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Biofuel Situation in Germany

Jürgen Krahl and Axel Munack

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Outline

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Introduction

Biofuel research at the FAL

Biofuel potentials

Conclusions and outlook

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Funding of Biofuel-related Research Projects

- FNR (Fachagentur Nachwachsende Rohstoffe e.V. – Agency of Renewable Resources)
- State Ministries of Agriculture or Environment
- UFOP (Union zur Förderung von Oel- und Proteinpflanzen e.V. – Union for the Promotion of Oil and Protein Plants)
- VDB (Verband Deutscher Biokraftstoffhersteller e.V. – Association of German Biofuels Producers)
- Car Manufacturers and Related Industries

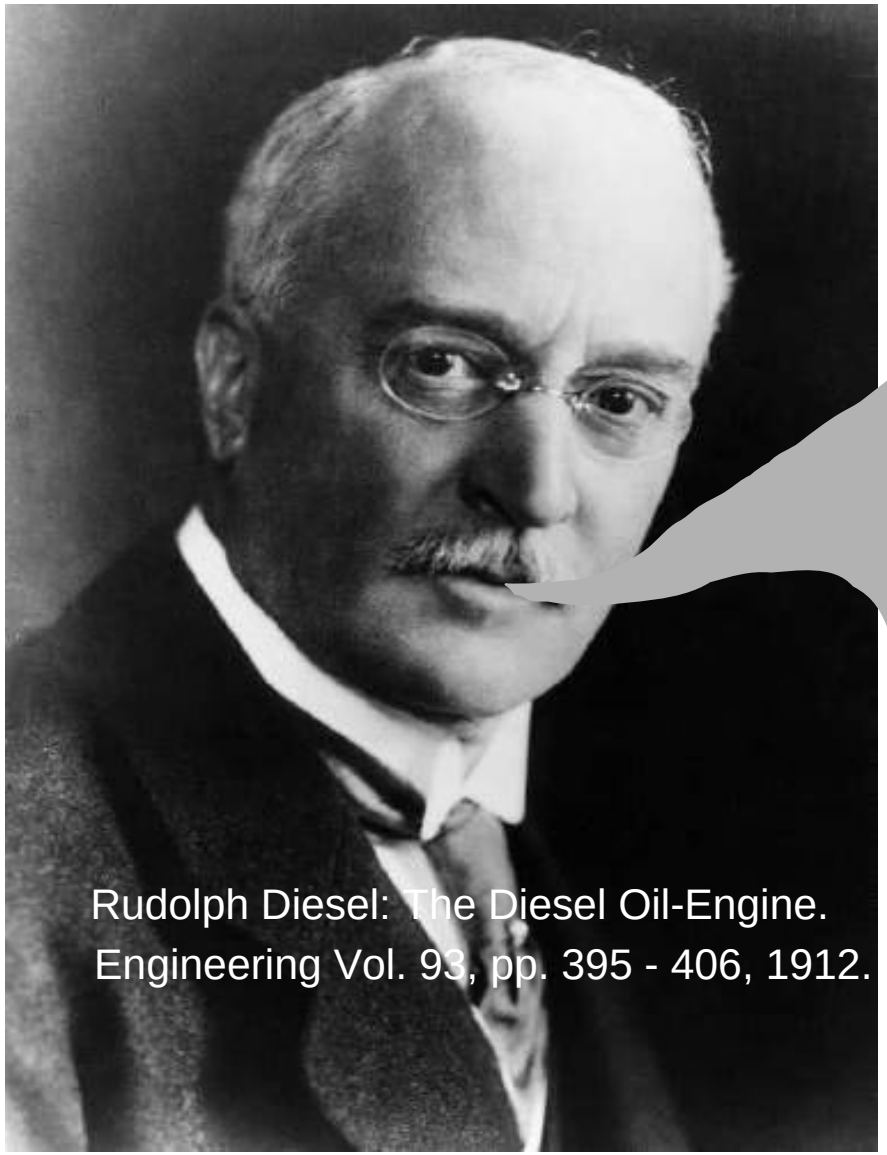
Aims and Accomplishments of the FNR

In 1993 the *FNR* was initiated by the Federal Ministry of Food, Agriculture and Forestry in order to support research and development in the subject area of renewable resources. Besides professional consultation and financial support, the *FNR* takes part in scientific events, notifies current results of research to the public and informs about the whole range of applications of renewable resources.

Research on biodiesel was funded through 15 projects with 2.3 Million €

Research on plant oils was funded through 8 projects with 5.3 Million €

Historical Remark



Rudolph Diesel: The Diesel Oil-Engine.
Engineering Vol. 93, pp. 395 - 406, 1912.

"It has been proved that Diesel engines can be worked on earth-nut oil without any difficulty"

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Encrustion of a Injection Nozzle after Running 50 h on Vegetable Oil

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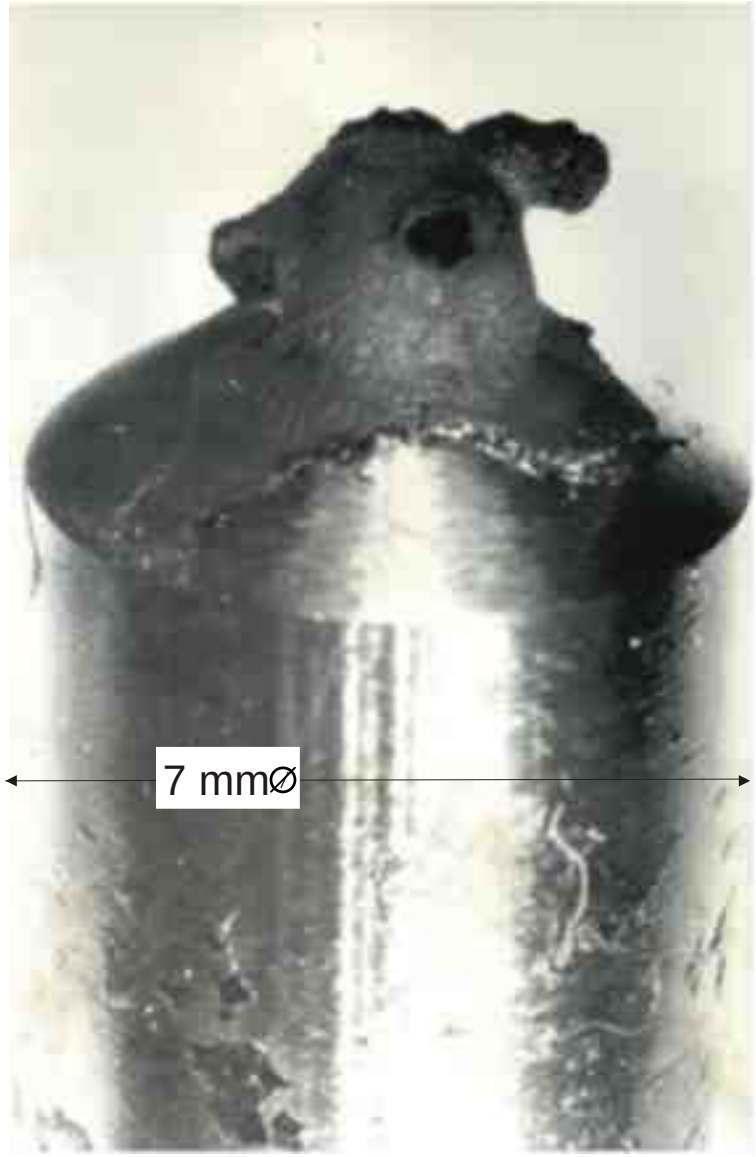

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Engine damage: Oil-box of OM Series 500

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Engine damage: Oil-box of OM Series 500

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Recent Research Projects Funded by the FNR Concerning Vegetable Oils

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Title / Aim of the Project
Field experiments with neat rapeseed oil
Quality assurance in decentralized plant oil production for the non-food sector
Operation of T3 diesel engines with rapeseed oil
Practical tests of new tractors for utilization of rapeseed oil
State of utilization of plant oils in internal combustion engines
Motor tests with blends of rapeseed oil and fossil diesel fuel
100 tractors demonstration project (various tractors, various conversion concepts)

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Research Projects Funded by the FNR Concerning Biodiesel

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Title / Aim of the Project
Research and development project concerning RME (engine optimization, sensor development)
Impact of RME on the lubricity of diesel fuels with low sulfur content
Scientific supervision of the RME energy supply project for the German Parliament Building
Ozone-forming potential of biodiesel and fossil diesel fuel
Environmentally-friendly tractor: test-stand research and optimization of the engine

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Recent Research Projects Funded by the FNR Concerning Biodiesel

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Title / Aim of the Project
Selective glycerol processing
Measurement of ultrafine particles in the exhaust of diesel engines at the operation with biodiesel
State of the utilization of biodiesel on farms
Pilot-scale plant for production of biodiesel using distillation technology
Use of PME in various applications, with a final utilization in combustion engines
Ecobalances for rapeseed oil methyl ester and rape seed oil
Market analysis for small-scale plants for production of plant oils and FAME as fuels

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Biodiesel:
Milestones of the UFOP

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1990 Foundation of the UFOP

Consequent promotion of biodiesel as neat fuel (B100), also through non-conventional sponsoring of car racing, fairs (Interboot, IAA), and research projects

Project Funding of the UFOP Concerning Biofuels and Renewable Resources

27 projects

among these:

Standardization, plant breeding, lubricants, hydraulic oils

3 x Congresses / Workshops

4 x Overviews

5 x Ecobalances / life cycle analyses

11 x Research concerning technical aspects of the utilization of biodiesel

Releases of Manufacturers Concerning Operation with Biodiesel (RME, B100)

Passenger cars	mainly cars of the Volkswagen Group during the years from 1996 to 2004
Heavy duty vehicles	D/C already for EURO IV und EURO V; IVECO, Scania, MAN, DAF each in part
Agricultural vehicles	with few exceptions all vehicles obtained a release
Special machines, accessories	Still, Eberspächer, Webasto (recent types)

Basic Life-Cycle Comparisons for Rape Seed Oil, RME, and Diesel Fuel

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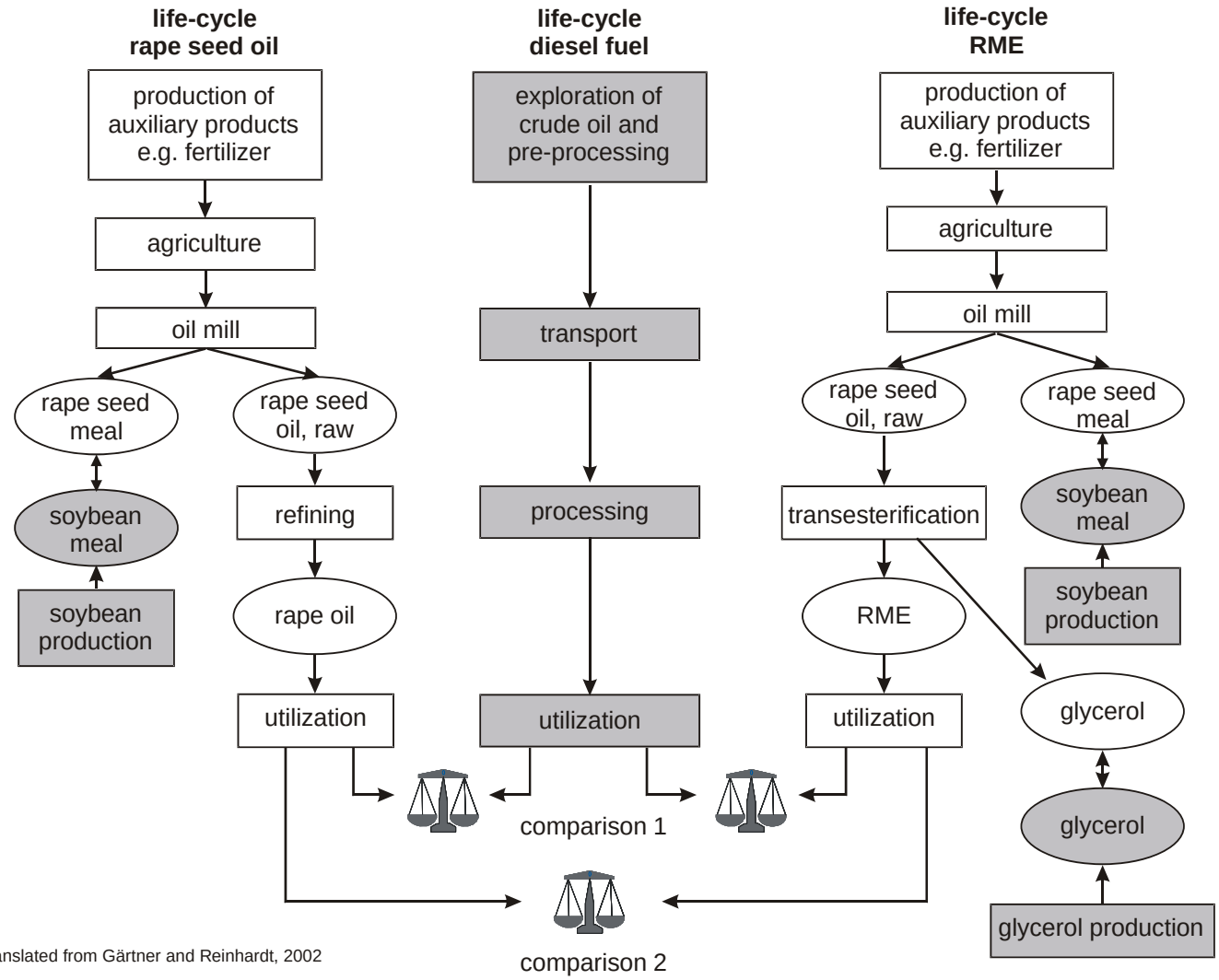
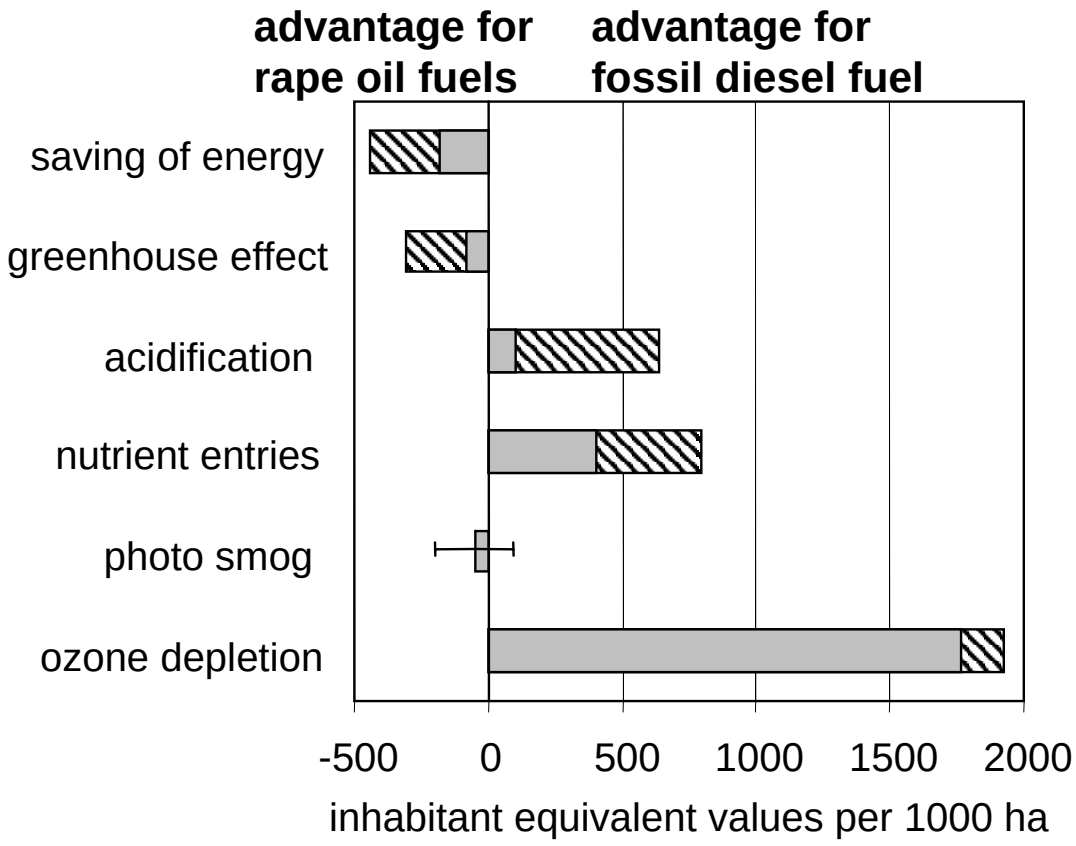


