



Biofuels – Current Status in Germany and Europe

Production Costs and Market Opportunities

VCW Conference „Biokraftstoffe - Chancen und Herausforderungen in Deutschland und Europa“

Frankfurt, December 6, 2006

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- FESTEL CAPITAL **invests in selected companies** and supports companies based on **equity participation**
- FESTEL CAPITAL has special expertise and experience in business development and partnering in **China**

- **For queries, please contact**

Dr. Gunter Festel

Schuermattstr. 1, CH-6331 Huenenberg/Zug

E-Mail gunter.festel@festel.com

Internet www.festel.com

Phone/Fax +41 41 780 1643

Mobile Switzerland +41 79 6527 112

Mobile Germany +49 177 356 1837

Mobile China +86 1350 1880 189

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Abbreviations

Abbreviations

- | | | | |
|--------|-------------------------|------------------|-------------------------|
| • BTL | Biomass-to-Liquid | • H ₂ | Hydrogen |
| • CNG | Compressed Natural Gas | • l | Litre |
| • CTL | Coal-to-Liquid | • kt | Kilotonne |
| • DME | Dimethyl Ether | • LNG | Liquified Natural Gas |
| • FAME | Fatty Acid Methyl Ester | • LPG | Liquified Petroleum Gas |
| • FT | Fischer-Tropsch | • MeOH | Methanol |
| • GHG | Greenhouse Gas | • RME | Rape Seed Methyl Ester |
| • GTL | Gas-to-Liquid | • SNG | Synthetic Natural Gas |

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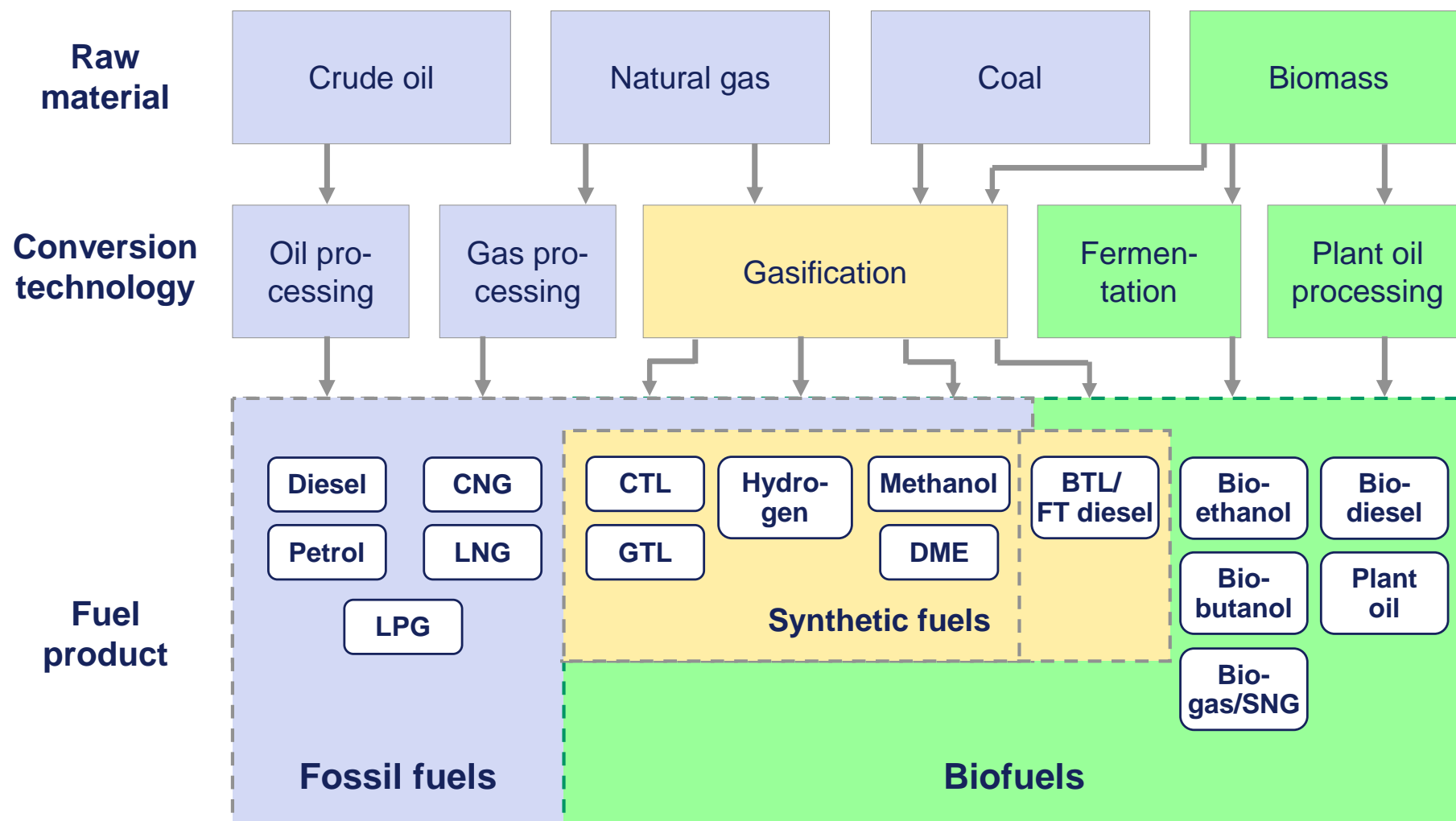
Biobutanol Production Process

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Appendix: Information on FESTEL CAPITAL

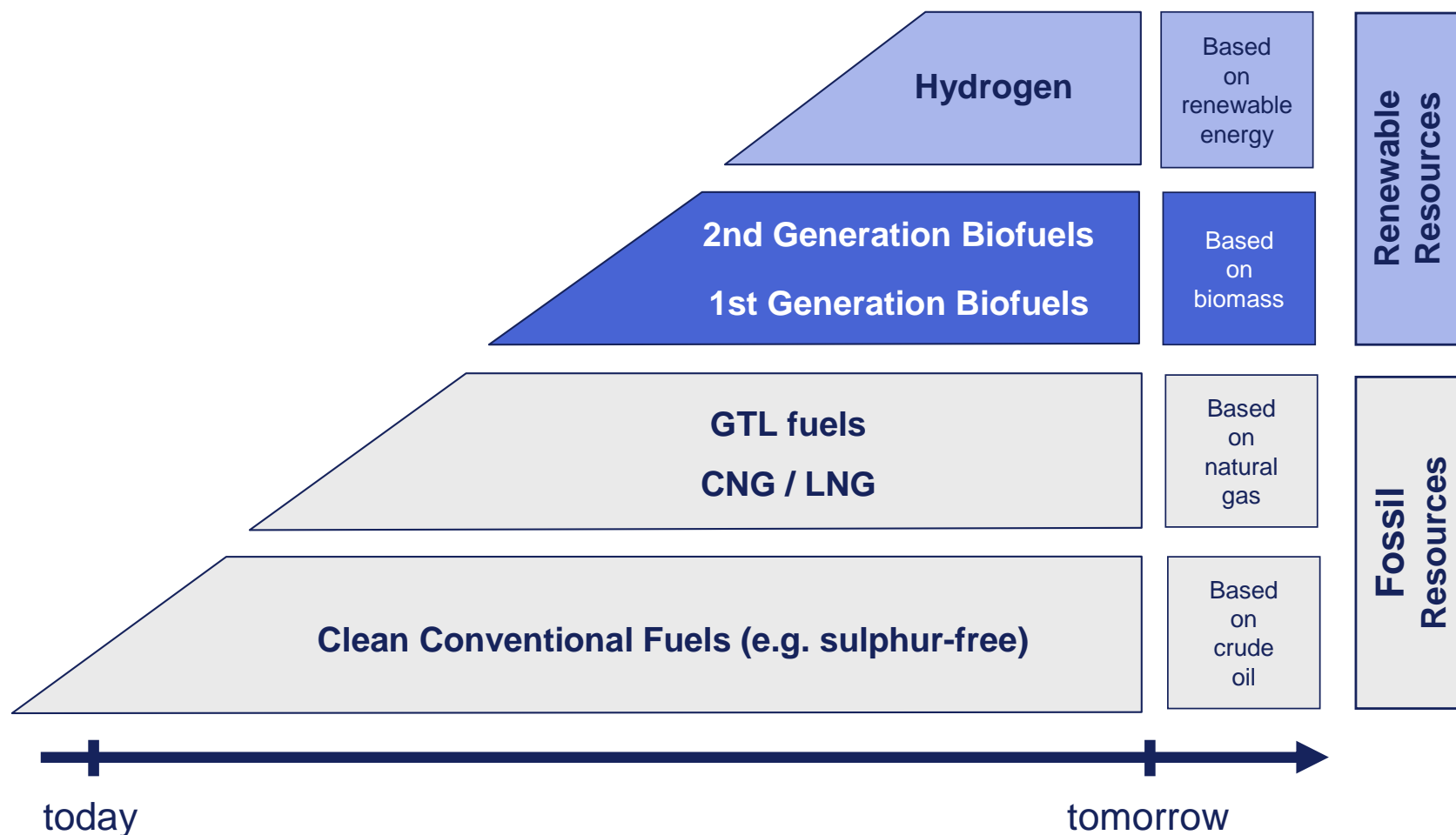
Biofuel Evaluation Methodology - Fuel Types

