Fuels for Future Heavy Duty Vehicles

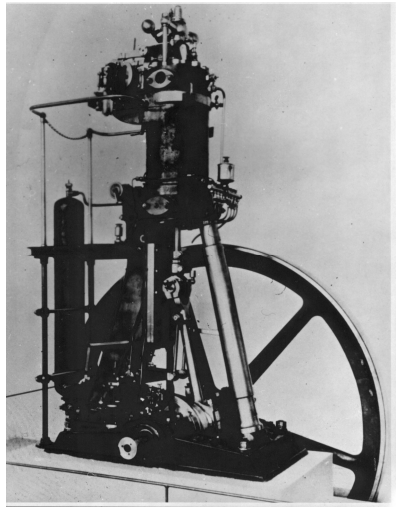
Contents

- Future Fuels
- Biodiesel
- Rape Seed Oil
- Gas Engines
- Summary

Contents

Overview of engines

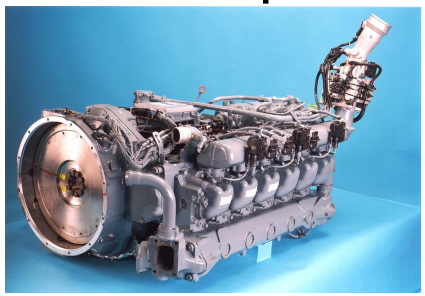
1897 / Diesel



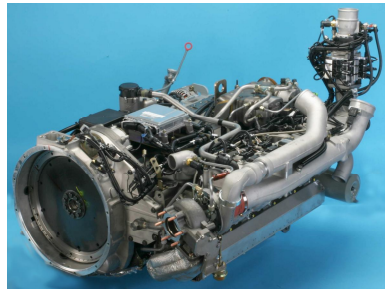
2003 / Diesel
D20 Common Rail

?

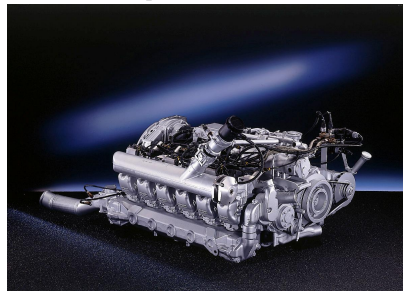
?



LPG



CNG



H_2

Questions

- Which alternative fuels are suitable for commercial-vehicle engines?

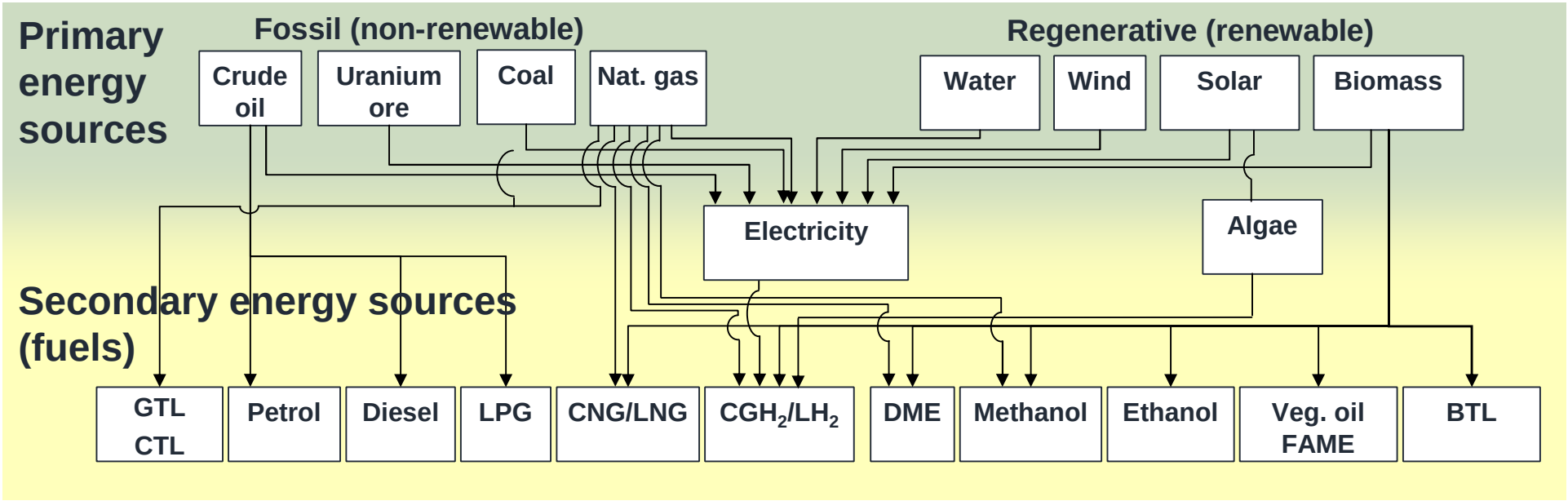
- What is their availability?
  - Fossil: how long will reserves last?
  - Regenerative: what percentage can they achieve?