translated from Gärtner and Reinhardt, 2002

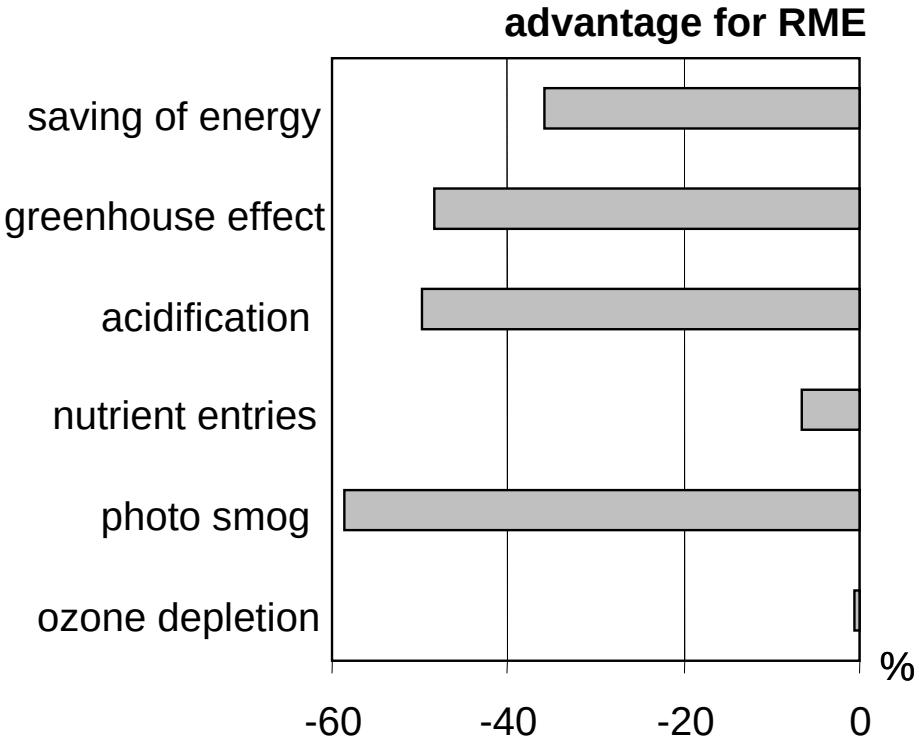
Comparison 1:
Rape Oil Fuels ↔ Fossil Diesel Fuel



Interpretation at the example of the first bar:
The diagram shows the bandwidth of all results for different variations. If the rape gained from 1,000 ha is used as bio-fuel, then the saved energy corresponds to the average yearly energy consumption of min. 200 to max. 450 inhabitants of the Federal Republic of Germany.

translated from Gärtner and Reinhardt, 2002

Comparison 2:
RME ↔ Rape Oil



Interpretation at the example of the first bar:
The utilization of RME as fossil diesel substitute saves about 35 % more fossil energy sources than the utilization of rape oil.

translated from Gärtner and Reinhardt, 2002

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Biodiesel: Early Research

1982 Publication of the results obtained by G. Vellguth (FAL) in „Grundlagen der Landtechnik“

Eignung von Pflanzenölen und Pflanzenölderivaten als Kraftstoff für Dieselmotoren

Von Gerhard Vellguth, Braunschweig-Völkenrode*)

Mitteilung aus dem Institut für landtechnische Grundlagenforschung der Bundesforschungsanstalt für Landwirtschaft, Braunschweig-Völkenrode

Professor Dr.-Ing. Wilhelm Batel zum 60. Geburtstag

DK 631.372:621.436:662.756.3

Pflanzenöle haben Eigenschaften, die sie grundsätzlich als Ersatz für Dieselkraftstoff geeignet erscheinen lassen. In Motoren mit direkter Einspritzung, wie sie heute in landwirtschaftlichen Schleppern und in Nutzfahrzeugen gebräuchlich sind, ist jedoch ein Dauerbetrieb mit Pflanzenölen — auch in raffinierter Form — nicht möglich. Maßnahmen zur Vermeidung der auftretenden Probleme wurden auf einem Motorprüfstand systematisch untersucht. Das Ergebnis ist, daß beim Einsatz von Pflanzenölderivaten, die sich durch Umesterung mit Ethanol oder Methanol herstellen lassen, die Probleme nicht auftreten, wenn außerdem die Einspritzung vorverlegt wird.

weil sie besser verfügbar und wesentlich preiswerter waren. Hinsichtlich dieser Voraussetzungen ist jedoch in den letzten 10 Jahren eine bedeutsame Veränderung eingetreten. Der hohe Verbrauch an Erdöl für Kraftstoffe und als Grundstoff der chemischen Industrie einerseits und die begrenzten abbaubaren bzw. abbauwürdigen Vorräte andererseits haben die Erschöpfbarkeit aufgezeigt und zusammen mit politischen und wirtschaftlichen Gründen zu einer enormen Verteuerung geführt.

In vielen Ländern der Erde, vor allem in den erdölimportierenden und den landwirtschaftlich orientierten, werden daher Kraftstoffe aus nachwachsenden Rohstoffen, d.h. nicht unbegrenzten, jedoch unerschöpflichen Quellen, auf ihre Einsatzmöglichkeiten untersucht. Pflanzenöle haben dabei aufgrund verschiedener günstiger Eigenschaften eine gewisse Bedeutung als Kraftstoff für Dieselmo-

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Biofuel Research at the FAL

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1980 - 1990

Basic energetic and engine-related topics for RME

1990 - 2000

Emissions-related research and health effects for RME

2000 - 2006

Assessment of emissions and effects for different fuels and blends

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Recent and Current Research Projects of the FAL Concerning Biofuels

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Short Title	Title / Aim of the Project	Sponsor
Biodiesel in agriculture	State of the utilization of biodiesel on farms	FNR
Biogenic esters	Use of PME in various applications, with a final utilization in combustion engines (subcontract)	FNR
SMDS	Comparison of the exhaust emissions from Shell middle distillate, premium diesel fuel, fossil diesel fuel, and RME	UFOP Shell
SCR	Potential of application of selective catalytic reduction (SCR) systems with biodiesel fuels	UFOP VDB
Ultrafine particles	Measurement of ultrafine particles in the exhaust of diesel engines at the operation with biodiesel	FNR UFOP VDB
B20	Fleet experiment with B20 blend	VW AGQM
500 h	500-h test of RME in a heavy-duty diesel engine	MAN VDB

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General Scheme of the Emission Test Stand in the FAL

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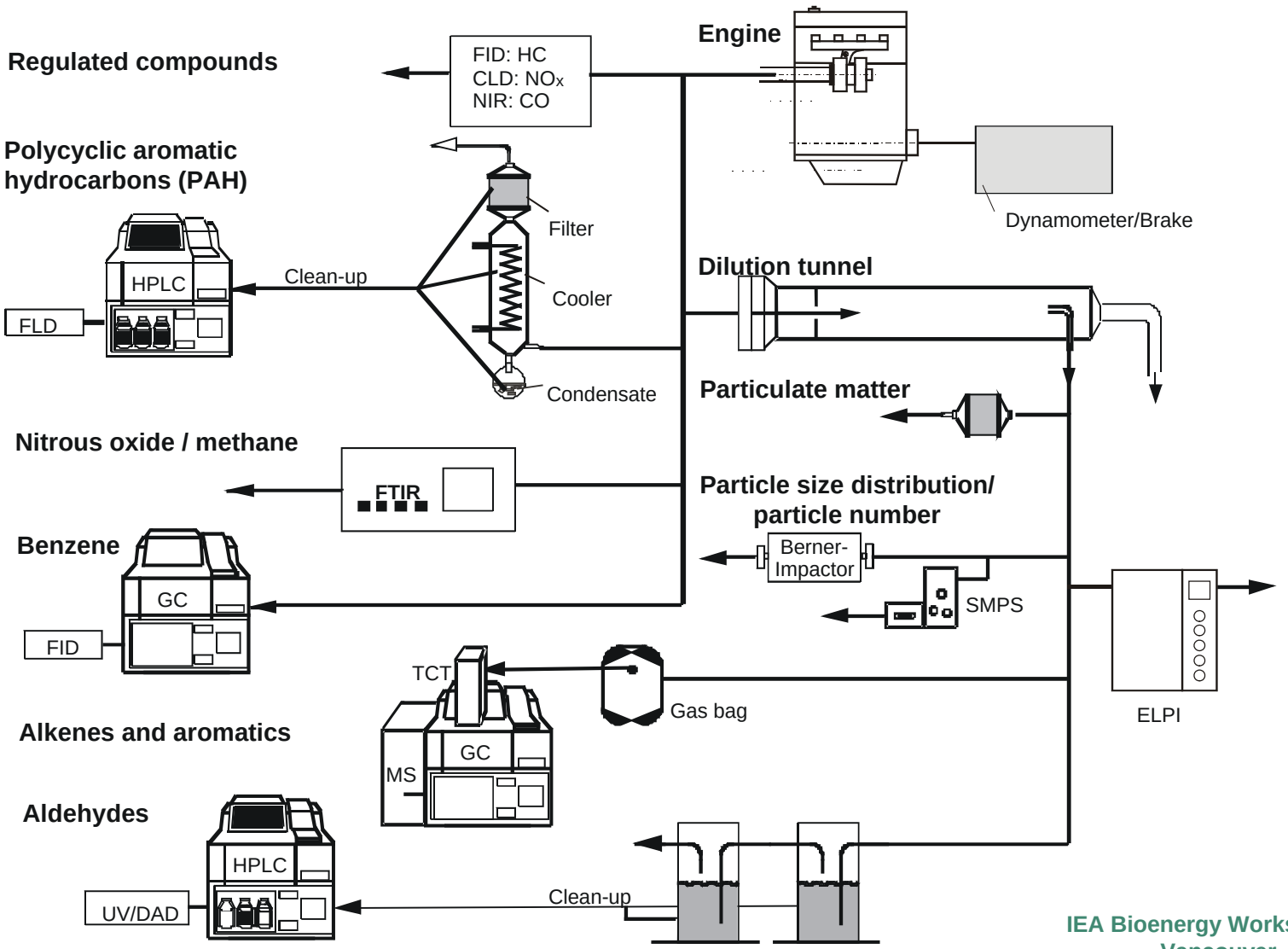
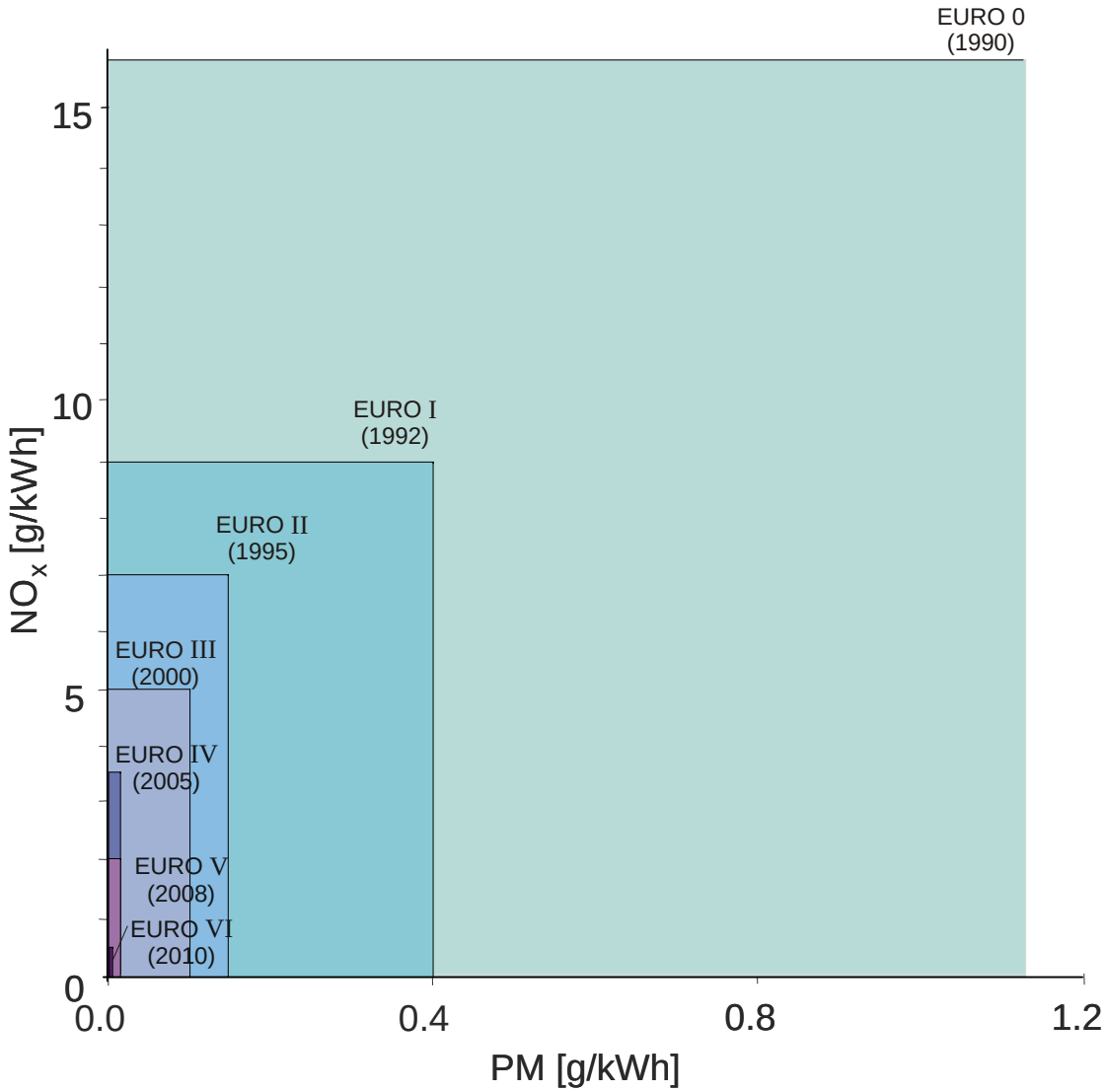


Exhaust Gas Regulations in Europe



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Exhaust Gas Regulations in Europe