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



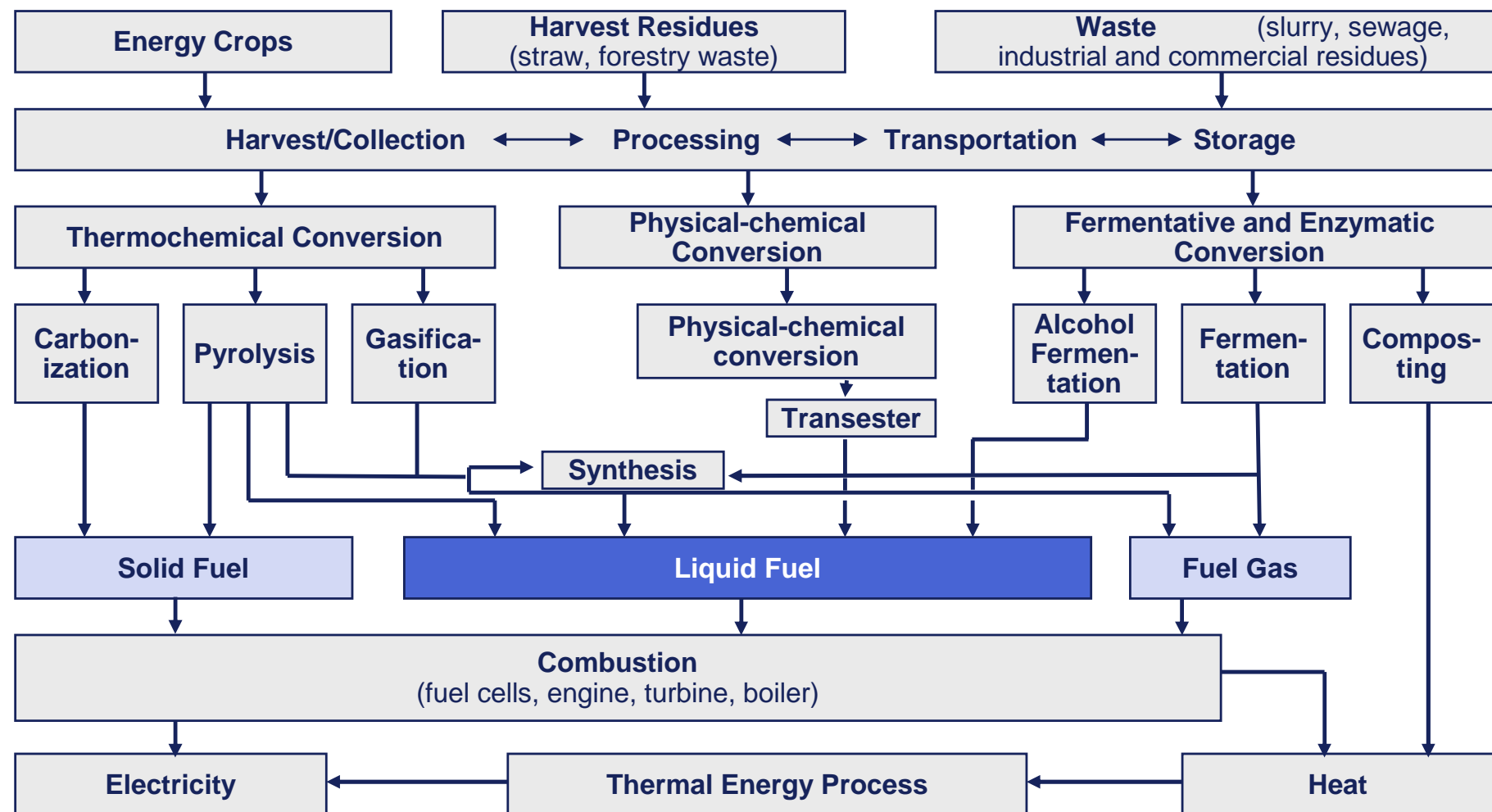
Biofuel Evaluation Methodology - Generations

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



Biofuel Evaluation Methodology - Interconnections

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



Source: Fraunhofer Institute for Environmental, Safety and Energy Technology

Biofuel Evaluation Methodology - Evaluation

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

Kind / Criteria	Biofuel production		Biofuel suitability concerning	
	Overall thermal efficiency ^a	Technical effort ^b	Current fuel distribution	Current vehicle fleet
FT diesel	→	↘	↗	↗
MeOH	→	→	↘	↘
DME	→	↘	→	→
SNG	↗	↗	→	→
H ₂	↗	↗	↘	↘

Legend: ↗ very promising → promising ↘ less promising

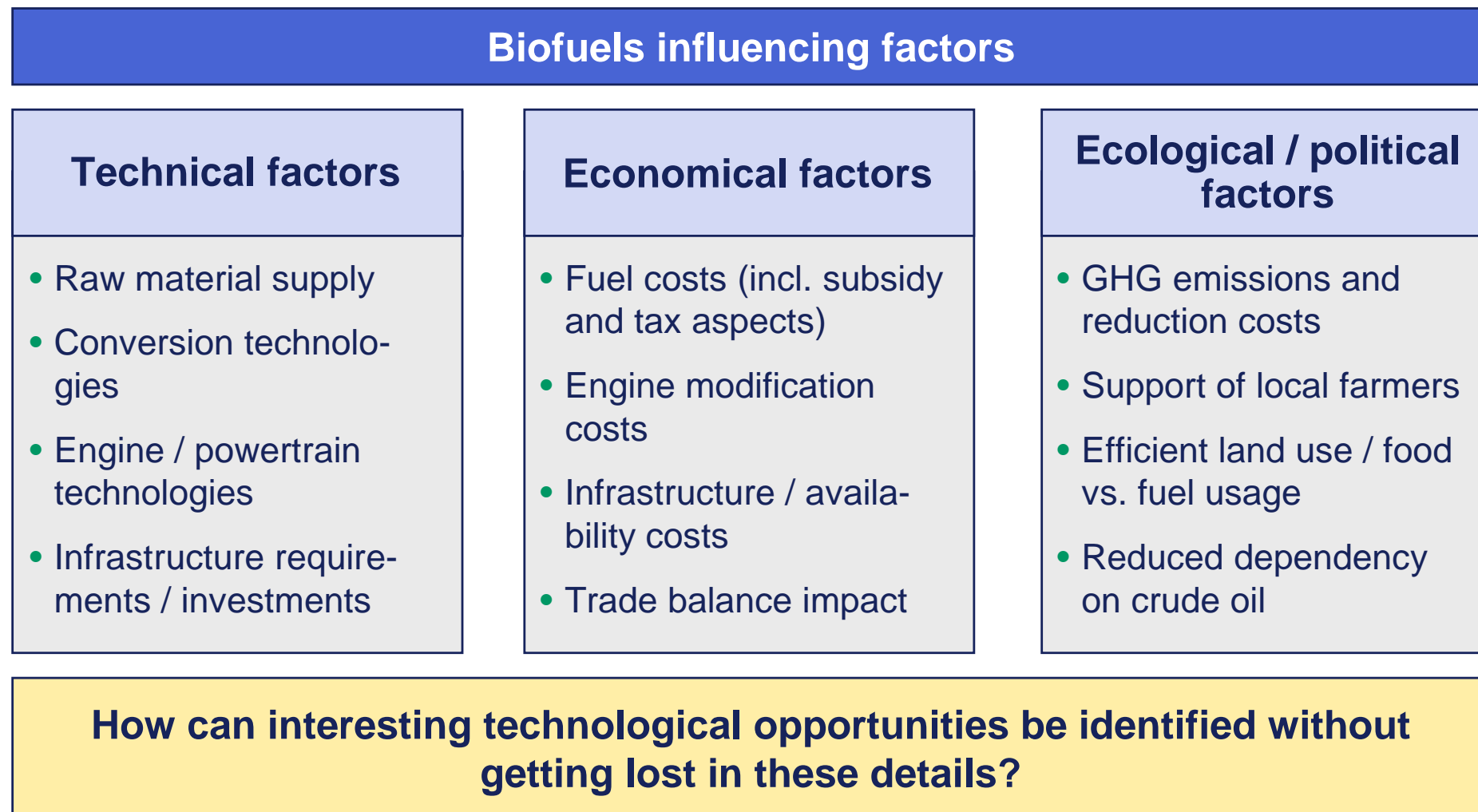
Evaluation of biofuels in relation to each other in context of present frame conditions