- In which direction should we influence the development of fuel in order to achieve the highest possible economy?

Important Issues

- Energy density
- Exhaust emissions
- Availability
- CO_2 balance
- Cost trend

Fuel matrix


Primary energy sources
Fossil (non-renewable)
Crude oil
Uranium ore
Coal
Nat. gas
Regenerative (renewable)
Water
Wind
Solar
Biomass
Electricity
Algae
Secondary energy sources (fuels)
GTL CTL
Petrol
Diesel
LPG
CNG/LNG
CGH_2/LH_2
DME
Methanol
Ethanol
Veg. oil FAME
BTL

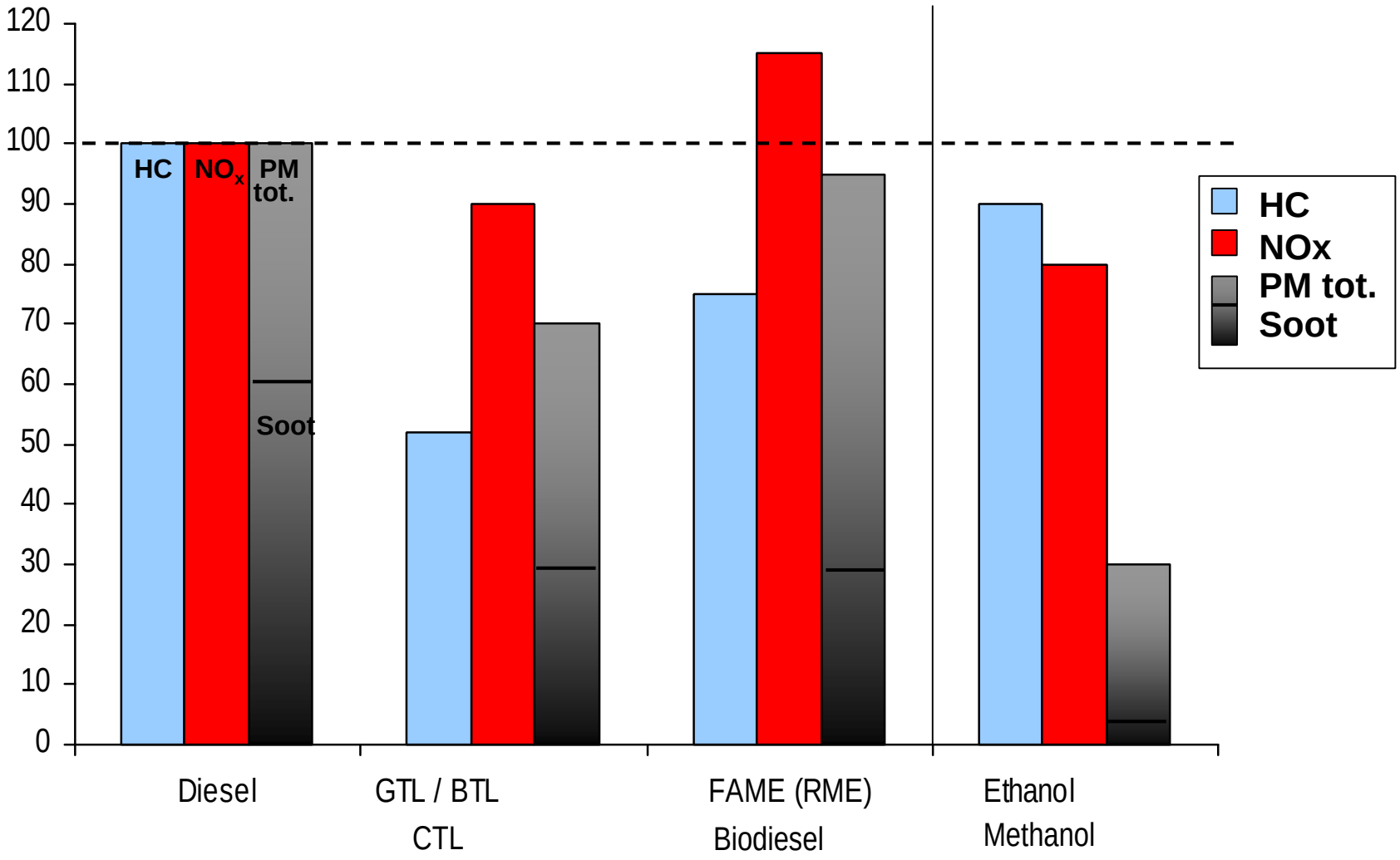
Alternative fuels

- In principle all fuels shown in the fuel matrix can be used in internal combustion engines