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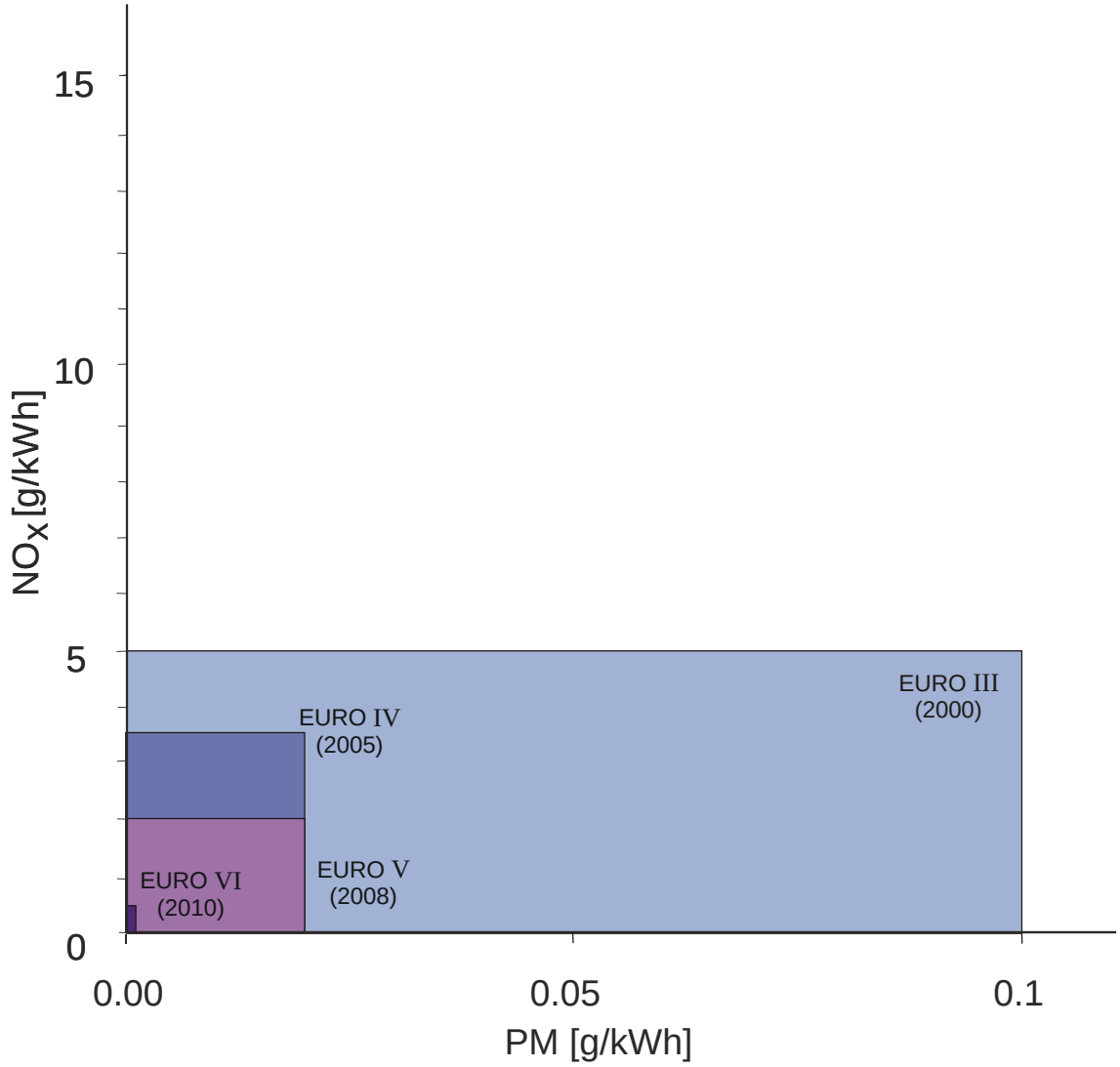
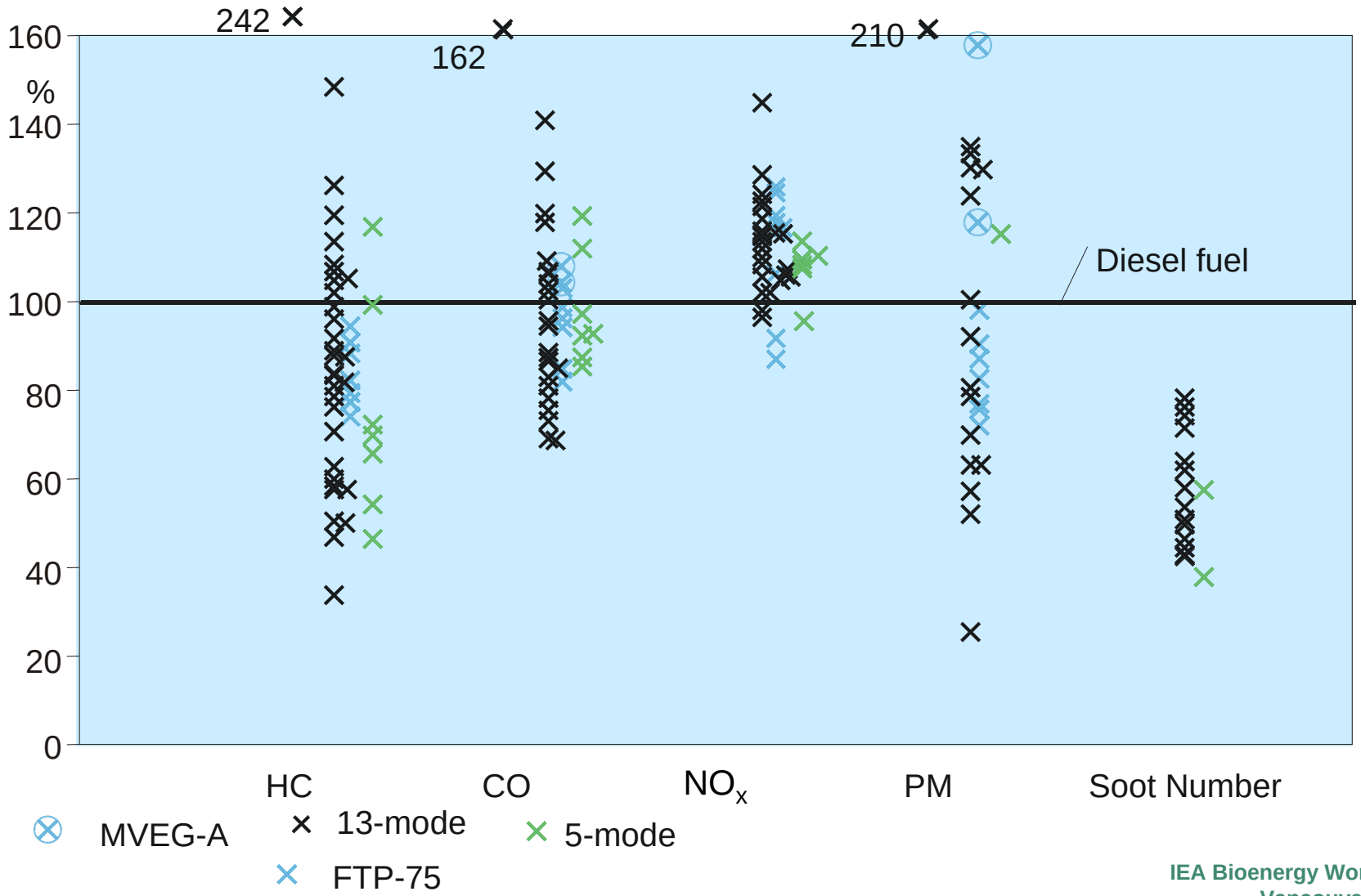
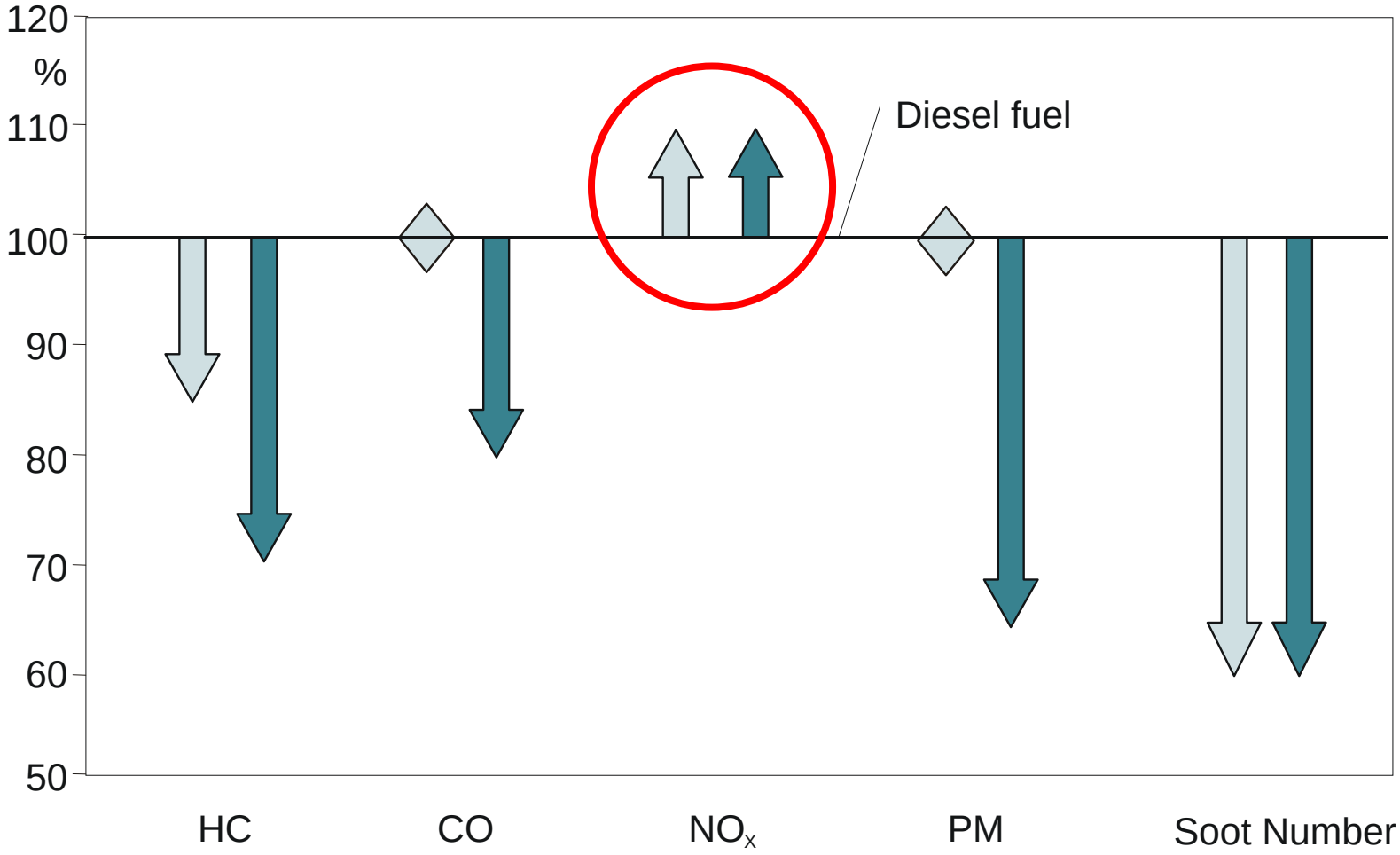


Emissions of Regulated Compounds from DI Engines Fueled with RME Compared to Diesel Fuel

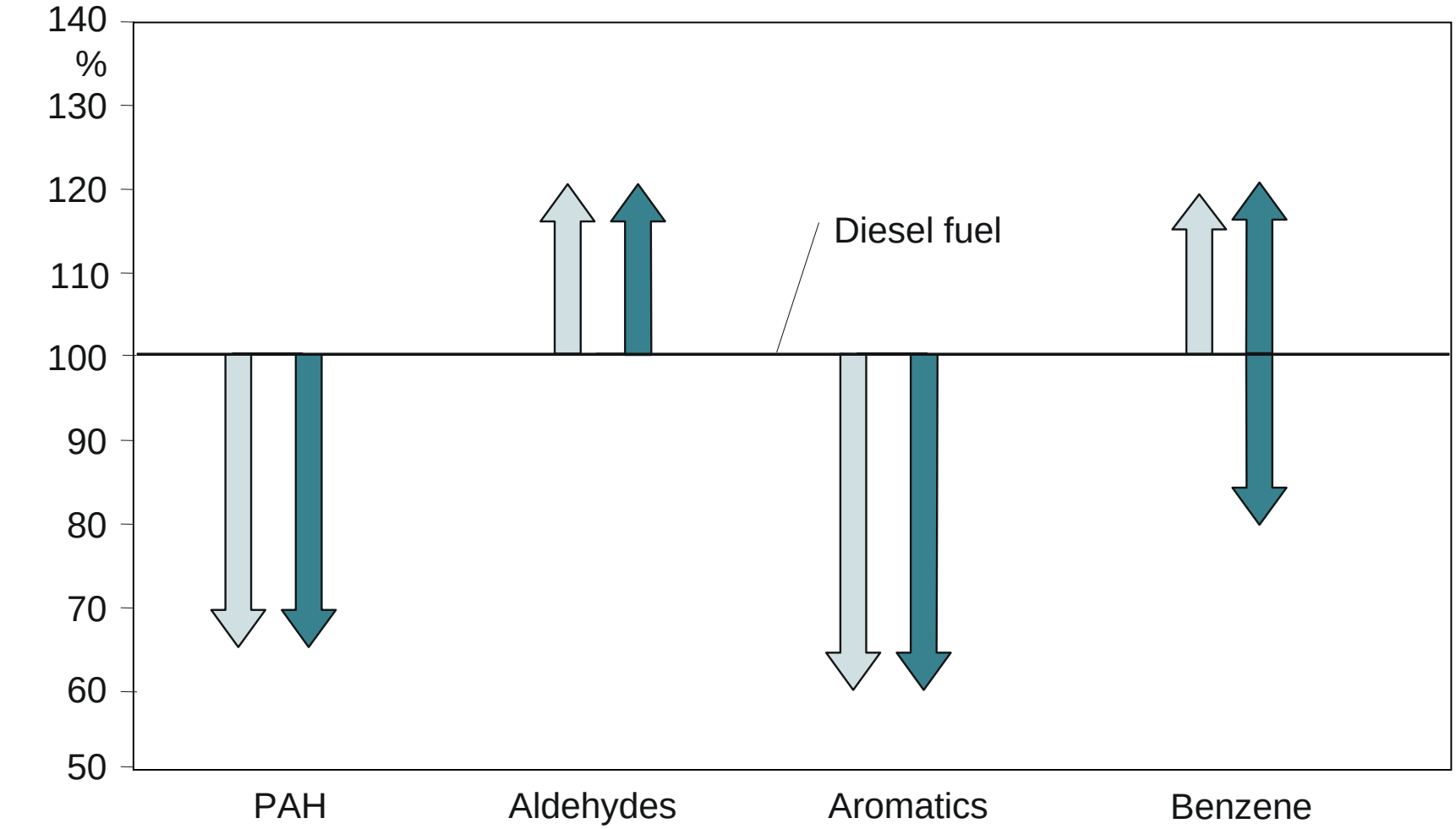


Emissions of Regulated Compounds from Biodiesel Relative to Diesel Fuel



DI: direct injection IDI: indirect injection

Emissions of Non-regulated Compounds From Biodiesel Relative to Diesel Fuel



DI: direct injection IDI: indirect injection

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Emissions of Regulated Compounds Fischer-Tropsch Fuels Relative to Diesel Fuel