^a based on selected references

^b in terms of system complexity

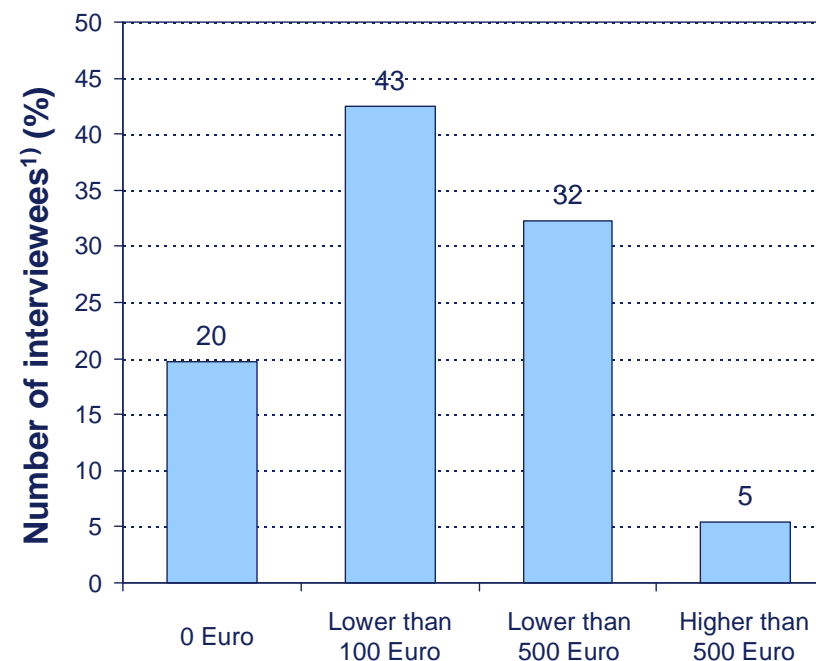
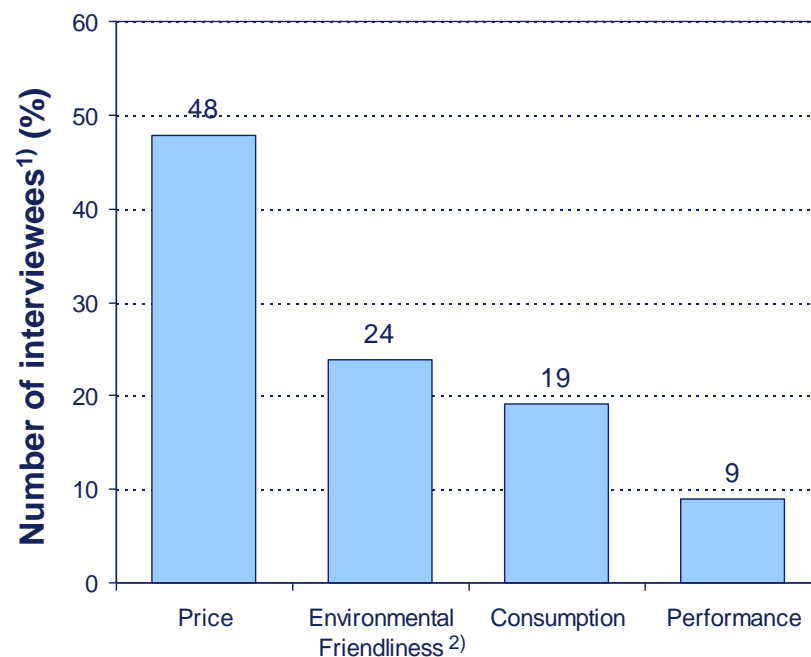
Source: Institute for Energy and Environment Leipzig

Biofuels are an extremely complex topic due to the high number of different influencing factors



Biofuel Evaluation Methodology - Customers

The analysis of the customer preferences shows clearly the importance of price and the no/low modification costs



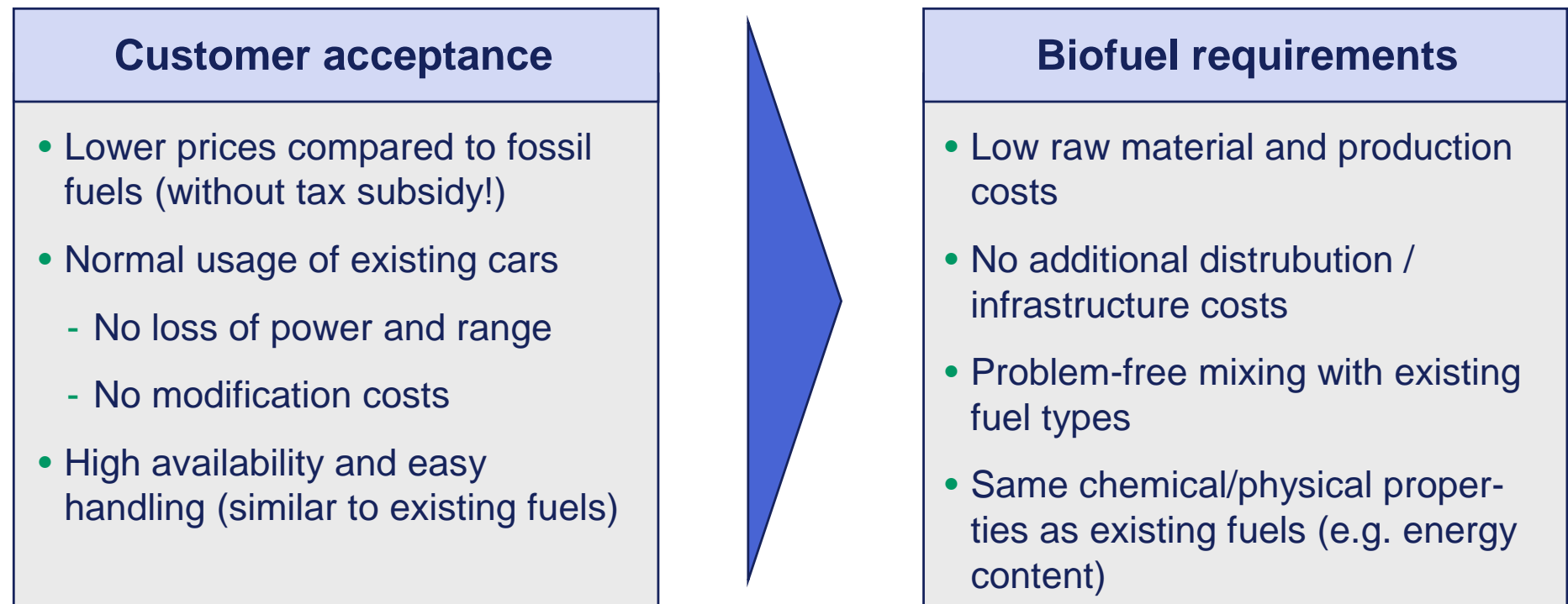
1) Multiple answers were not possible

2) At the same fuel price

Source: Interview conducted by the Hochschule Reutlingen together with FESTEL CAPITAL