- Criteria for use in commercial-vehicle engines:

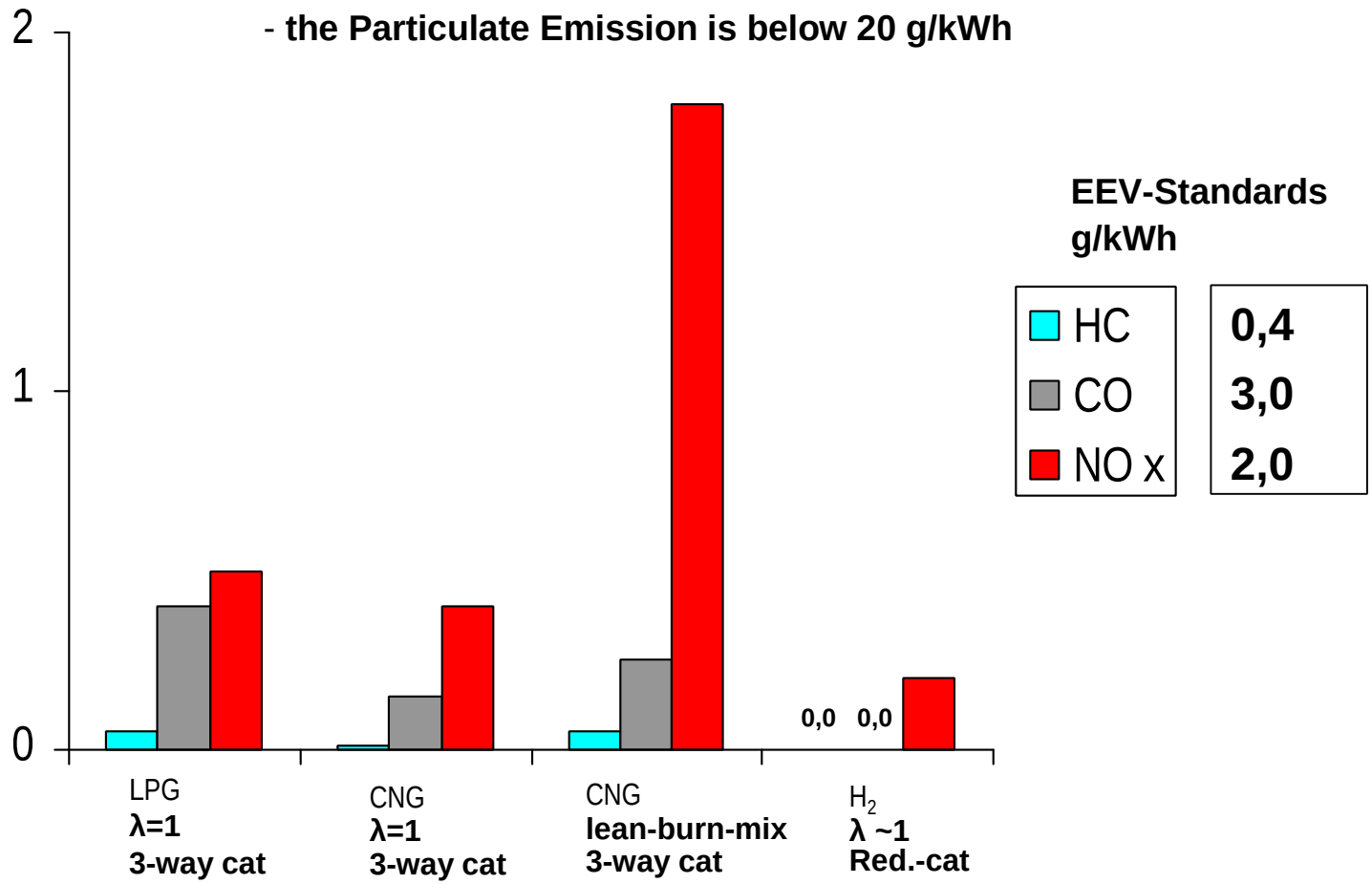
  - Energy density
  - Exhaust-gas emissions
  - Fuel cost