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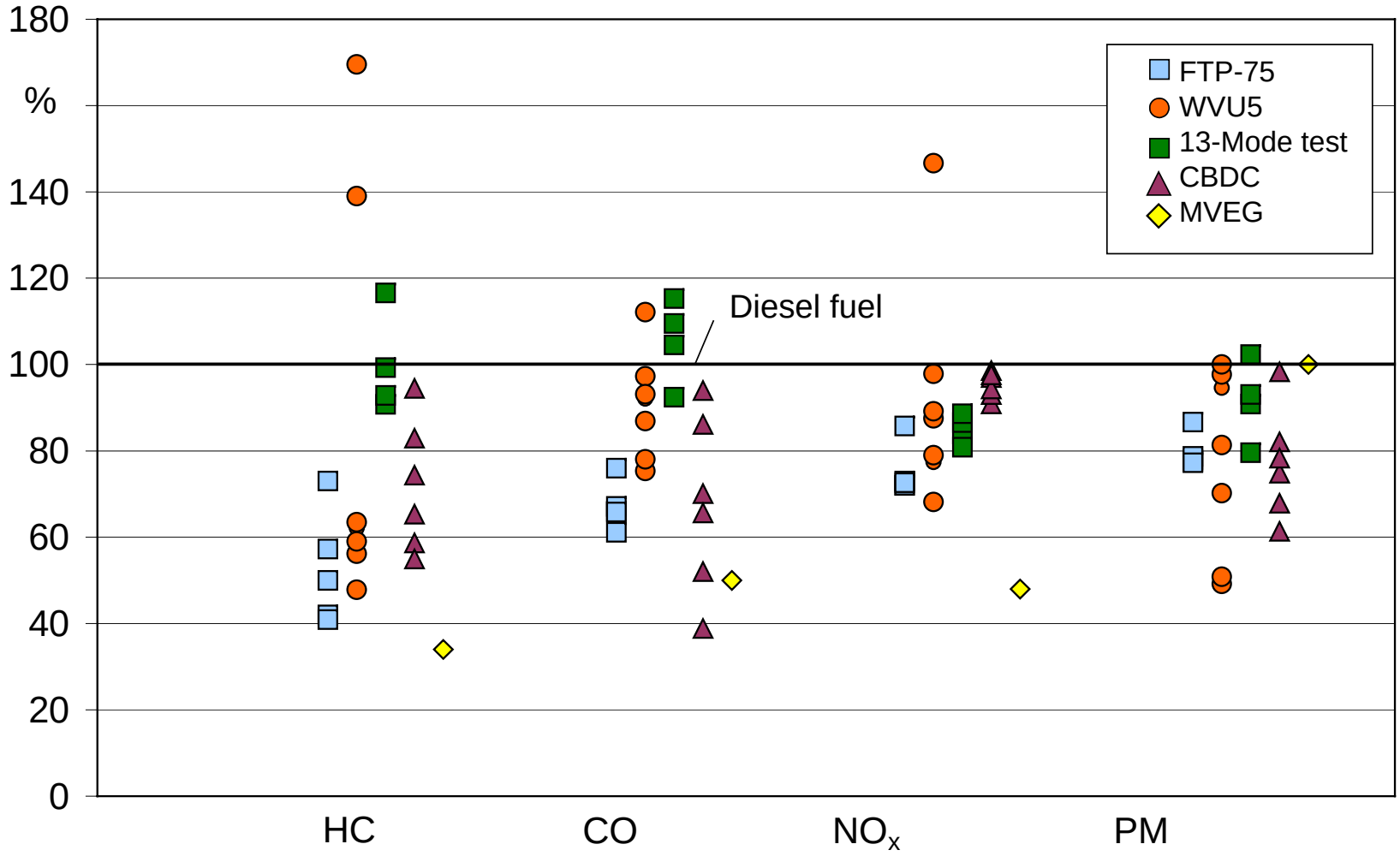
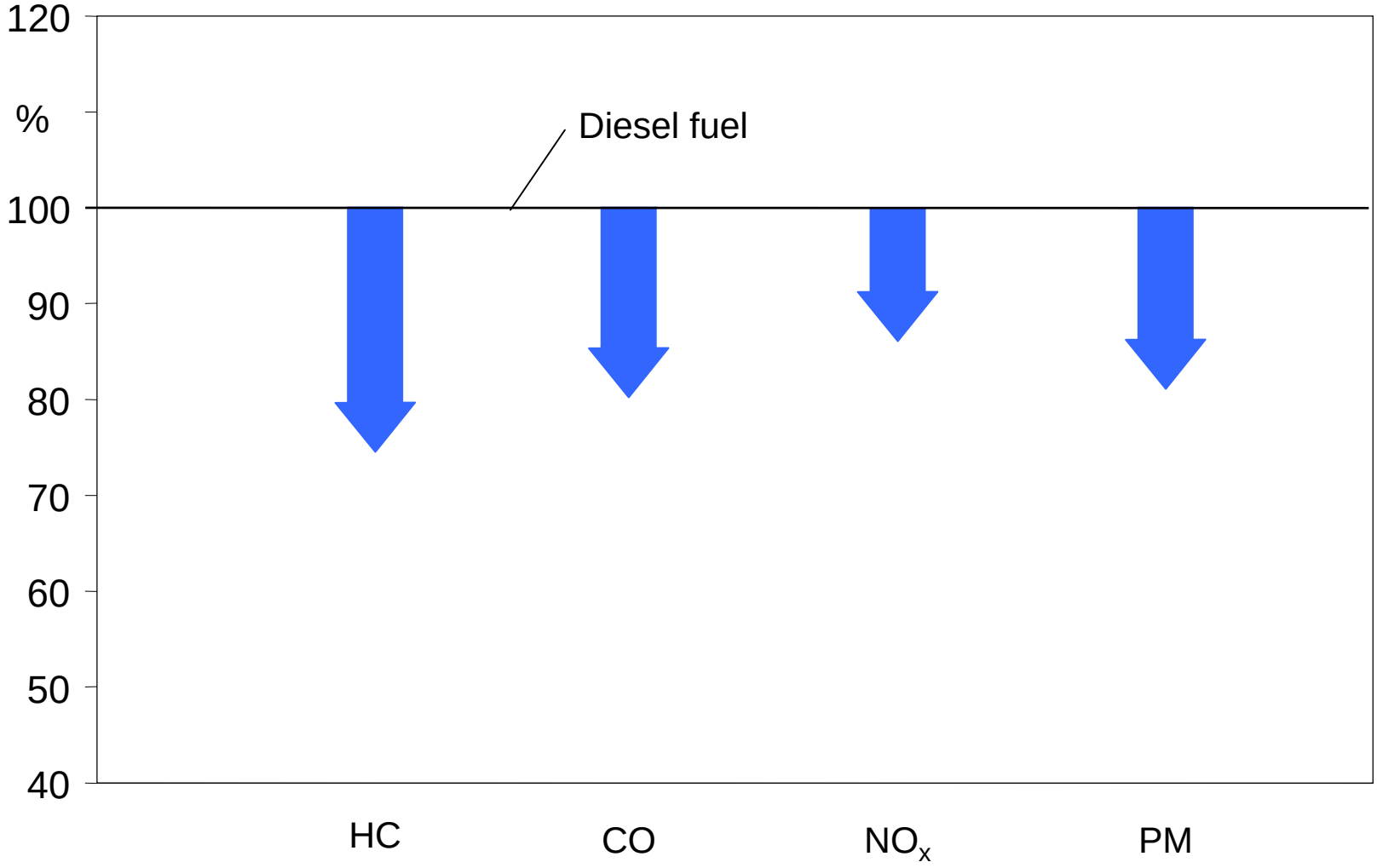
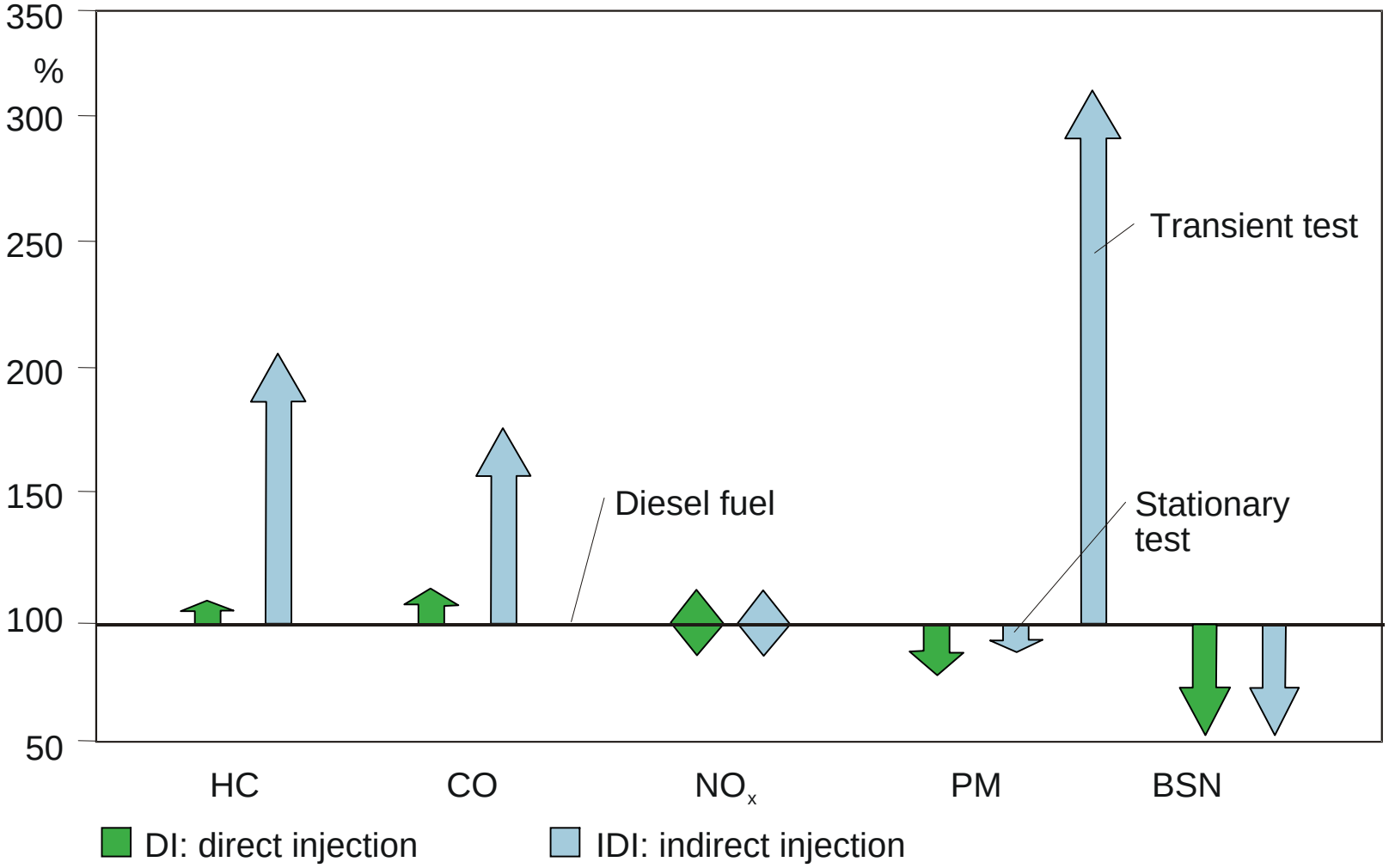


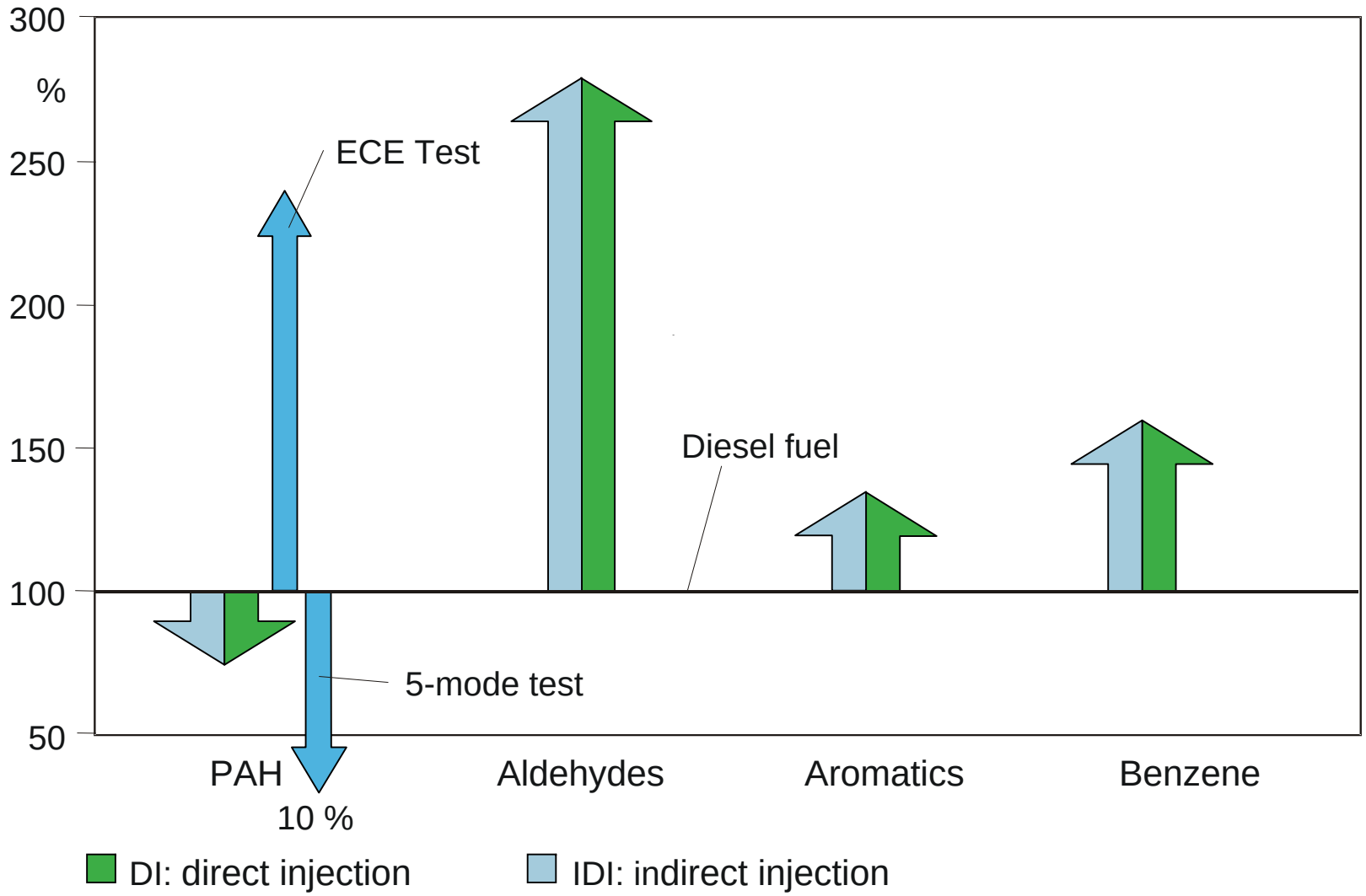
Emissions of Regulated Compounds Fischer-Tropsch Fuels Relative to Diesel Fuel



Emissions of Regulated Compounds from Rape Seed Oil Relative to Diesel Fuel



Emissions of Non Regulated Compounds from Rape Seed Oil Relative to Diesel Fuel



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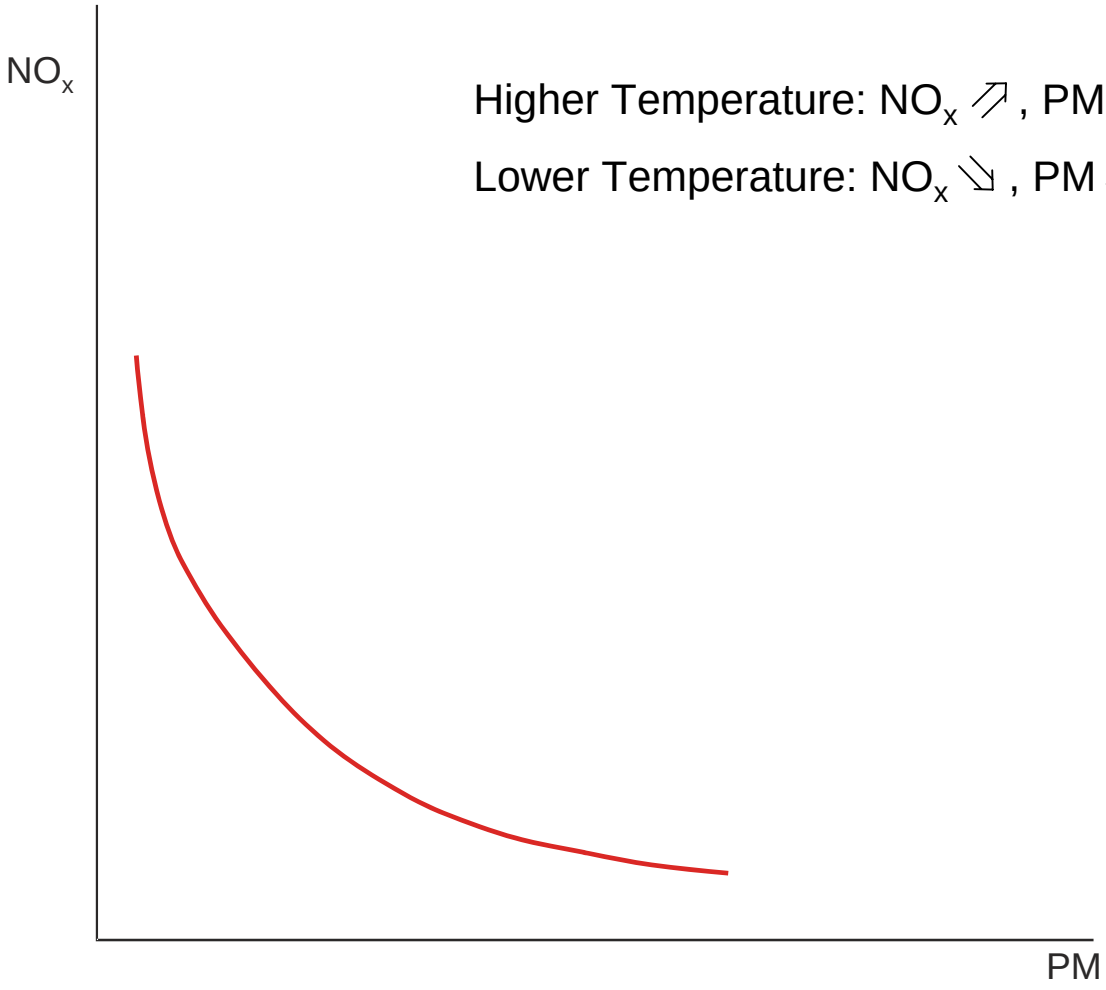
NO_x/PM Trade-off