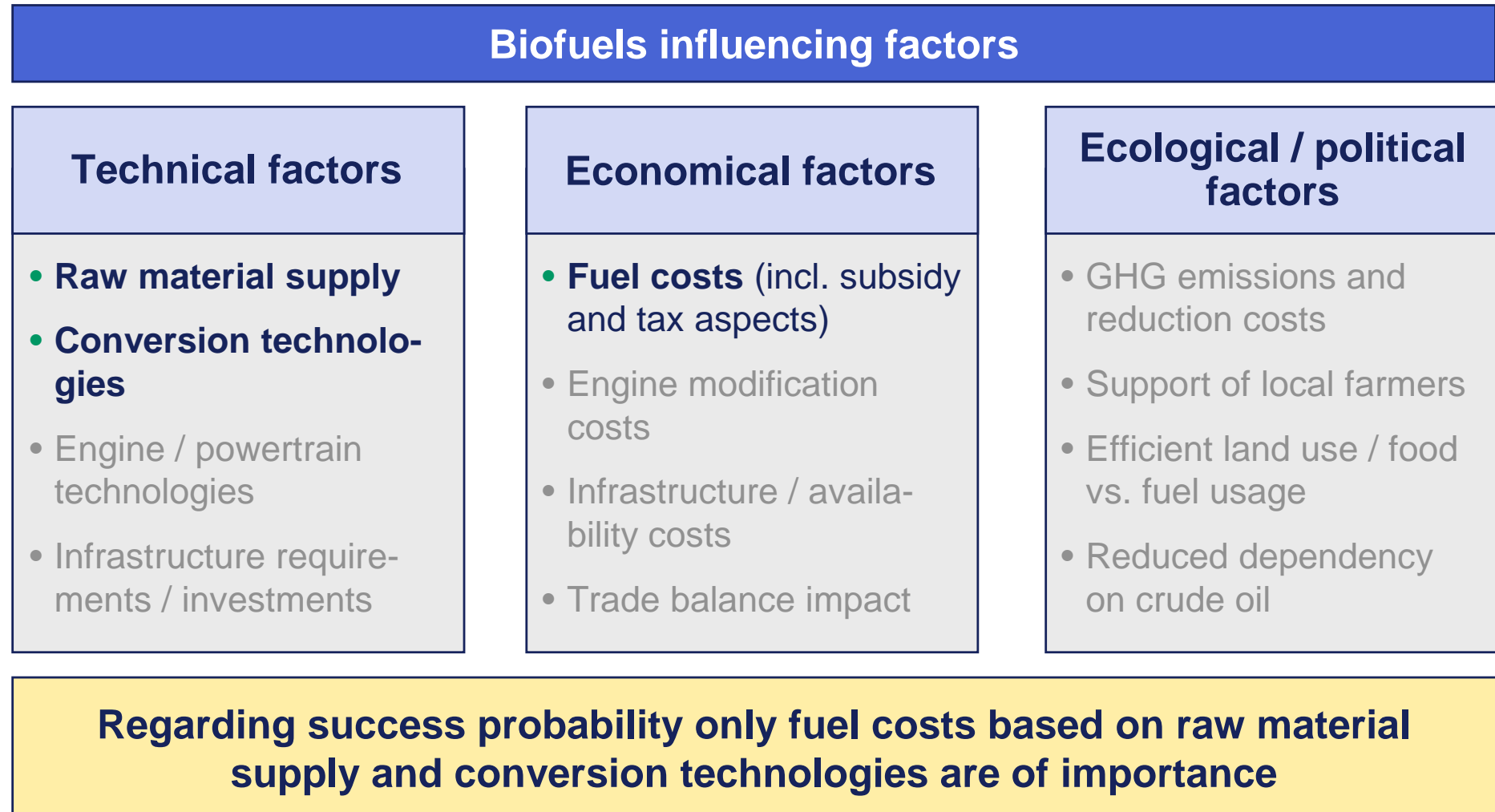
Fundamental aspects of customer acceptance will define the requirements for short- to mid-term biofuel solutions

Hypotheses regarding biofuel usage



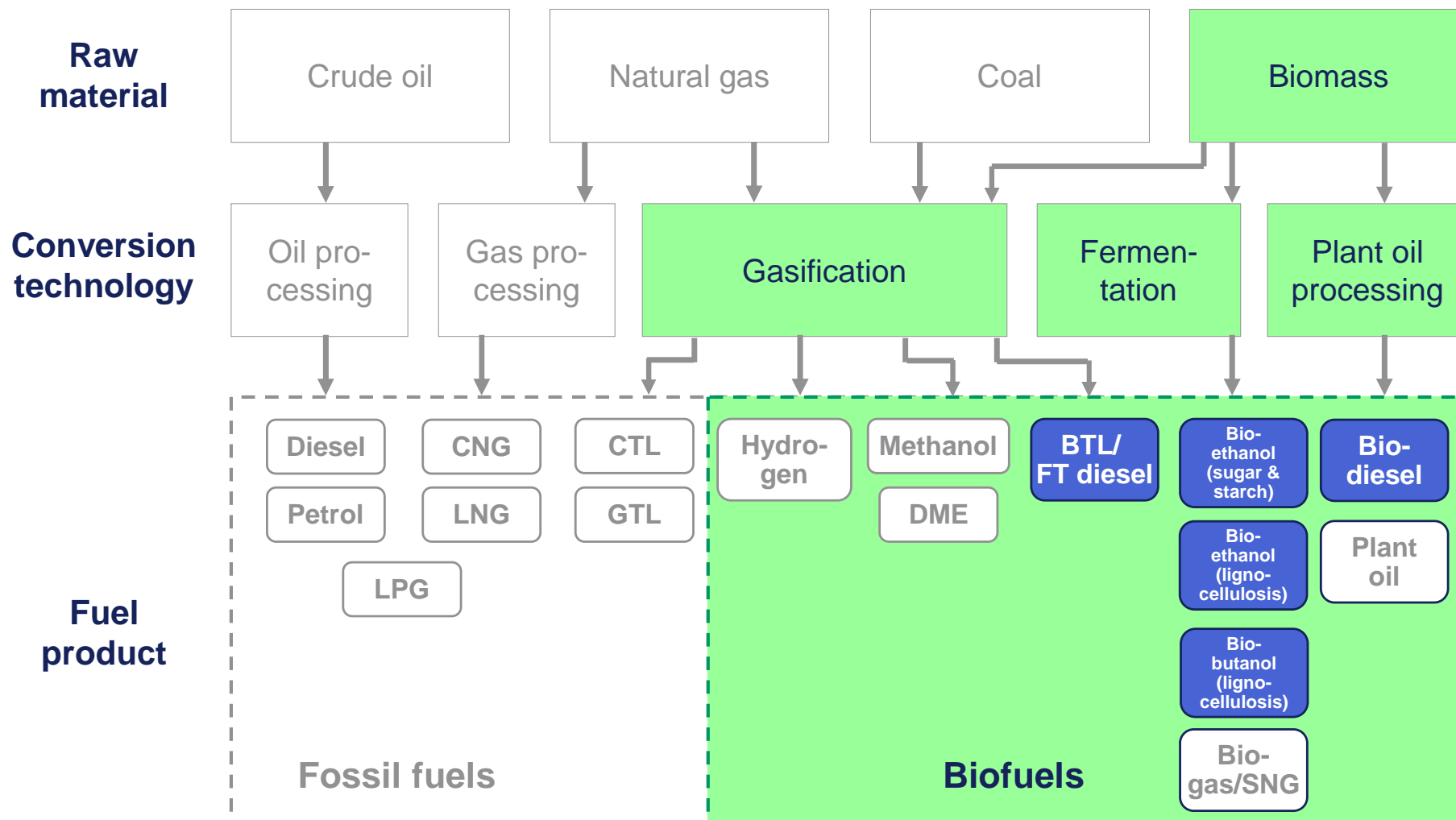
Important are economical factors and not ecological aspects - the deciding factor for market success are the costs for the car owner at the filling stations

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



Biofuel Evaluation Methodology - Selection

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



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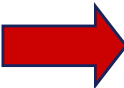



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Production Cost Comparison - Profit Margins

A model calculation for Germany shows the competitiveness of the different biofuel types (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

Production Cost Comparison - Profit Margins

A model calculation for Germany shows the competitiveness of the different biofuel types (2/2)

