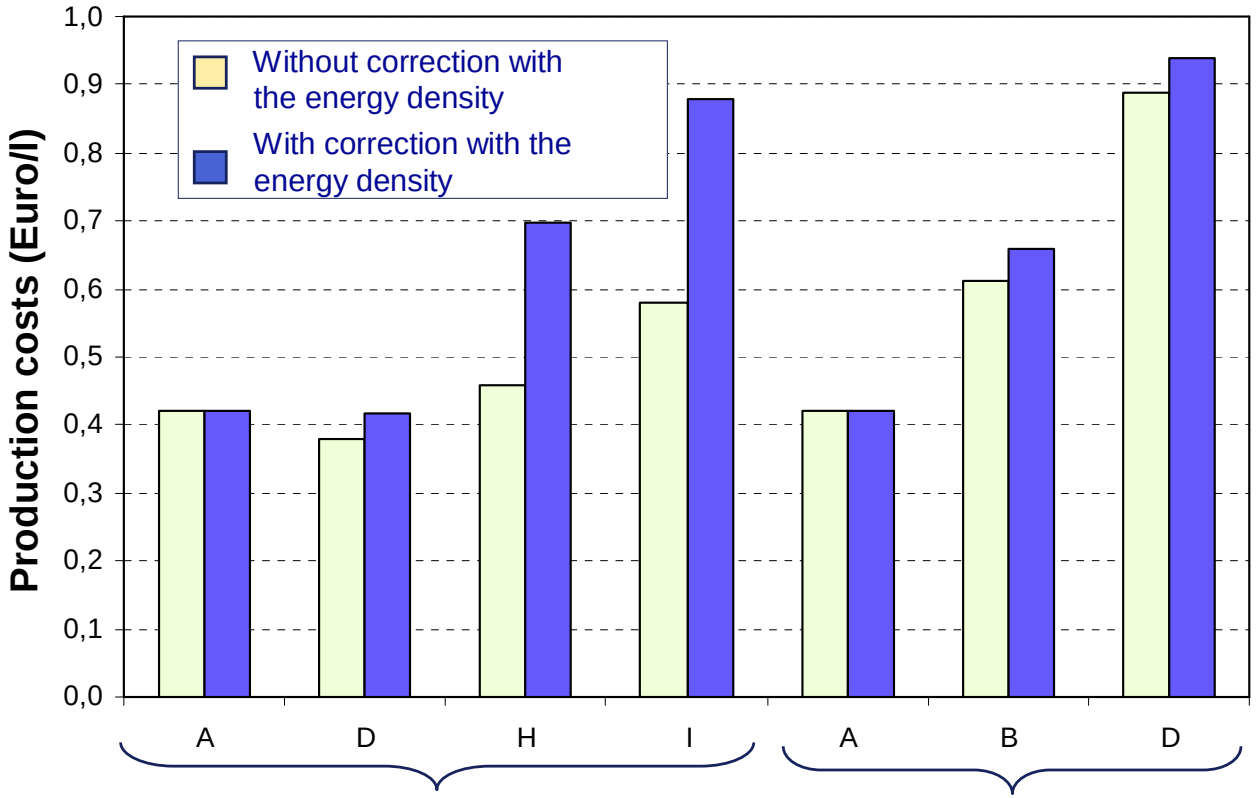
# The most competitive biofuel type for the German market is European bio-butanol made from straw




A: Petrol (crude oil, 60 USD/barrel)
D: Biobutanol (straw, Europe, Large scale 2008)
H: Bioethanol (straw, Europe, Large scale 2008)
I: Bioethanol (corn, Europe, Large scale 2006)

A: Diesel (crude oil, 60 USD/Barrel)
B: Biodiesel (rape seed, Europe, Large-scale 2006)
D: BTL (wood, Europe, Large scale 2012)

Source: FESTEL CAPITAL analysis

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# Butanol (1-butanol / n-butanol) is being seen as a more superior alternative fuel than ethanol due to its more favourable chemical / physical properties

- Butanol has **clear advantages** compared to ethanol
  - Lower vapour pressure and higher flashpoint[1)]
  - Less miscible with water and far less corrosive
  - Can be shipped and distributed through existing infrastructure (pipelines and filling stations)
  - Can replace fossil fuels up to 100% without modifying the engine (some sources say only 40%)[2)]
  - Can be blended with diesel or biodiesel and burned in diesel engines
- Butanol has also **some disadvantages** compared to ethanol
  - Lower octane rating[3)]
  - Higher viscosity

1) Vapour pressure (20°C): butanol 5,6 h Pa, ethanol 58,5 hPa; flashpoint: butanol 36°C, ethanol 12°C
2) Ethanol can only be blended up to 85% and here modifications to the engine are required (e.g. flexible fuel vehicle)
3) Research octane number (RON): butanol 96, ethanol 130

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# The whole value chain has to be optimised before a biobutanol production process can be realised successfully