Higher Temperature: NO_x ⇗ , PM ⇘ , Consumption ⇘

Lower Temperature: NO_x ⇘ , PM ⇗ , Consumption ⇗



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Optimization of the Engine

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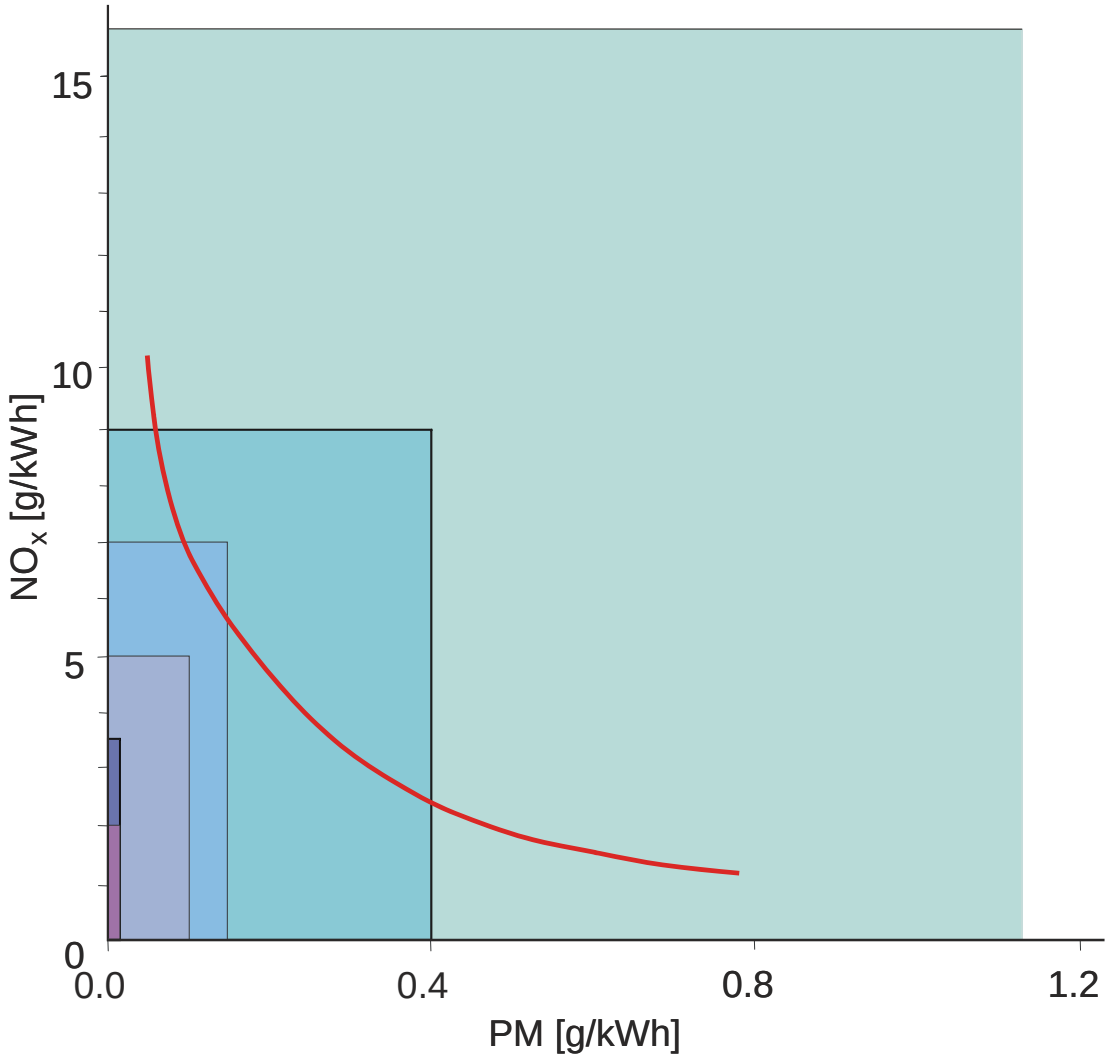

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Optimization of the Engine

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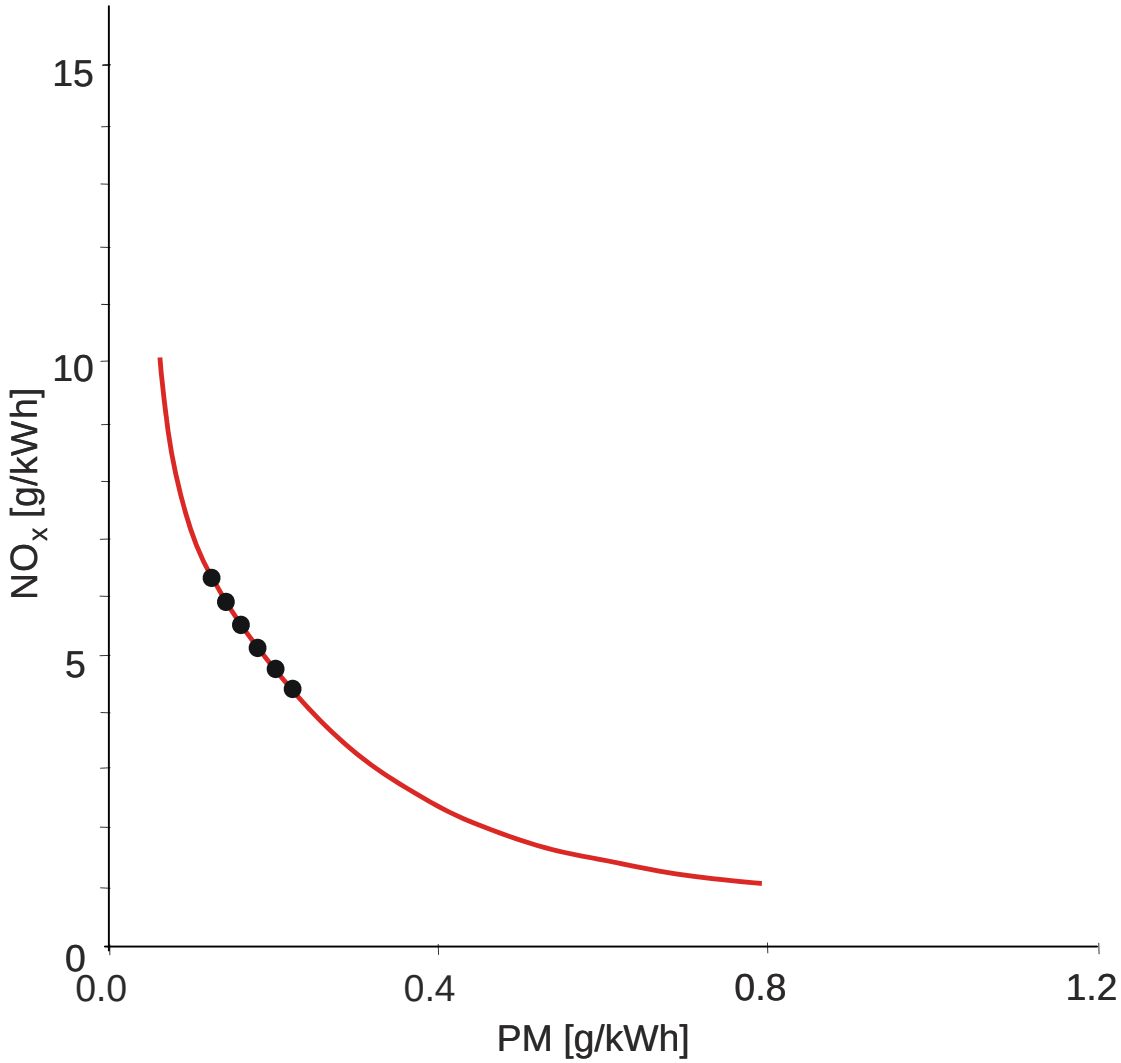

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Two FAL Fuel Sensor Prototypes (Screw-in Versions)

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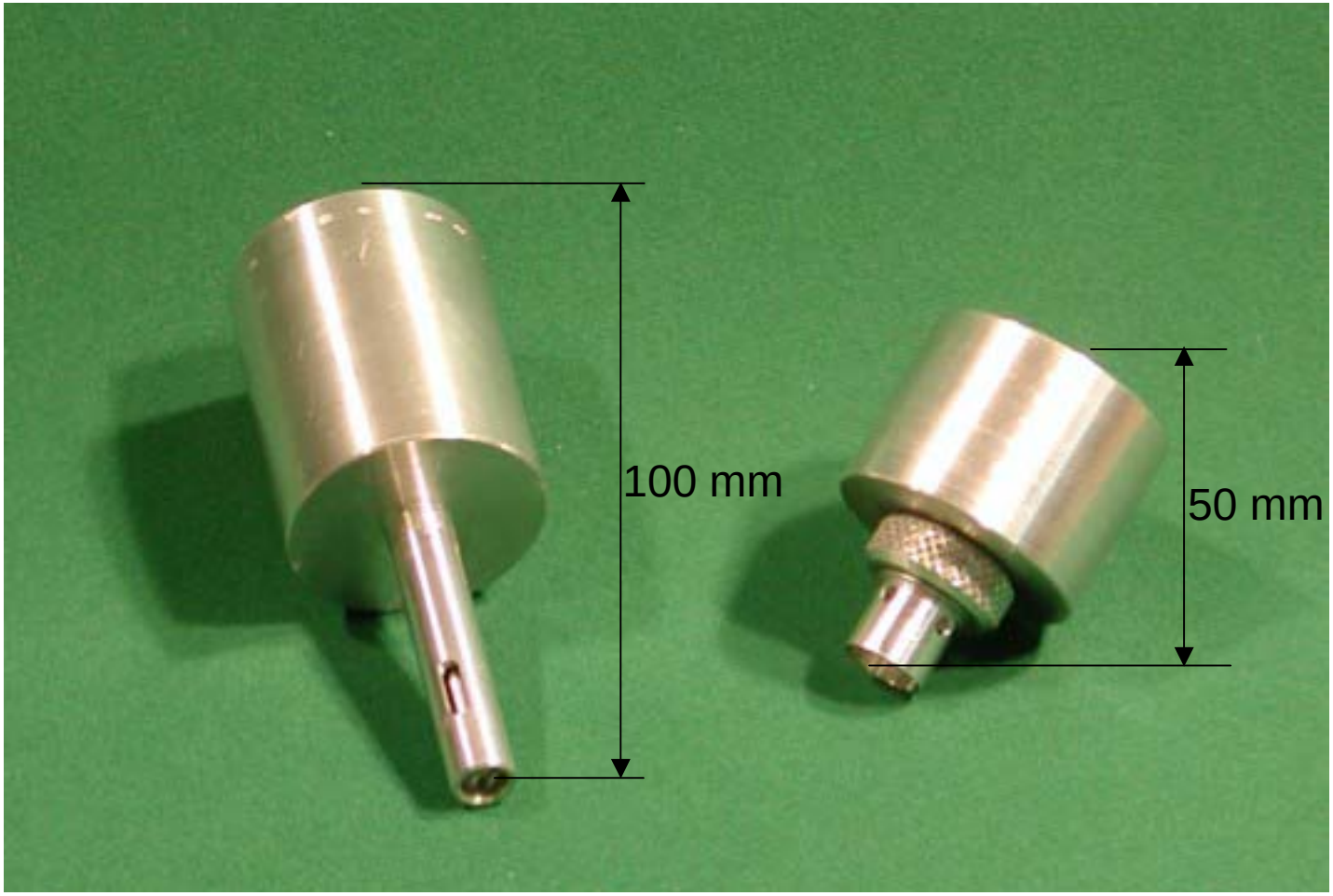

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Another FAL Fuel Sensor Prototype (Flow-through Version)

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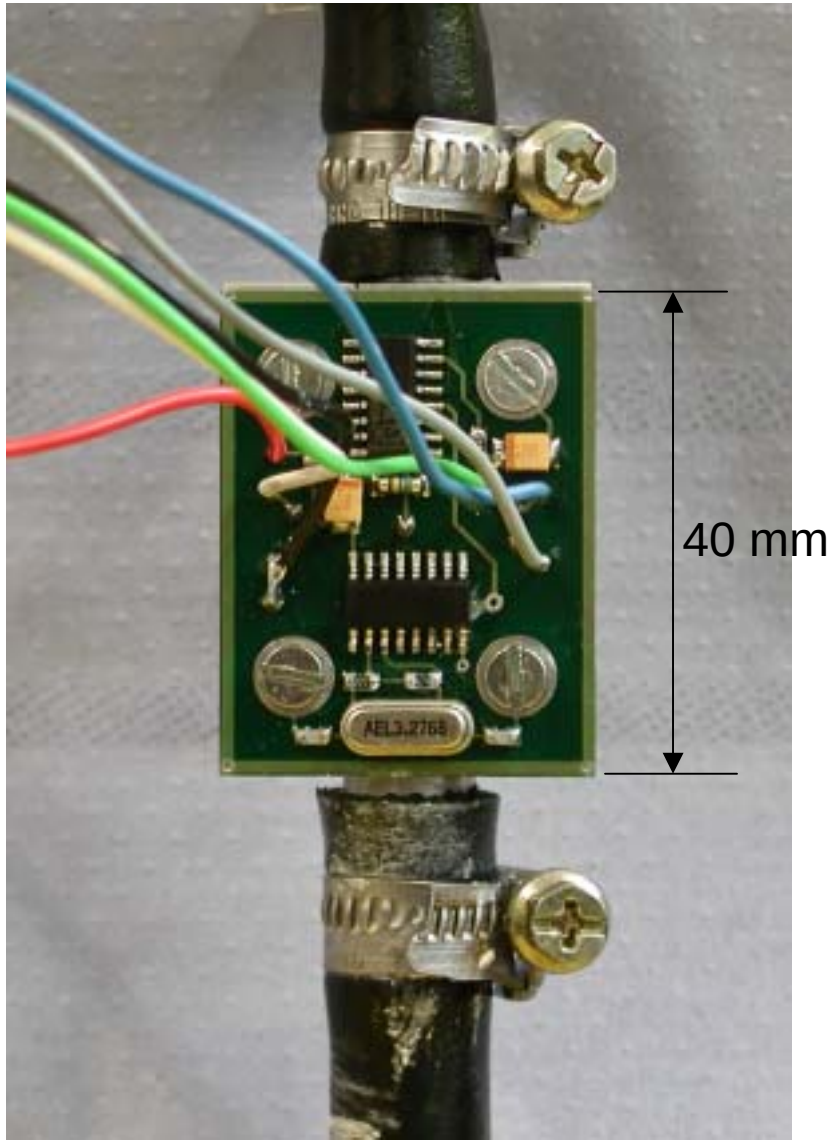

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The New Version of the BERU Sensor

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Optimization of the fuel

- Reference diesel fuel according to DIN EN590
- RME blended with palm oil methyl ester
- RME according to DIN EN 14214
- RME blended with soy bean oil methyl ester
- RME blended with palm and soy bean oil methyl ester
- Gas-to-liquid fuel (GTL)