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

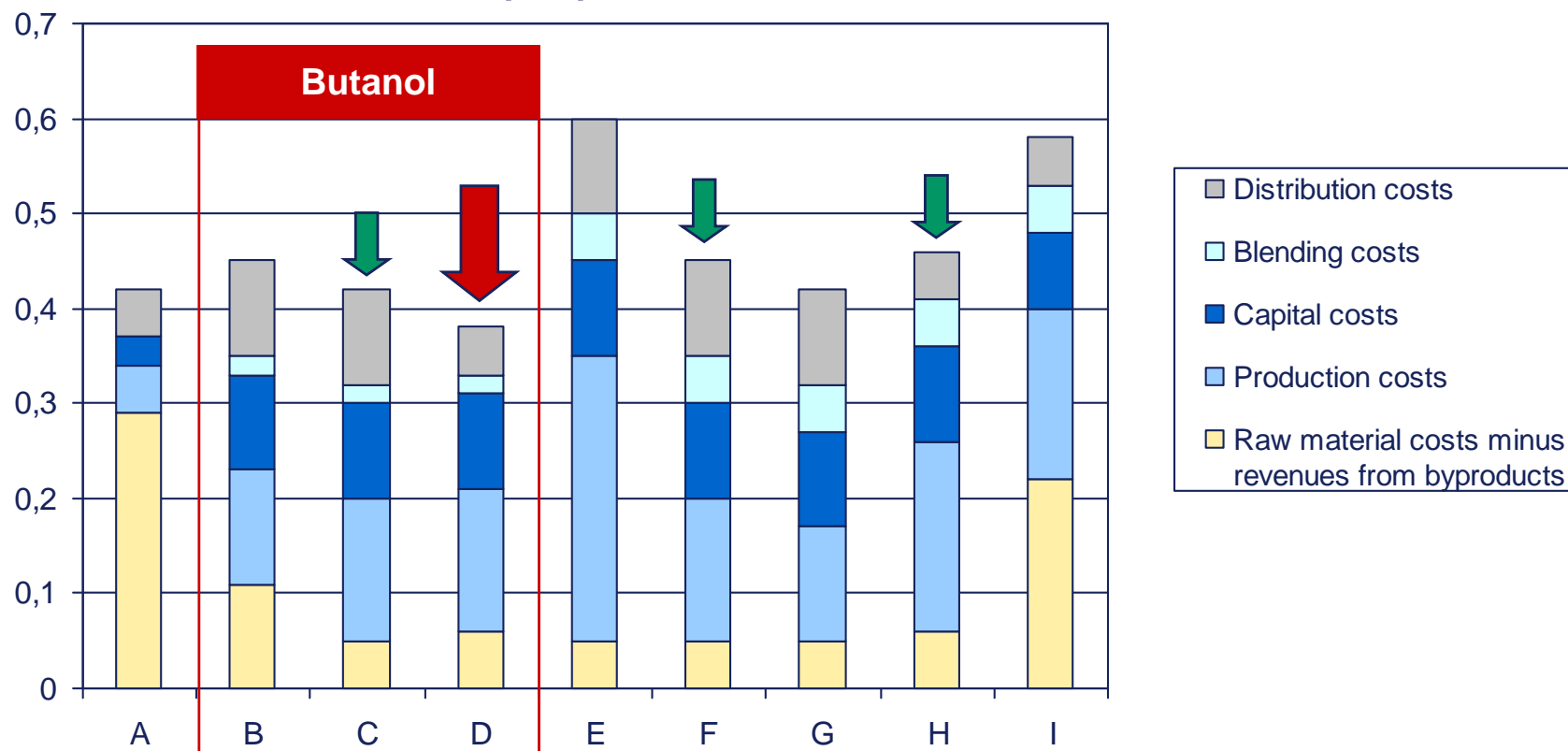
Biofuel	Raw Material	Region	Scenario	Plant Size (kt/year)	Plant Investment (mn Euro)	Production Costs (Euro/l fuel)	Profit Margin (Euro/l)	Price at Filling Station (Euro/l)
 Diesel	Crude oil	Europe	60 USD/barrel	10,000	2,600	0.37	0.06	1.10
 Biodiesel	Rape seed	Europe	With tax	200	40 ¹⁾	0.54	-0.13	1.10
 Biodiesel	Rape seed	Europe	Without tax	200	40 ¹⁾	0.54	0.34	1.10
BTL	Wood	Europe	Small scale with tax	120	180	1.02	-0.61	1.10
 BTL	Wood	Europe	Large scale with tax	1,200	1,800	0.82	-0.41	1.10
 BTL	Wood	Europe	Large scale without tax	1,200	1,800	0.82	0.06	1.10

1) Including oil mill

Source: FESTEL CAPITAL analysis

Production Cost Comparison - Cost Categories

The most competitive biofuel type for the German market is European bio-butanol made from straw (1/2)



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)

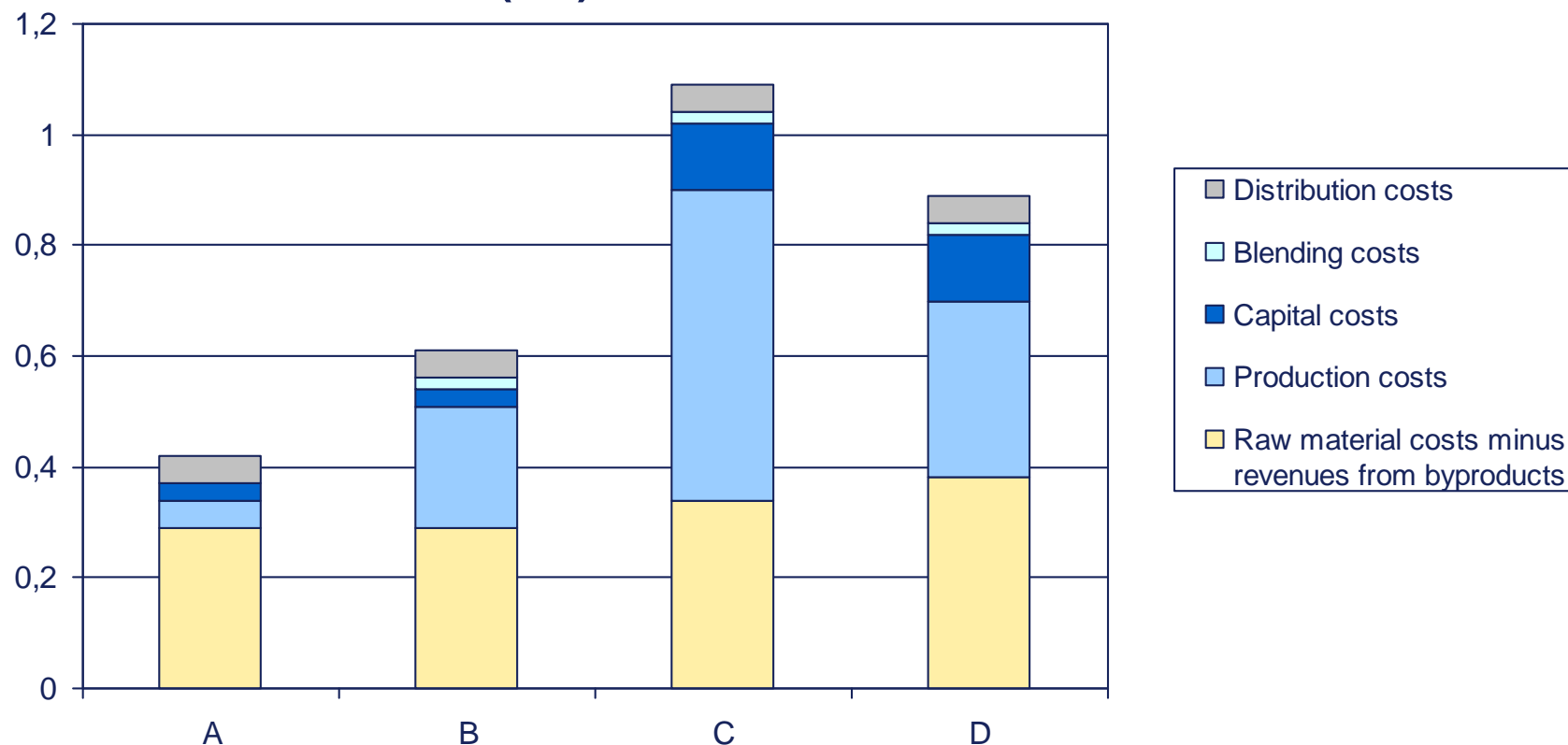
H - Bioethanol (straw, Europe, large scale 2008)

I - Bioethanol (wheat, Europe)

Source: FESTEL CAPITAL analysis

Production Cost Comparison - Cost Categories

The most competitive biofuel type for the German market is European bio-butanol made from straw (2/2)

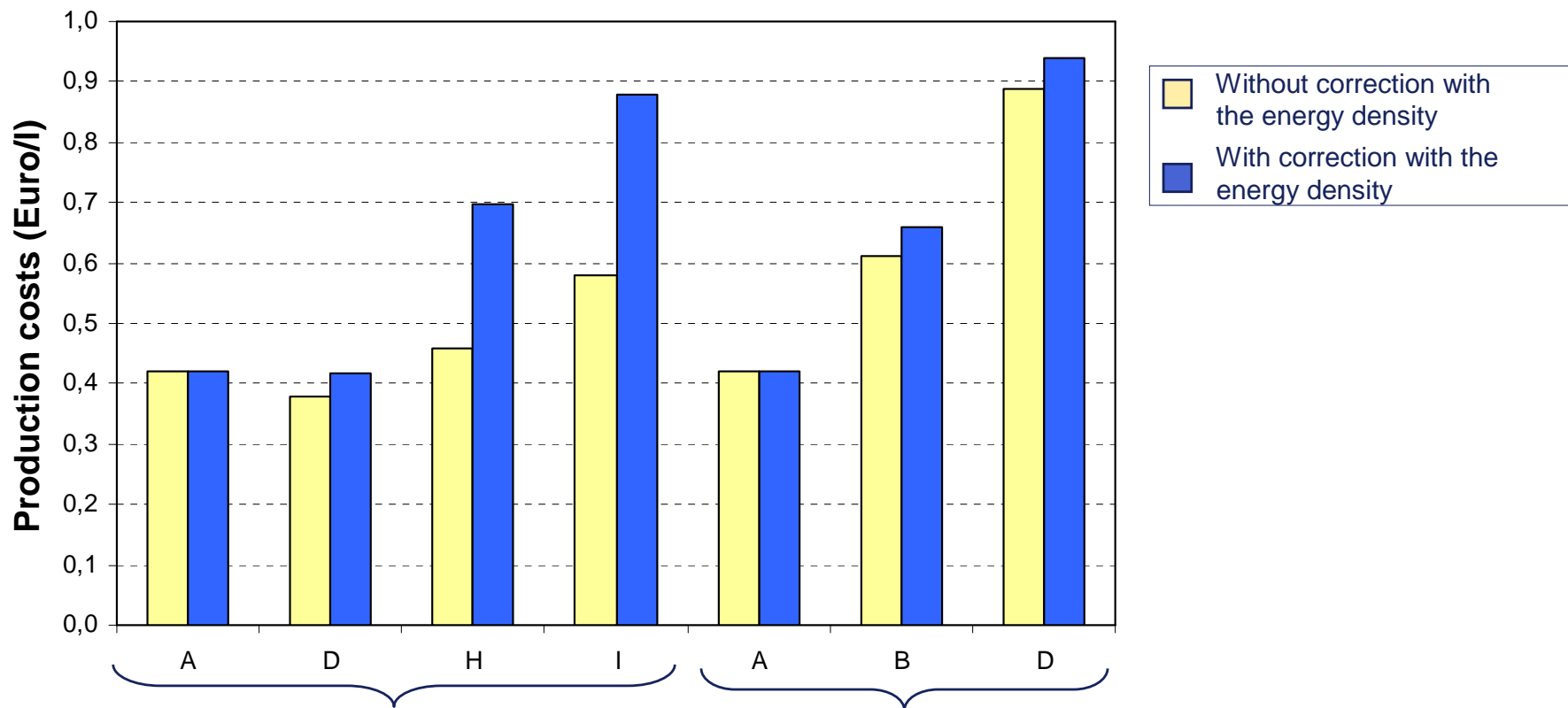


- A - Diesel (crude oil, 60 USD/barrel)
- B - Biodiesel (rape seed, Europe)
- C - BTL (wood, Europe small scale 120 kt)
- D - BTL (wood, Europe large scale 1,200 kt)

Source: FESTEL CAPITAL analysis

Production Cost Comparison - Cost Categories

The most competitive biofuel type for the German market is European bio-butanol made from straw (also after correction with the energy density)



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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Biobutanol Production Process - Properties

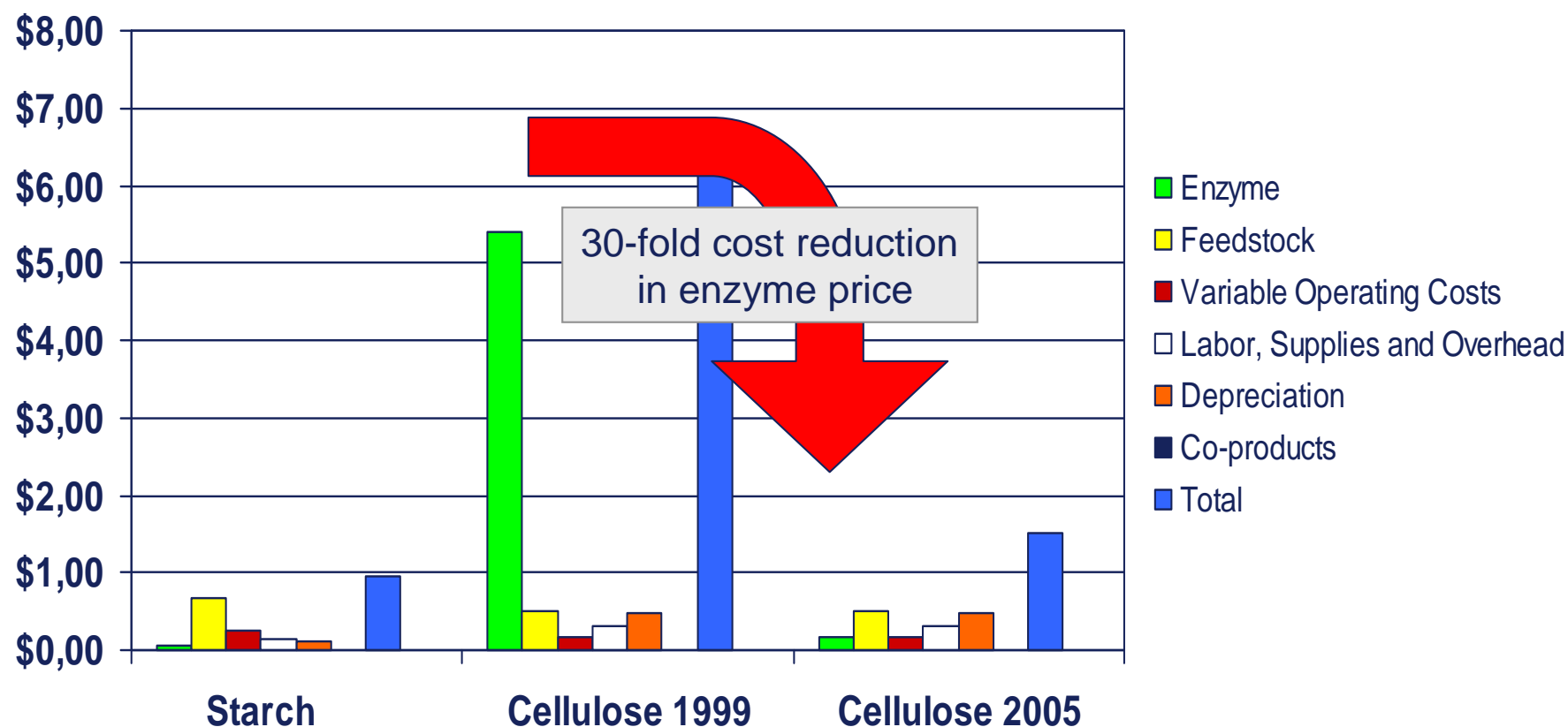
Butanol is being seen as a more superior alternative fuel than ethanol due to its more favourable chemical / physical properties

- Butanol has a **high flashpoint** of 35°C compared to ethanol with 13°C (this is an advantage with regard to fire safety)
- Butanol has a **lower vapour pressure** and is less miscible with water than ethanol
- Butanol can replace fossil fuels **up to 100% without modifying the engine** (some sources say only 40%!) whereby ethanol can only be blended up to 85% and here modifications to the engine are required (FFV = Flexible Fuel Vehicle)
- Butanol is **far less corrosive** than ethanol and it can be shipped and distributed through existing pipelines and filling stations
- Besides using butanol as a straight substitute for petrol, butanol can be blended with diesel or biodiesel and **burned in diesel engines**
- **Disadvantages:** Butanol has a lower octane rating than ethanol (it has research octane numbers of 96 compared to 130 ethanol) and a higher viscosity

Biobutanol Production Process - Enzymes

Enzyme cost no longer dominates the bioethanol/biobutanol cost picture but the hydrolysis step is not yet feasible in large scale

Cost comparison after recent achievements: starch vs. cellulose (USD/gallon ethanol)



Source: "Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks", NREL/TP-580-28893 joint USDA, NREL study released in October 2000