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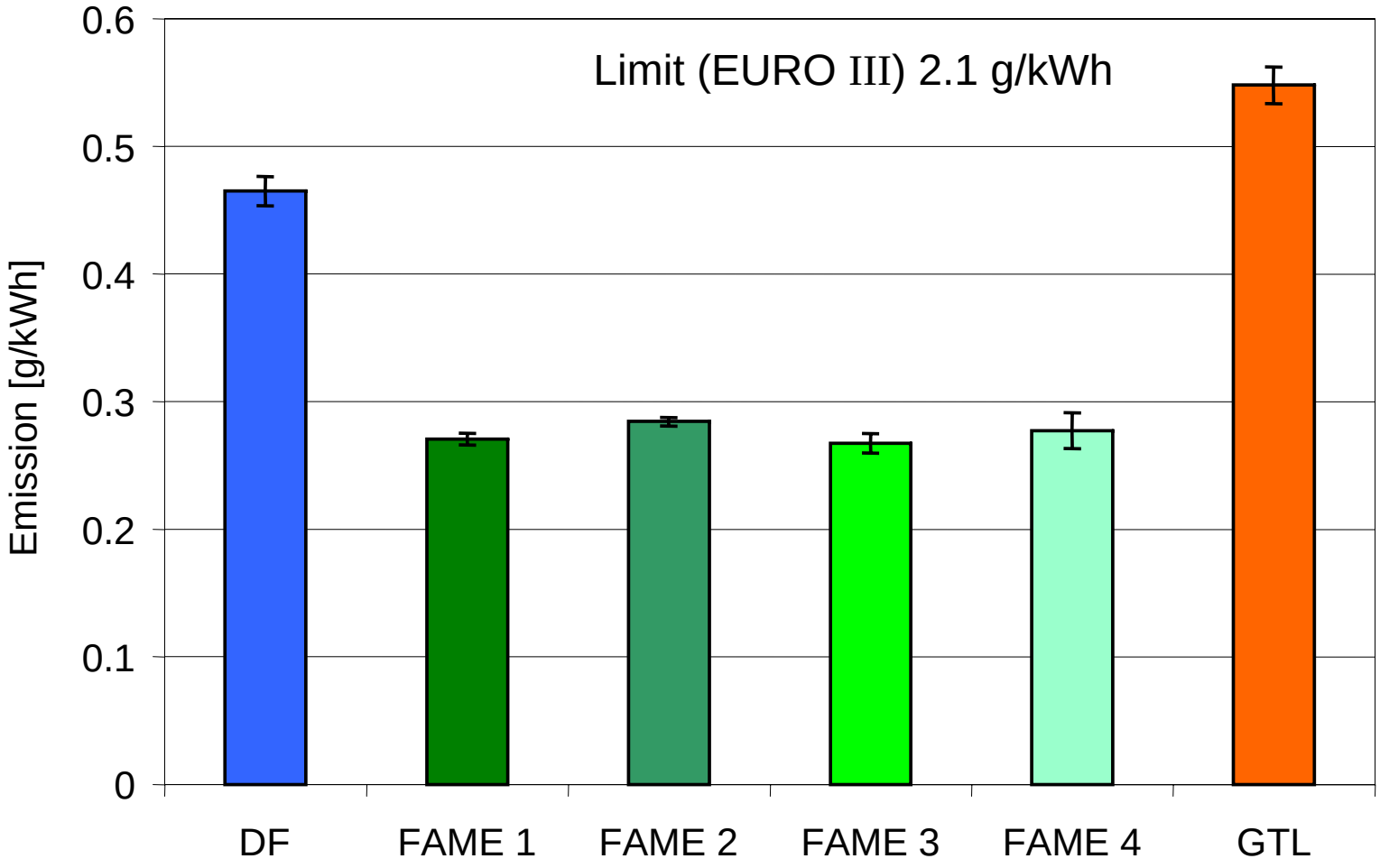
CO Emissions

ESC-Test, OM 906 LA



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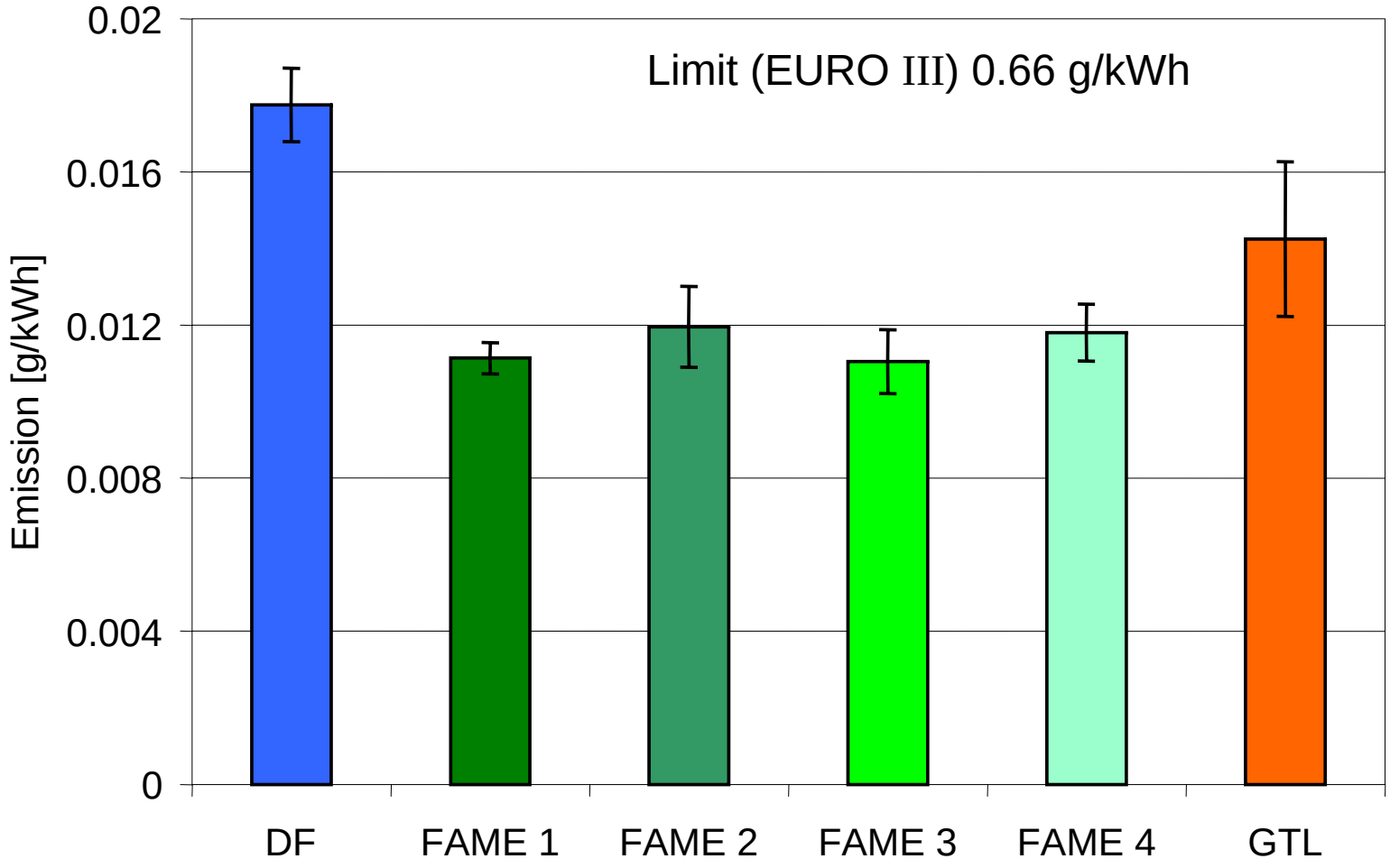
HC Emissions

ESC-Test, OM 906 LA



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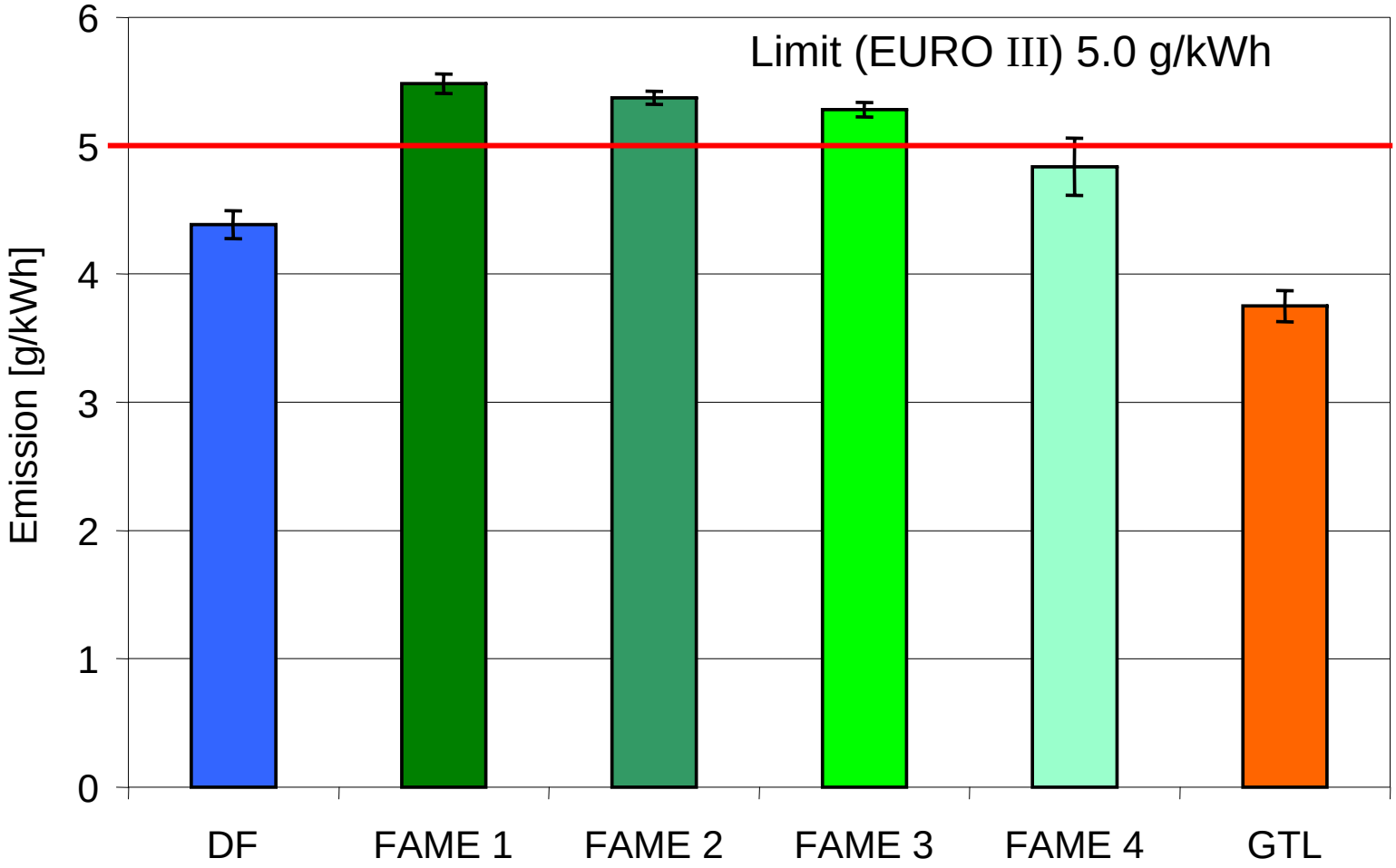
NO_x Emissions

ESC-Test, OM 906 LA



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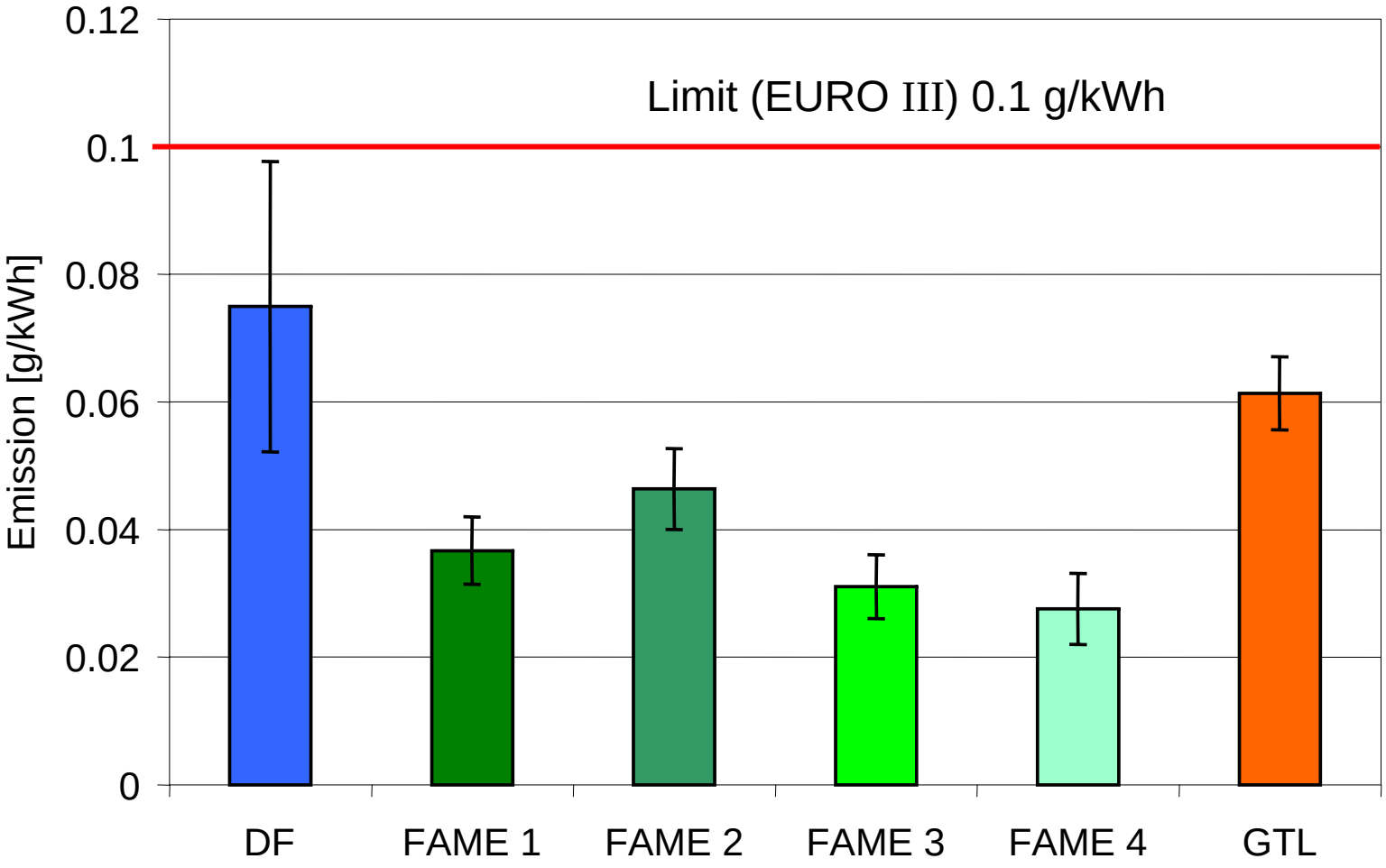
PM Emissions

ESC-Test, OM 906 LA



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Today‘s Pathways for Use of Biomass as Energy Source

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Biomass	Conversion	Energy Carrier	Main Utilization
oil plants	physical/chemical	vegetable oil vegetable oil methyl ester	electricity, heat, fuel fuel, electricity, heat
wood, residuals	physical	pellets	heat, electricity
energy plants, liquid manure, organic residues	biochemical	bio-gas	heat, electricity
sugar, starch, lignocelluloses, organic residues	biochemical	bio-ethanol, ethyl tertiary butyl ether (ETBE)	fuel, additive