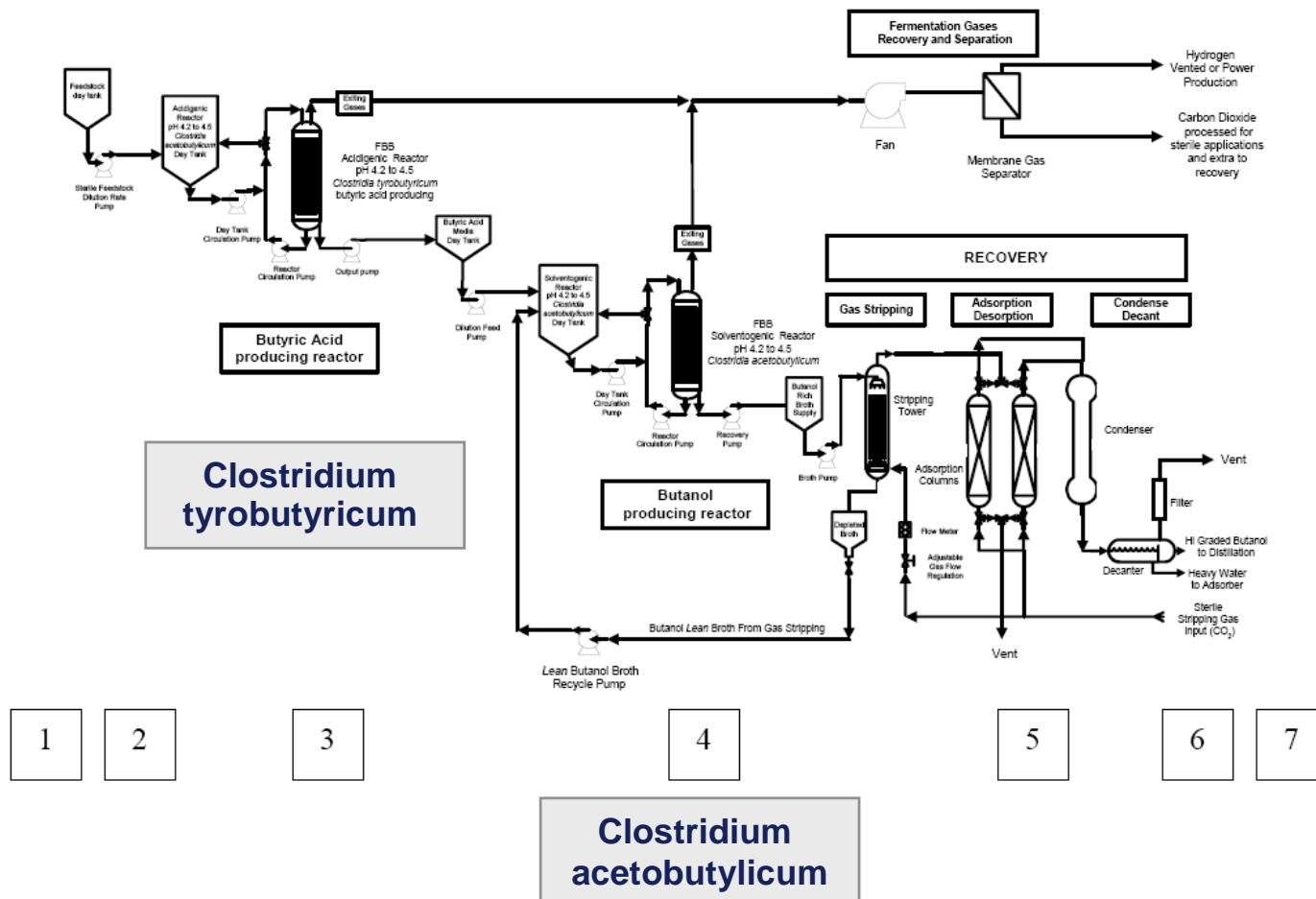
Biobutanol Production Process - Fermentation

Normally the ABE (acetone, butanol, ethanol) or Weizmann process is used to produce butanol

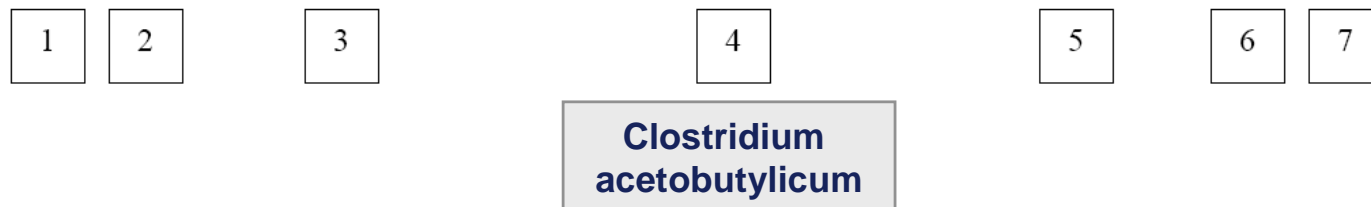
- **Clostridium acetobutylicum** and many other Clostridiums can digest whey, sugar, starch, lignin, cellulose fiber and other biomass directly into butanol, propionic acid and other substances
- In the **ABE or Weizmann process** these bacteria begin with butyric acid fermentation, but, when the pH drops below 5, they switch into butanol and acetone production in order to prevent further lowering of the pH (two molecules of butanol are formed for each molecule of acetone)
- The **yield of butanol** from the ABE process may be substantially increased by using a coculture of at least two different Clostridium species
 - Researchers have discovered that by using a coculture of a Clostridium species where one produces butyric acid (e.g. *C. pasteurianum* or *C. butyricum*) and one for the conversion of butyric acid to butanol (e.g. *C. butylicum* or *C. acetobutylicum*), at least 20% more butanol can be yielded from the conventional ABE Process
 - It is reported that the two different species could not only be used in a multiple stage system but also concurrently in the same reaction vessel whereas, at equilibrium, the number ratio of the butyric acid forming species to butanol conversion species should range between about 1:3 and about 3:1

Biobutanol Production Process - EEI

Environmental Energy Inc. (EEI) has developed dual immobilized reactors with continuous recovery process



1. Dry or wet milling
2. Conversion of biomass into usable sugars
3. **Butyric acid and hydrogen fermentation (acidogenic)**
4. **Butanol fermentation (solventogenic)**
5. High grading: gas-stripping/adsorption/desorption/condensing/decantation
6. Distillation: high purity
7. By-product recovery



Source: Environmental Energy Inc.

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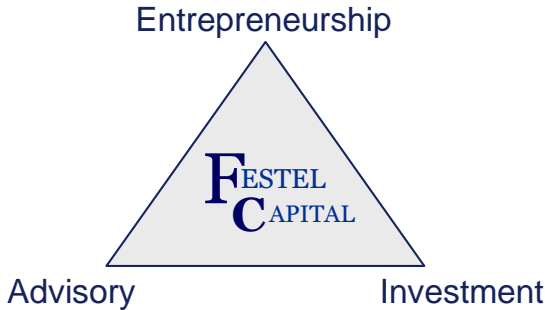
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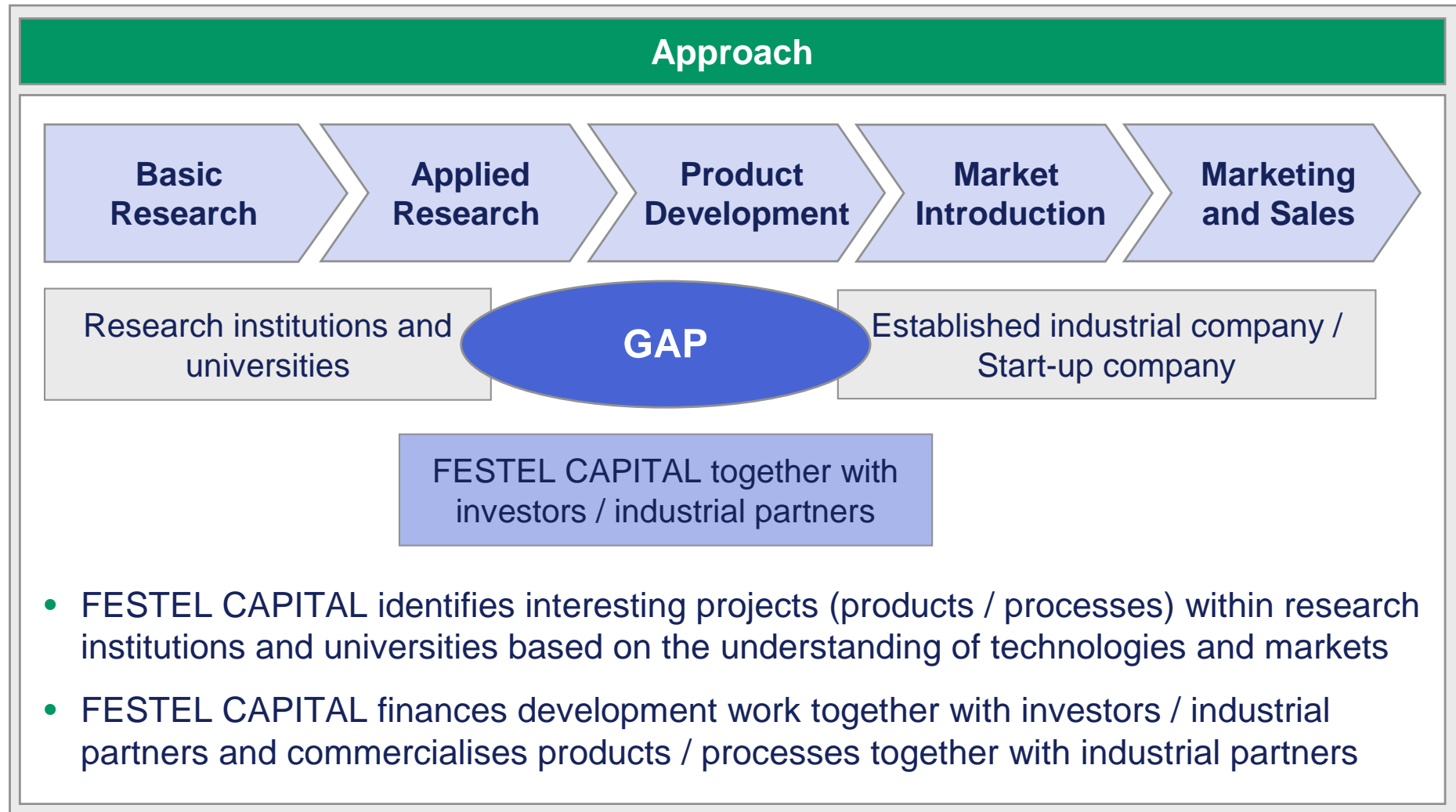
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A Appendix: Information on FESTEL CAPITAL

FESTEL CAPITAL is an international advisory and investment firm focusing on the development / commercialisation of technologies

Profile	Activities (Examples)
<p>FESTEL CAPITAL is an advisory and investment firm focusing on the development / commercialisation of technologies in the areas of energy, environment, health, infrastructures, materials and nutrition</p>	<p>FESTEL CAPITAL ...</p> <ul style="list-style-type: none"> • supports companies, research institutions and universities to develop / commercialise innovative products and technologies • advises inventors as well as investors to successfully create and develop new businesses • finances development work together with external investors • invests in selected start-up and spin-off companies mainly in the seed phase • fosters the development of technology-related businesses and co-operations with China
<p>FESTEL CAPITAL combines entrepreneurship, advisory and investment to create and develop innovative businesses</p> 	

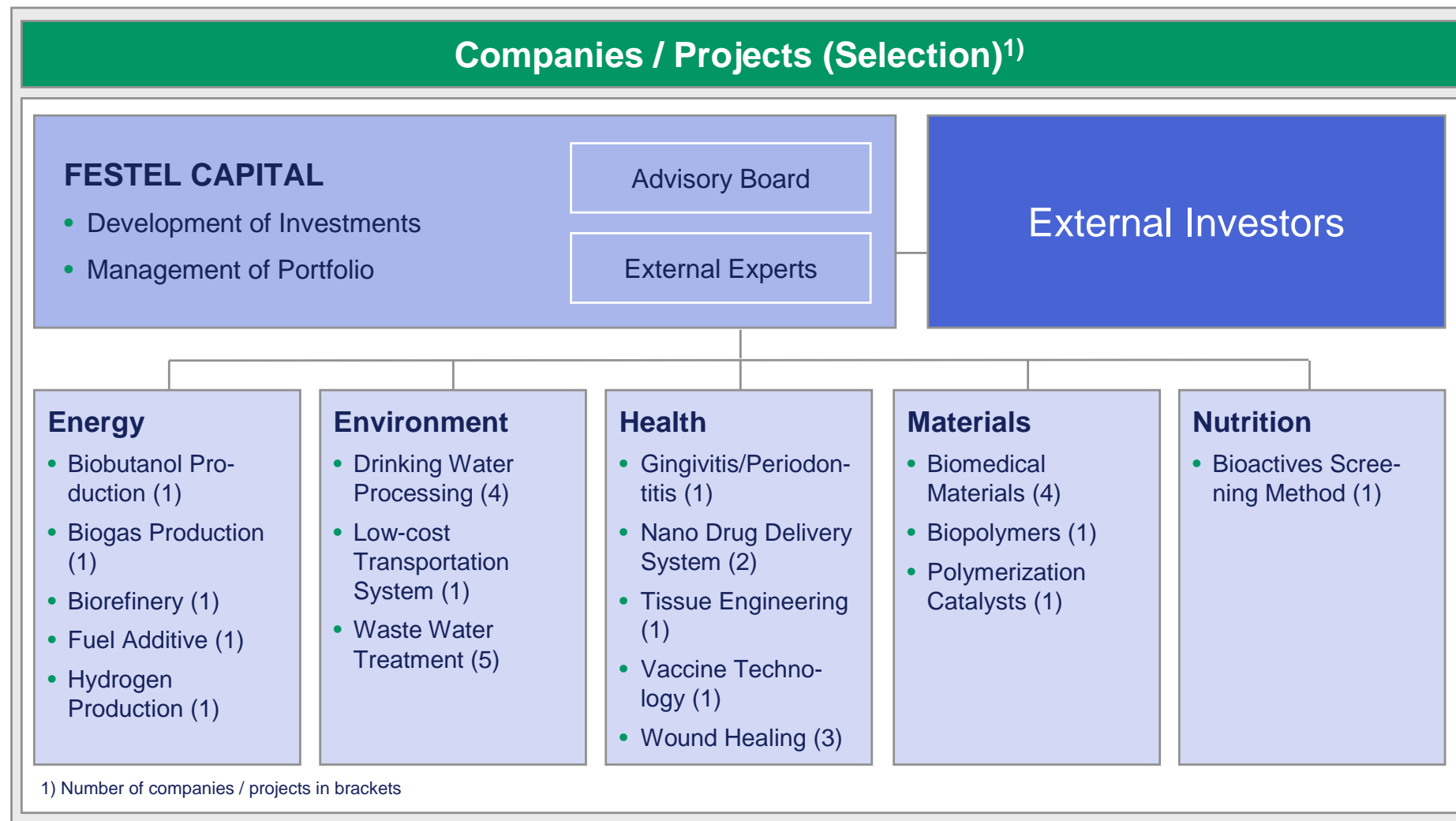
FESTEL CAPITAL identifies high potential "not market-ready" projects and develops / commercialises them together with investors / industrial partners



FESTEL CAPITAL has in-depth expertise in chemical / lifescience related technology fields, infrastructures and China

Area	Expertise (Examples)	
Energy	Drug Discovery & Development	<ul style="list-style-type: none"> • Biological Targets • Active Substances • Synthesis & Process Development
Environment	Industrial Biotechnology	<ul style="list-style-type: none"> • Bioconversion & Biorefineries • Biopolymers • Enzyme Technology
Health	Material Science	<ul style="list-style-type: none"> • Biomedical Materials • Fuel Cell Components • Tissue Engineering
Materials	Molecular Biology	<ul style="list-style-type: none"> • Bioactives • Drug Delivery • Wound Healing
Nutrition	Nanotechnology	<ul style="list-style-type: none"> • Nanobiotech & Nanomedical • Nanocomposites • Nanoelectronics
Infrastructure	Production Technology	<ul style="list-style-type: none"> • Biopharmaceuticals • Catalysis • Process Optimisation
China	Renewable Energy	<ul style="list-style-type: none"> • Bioenergy • Biofuels & Synthetic Fuels • Solar Energy
	Water Technology	<ul style="list-style-type: none"> • Drinking Water Processing • Waste Water Treatment • Water Chemicals

FESTEL CAPITAL is building up a portfolio of companies / projects in the investment areas energy, environment, health, materials and nutrition



FESTEL CAPITAL has worked together with leading technology-oriented companies

Partners (Selection)