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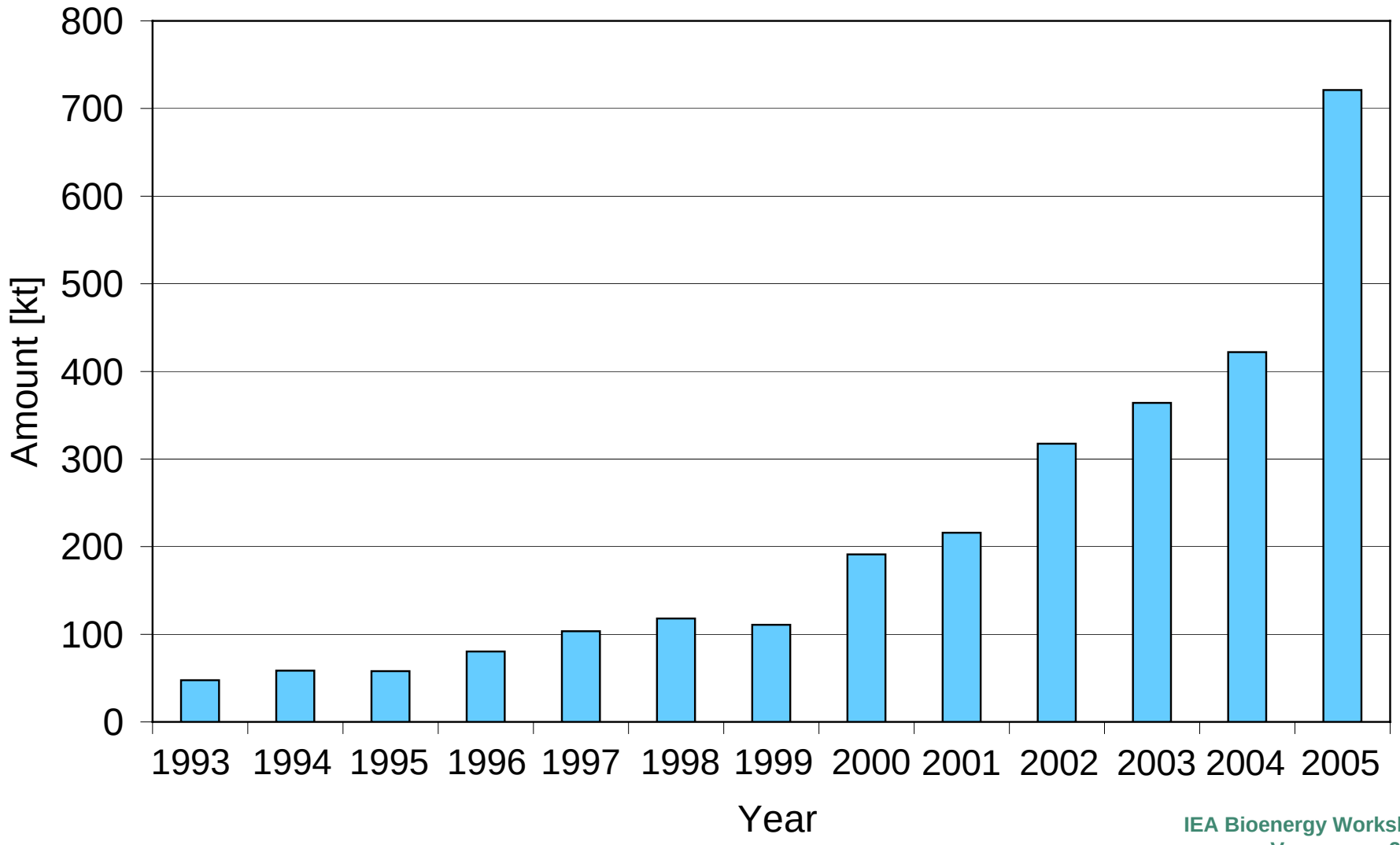
Production of Bio-Ethanol in Europe (EU-15; 2004/05: EU-25)



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Bio-Ethanol Production

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Source	Crop Yield [t/(ha·a)]	Ethanol Conversion Yield [L/t]	Ethanol Yield [L/(ha·a)]	Calorific Value [GJ/(ha·a)]
sugar cane	80	70	5,600	121
sugar beet	55	110	6,050	131
maize	8	400	3,200	69
cereals	7.5	380	2,850	62

acc. to Vorlop et al., 2002

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Processing Improvements in Ethanol Production

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Saccharomyces ssp.	Conventional Batch, Free Cells industrial	Melle Boinet (Brazil) Cell Recovery industrial	Kansai Paint (Japan) Continuous, Immobilized Cells techn. scale
conc. of cells [g/L]	3 - 5	9.6	40
conc. of ethanol [g/L]	10 - 11	5.5 – 8.0	12 - 16
conversion yield [%]	85 - 86	85 - 86	89 - 90
time-space yield of ethanol [kg/(m^{3}h)]	1.3 – 1.5	1.38	15 - 18

acc. to Vorlop et al., 2002

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Today‘s Pathways for Use of Biomass as Energy Source

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Biomass	Conversion	Energy Carrier	Main Utilization
oil plants	physical/chemical	vegetable oil vegetable oil methyl ester	electricity, heat, fuel fuel, electricity, heat
wood, residuals	physical	pellets	heat, electricity
energy plants, liquid manure, organic residues	biochemical	bio-gas	heat, electricity
sugar, starch, lignocelluloses, organic residues	biochemical	bio-ethanol, ethyl tertiary butyl ether (ETBE)	fuel, additive

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Bio-Gas: Potentials in Germany

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Agriculture (liquid manure, residues)

205 Mt/a
$5.5 \cdot 10^9$ m³/a

Industry, Municipalities (by-products, bio waste, grass)

24 Mt/a
$2.7 \cdot 10^9$ m³/a

Renewable Raw Materials (root crop, cereals, green plants)

60 Mt/a
$8.5 \cdot 10^9$ m³/a

technically usable: 60 %
$10 \cdot 10^9$ m³/a ≙ 234 PJ/a

Electrical Energy
22.8 TWh/a
82.1 PJ/a

Heat
35.8 TWh/a
128.9 PJ/a

for comparison:
German generation of electricity from bio-gas 2000: 0.45 TWh
German generation of electricity from bio-gas 2004: 3.17 TWh
(by 2,000 units)

acc. to Vorlop et al., 2002;
last update: June 2005

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Bio-Gas: Potentials in Germany

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Agriculture (liquid manure, residues)

205 Mt/a
$5.5 \cdot 10^9$ m³/a

Industry, Municipalities (by-products, bio waste, grass)

24 Mt/a
$2.7 \cdot 10^9$ m³/a

Renewable Raw Materials (root crop, cereals, green plants)

60 Mt/a
$8.5 \cdot 10^9$ m³/a

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Electrical Energy
22.8 TWh/a
82.1 PJ/a

Heat
35.8 TWh/a
128.9 PJ/a

for comparison:

German generation of electricity from bio-gas 2000:	0.45 TWh
German generation of electricity from bio-gas 2004:	3.17 TWh
German consumption of electric energy 2001:	570 TWh

acc. to Vorlop et al., 2002;
last update: June 2005

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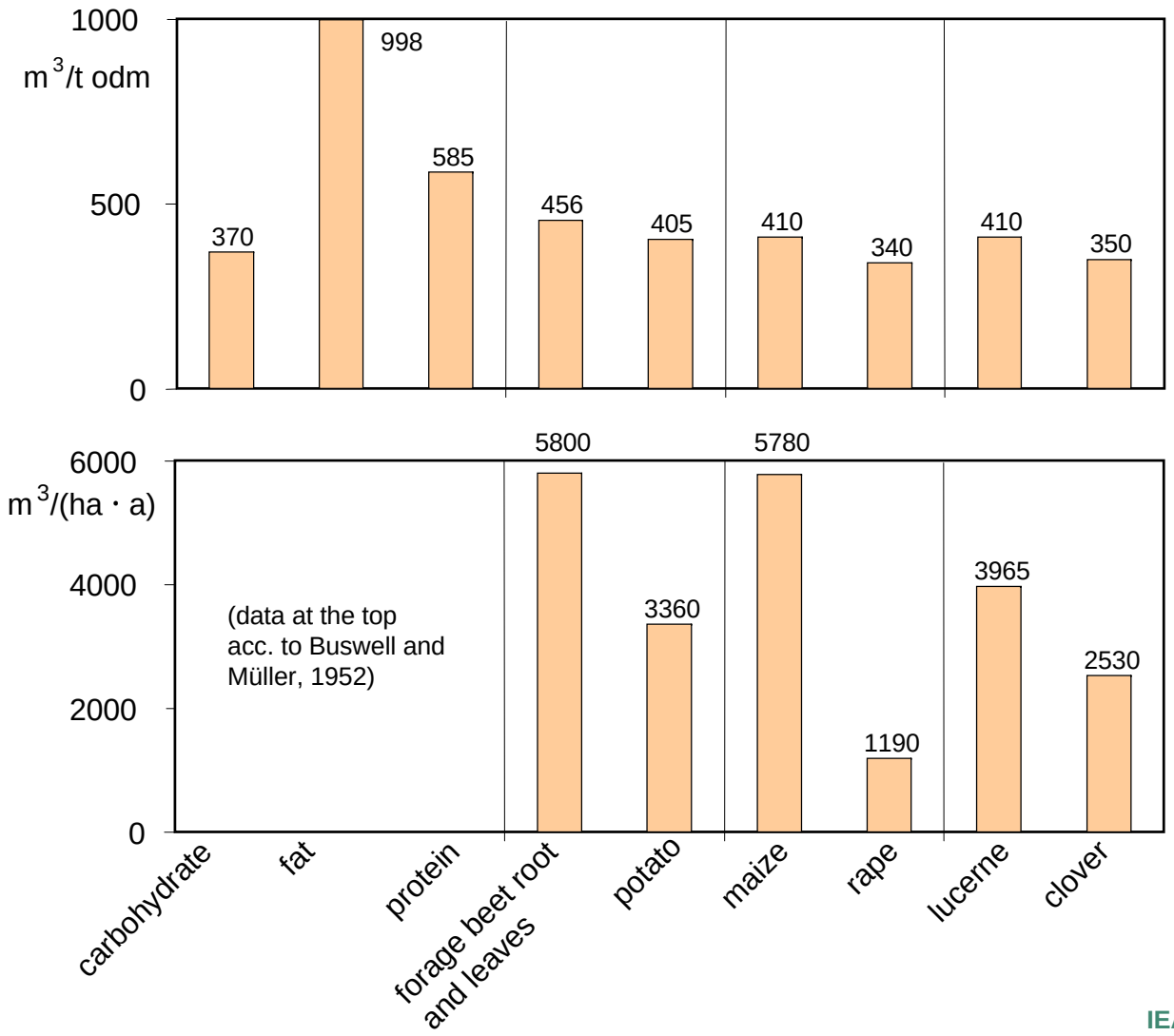
Examples of Methane Yields



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Further Pathways for Use of Biomass as Energy Source

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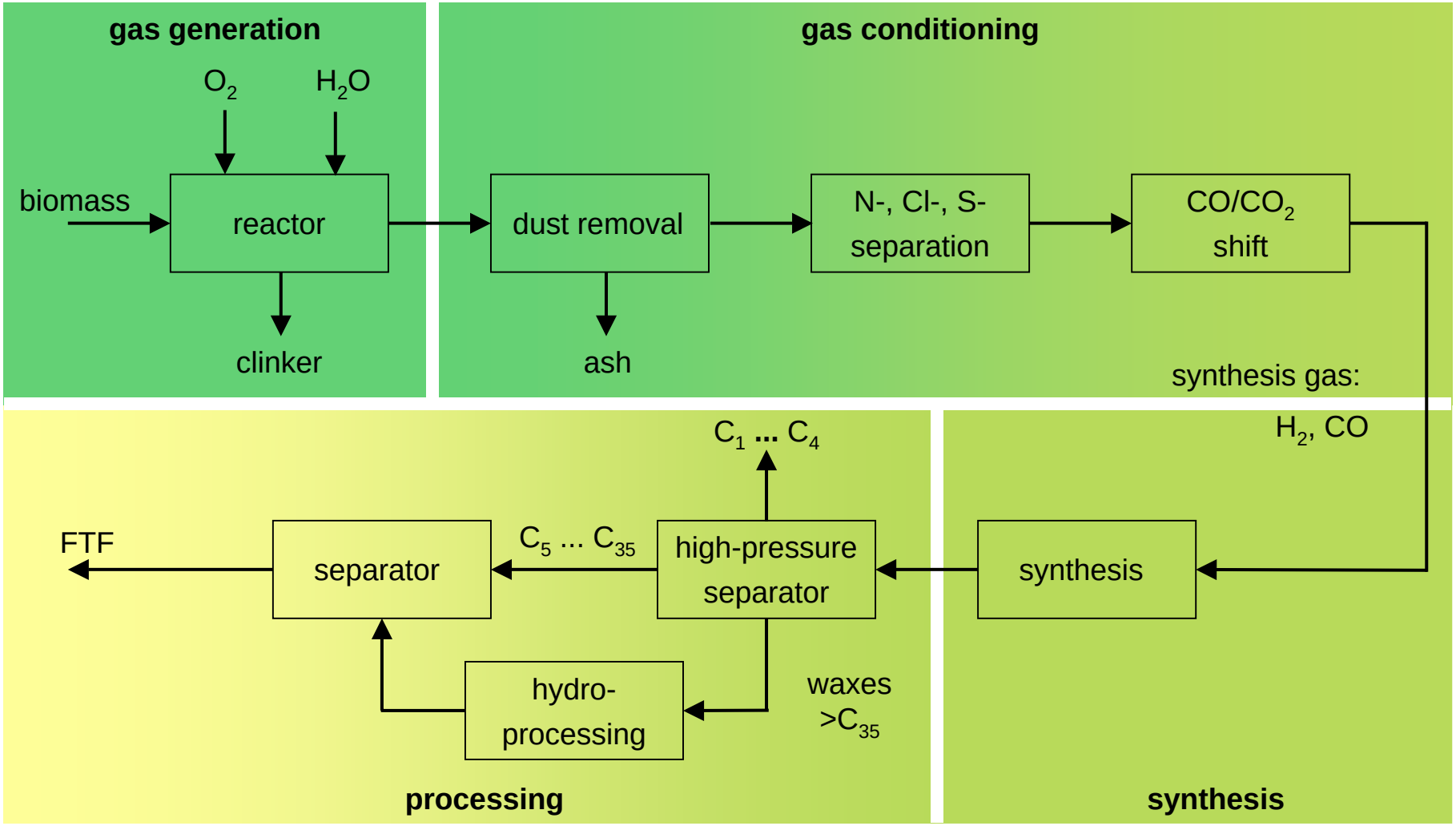
Biomass	Conversion	Energy Carrier	Possible Utilization
(solid) biomass	thermo-chemical	Fischer-Tropsch fuels (Biomass-to-Liquid: BTL)	fuel
		methanol	fuel (maybe via fuel cells)
		dimethyl ether (DME)	fuel
		hydrogen	fuel (maybe via fuel cells)

Schematic Diagram of the Production of Fischer-Tropsch Fuels (FTF)



acc. to CUTEC, 2002

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German Potential and Actual Utilization as Fuel for Different Biogenic Materials

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Raw Material	Calorific Value [PJ/a]		Fuel Yield [PJ/a]		Utilization [PJ/a]	
biomass containing lignocelluloses	wood, straw	752 - 803	FTF	188 - 281	≈0	
	energy plants*	< 333 - 422	FTF	83 - 148		
biomass containing oil, sugar, or starch	winter rape*	< 308	RME FTF	102 26 - 36	RME rape seed oil	44 0.2
	winter wheat*	< 285	bio-ethanol FTF	120 36 - 51		
	sugar beet*	< 195	bio-ethanol	195		
residues	organic residues	222 - 288	bio-gas	110 - 202	≈0	
	energy plants*	< 236	bio-gas	118 - 165		

acc. to Kaltschmitt et al., 2002 and own calculations; latest update: June 2005

*scenario: cultivation on 2 million ha; only one of the alternatives is realizable.

In the best case a fuel substitution potential of 678 PJ/a can be obtained in this scenario (≈ 25 % of the German energy consumption for traffic use).

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Outline

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Introduction

Biofuel research at the FAL

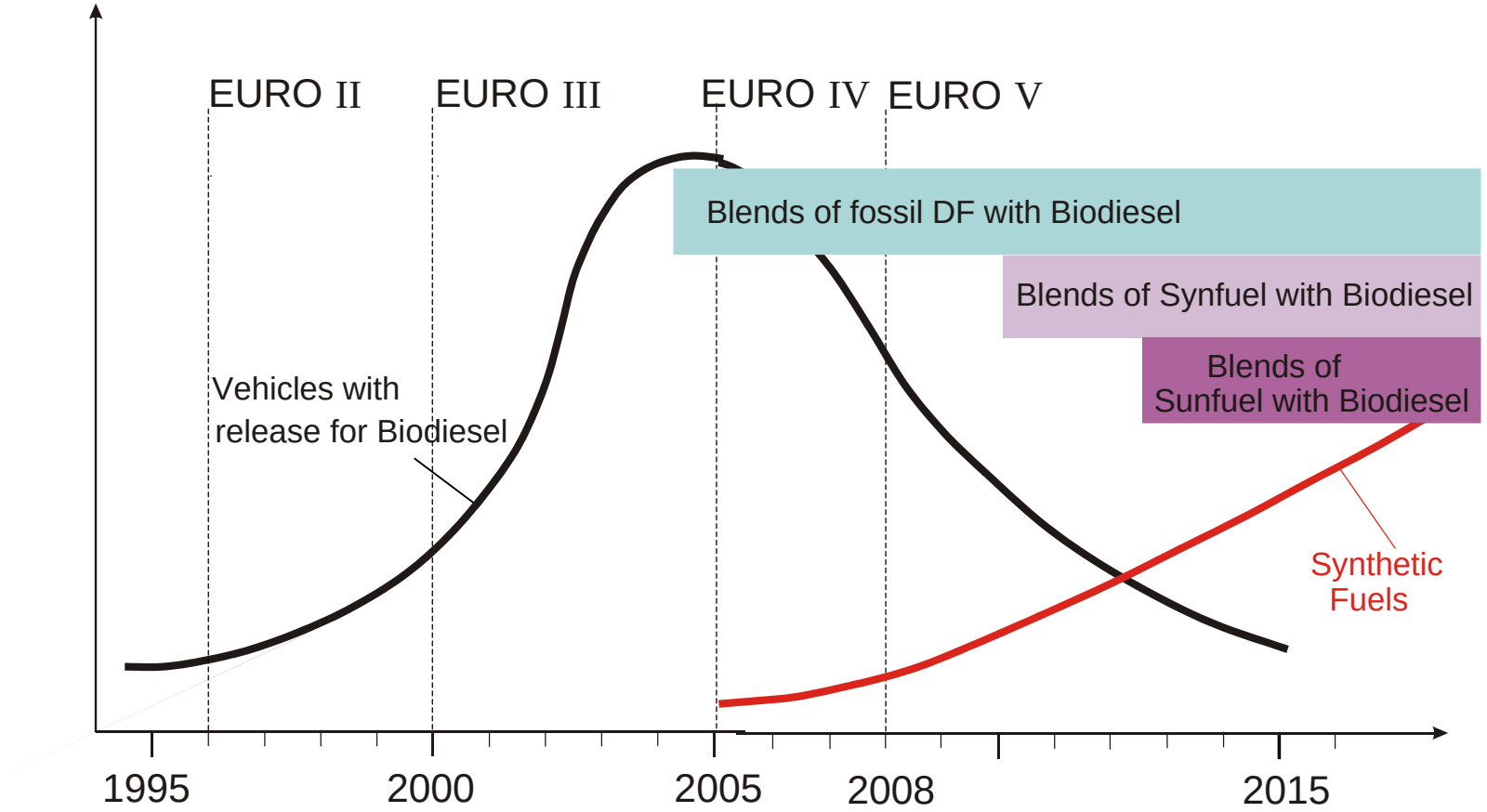
Biofuel potentials

Conclusions and outlook

Conclusions

- In Germany, biodiesel (rapeseed oil methyl ester) is the only biogenic fuel that is used in some considerable quantity today.
- Ethanol and ETBE can be used as additives.
- Engine manufacturers demand for a fuel optimization in parallel with the engine optimization (⇨ designer fuels – e.g. via Fischer-Tropsch synthesis).
- Due to the necessary high investments for the synthesis plants, FT fuels will be used in the near future as additives only.
- Internal combustion engines and the corresponding technologies have reached a high stage of development, which must be caught up by fuel cell technology (infrastructure, reliability, operation security, costs, …) Hydrogen technology will take quite some time until its broad application in the traffic sector.

Possible Evolution for Biodiesel Fuel



Source: UFOP

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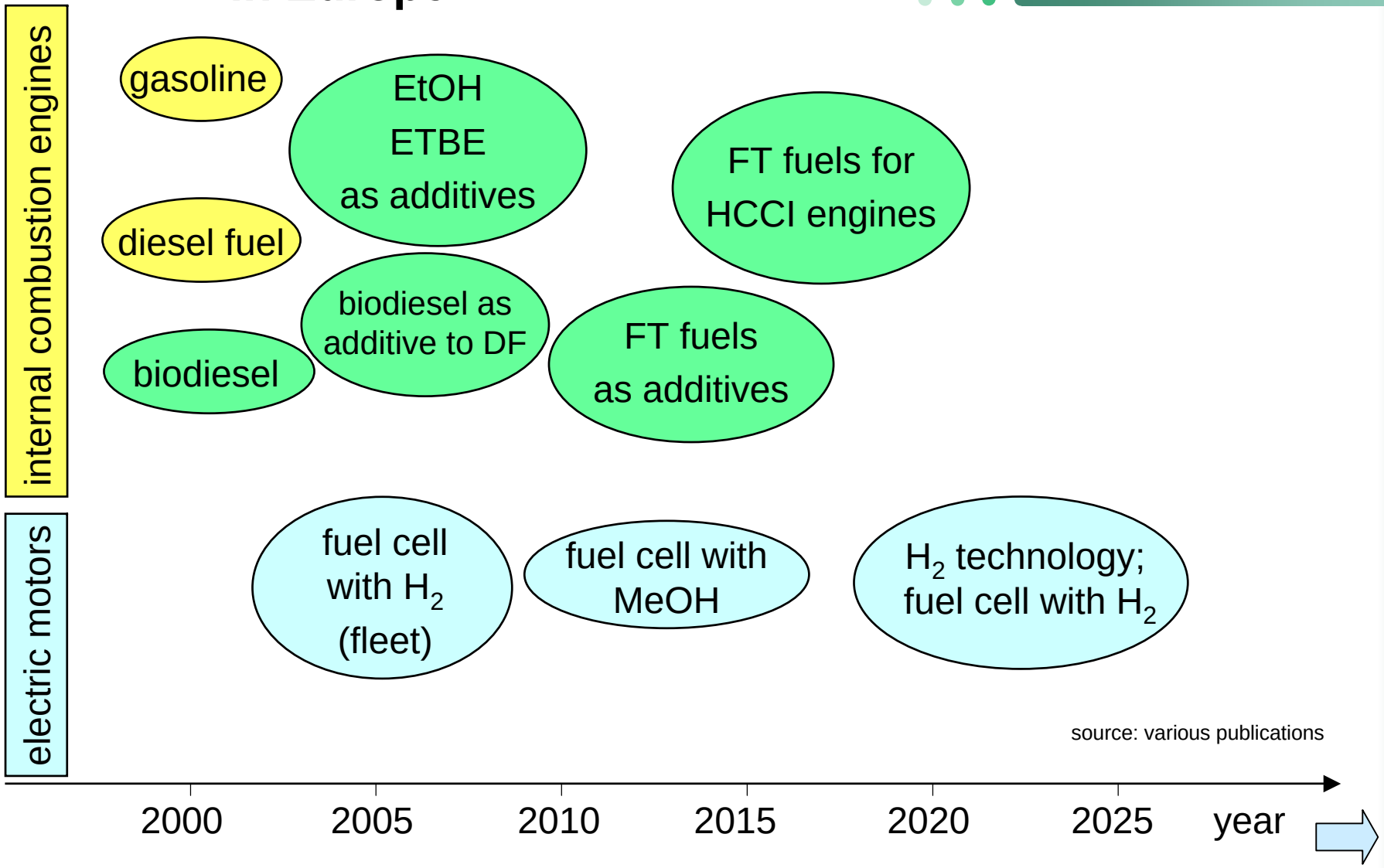
Opportunities for Broad Implementation of New Technologies for Biogenic Fuels in Europe



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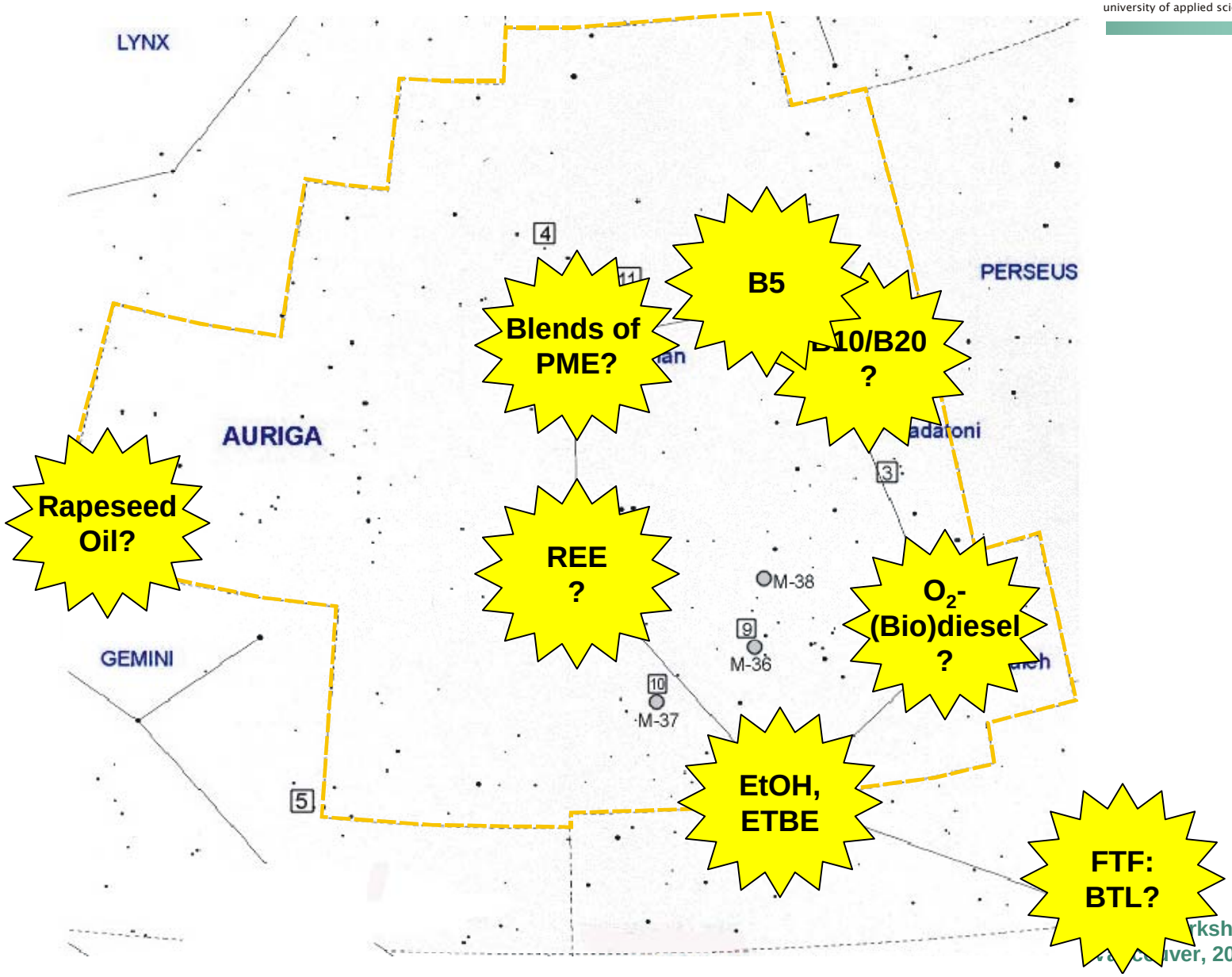
Auriga



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Future Potential Biogenic Fuels

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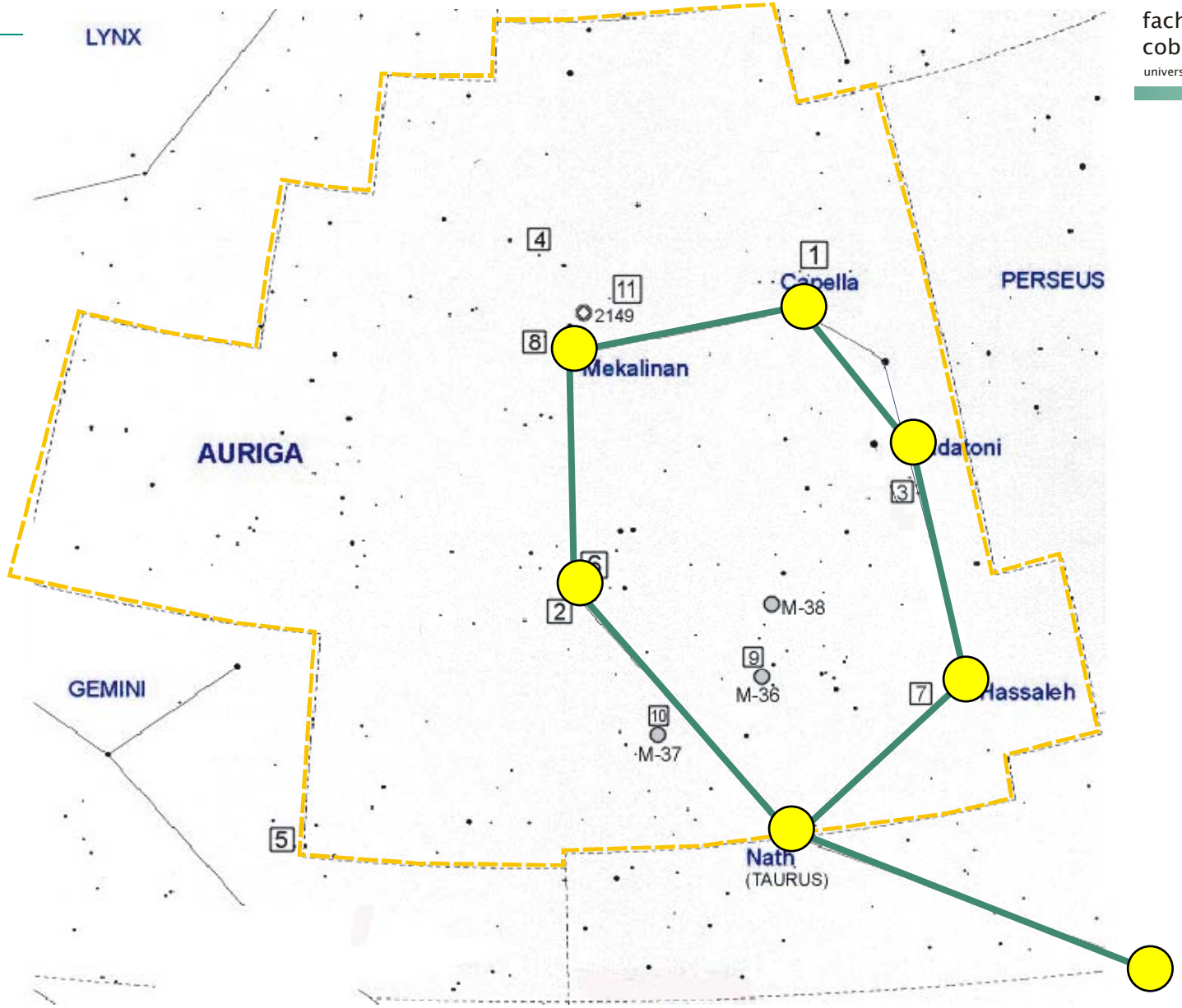
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Thank you for your attention!

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