Exhaust-gas emissions / liquid fuels



Emissions with Gaseous Fuels (MAN – Engines)

- **all MAN – Gas Engines meet the EEV – Emission Standard**
- **the Particulate Emission is below 20 g/kWh**



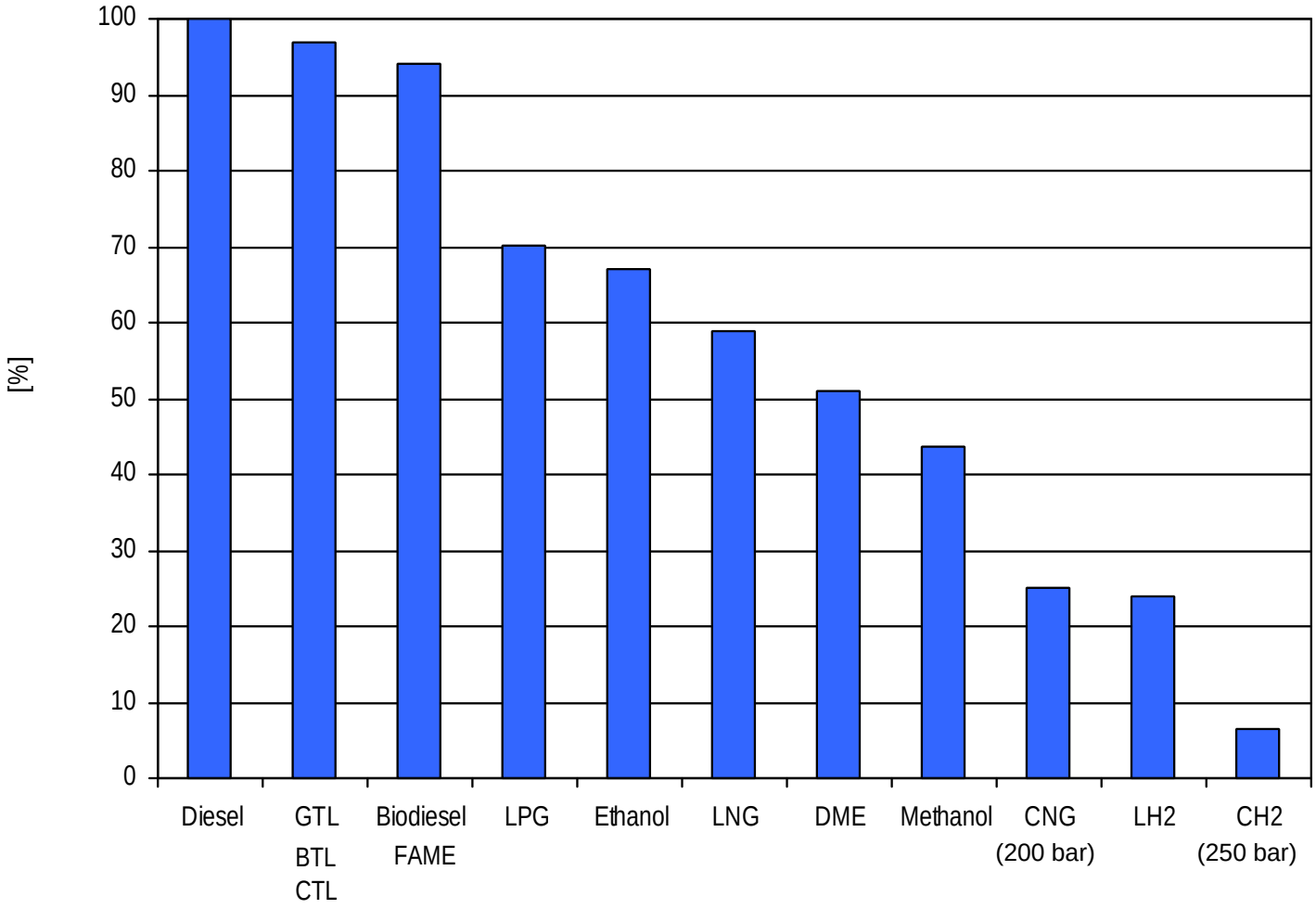
Exhaust-gas emissions of alternative fuels (summary)

→ Alternative fuels show larger or smaller advantages with regard to exhaust-gas emissions

(exception: NO_x emission with biodiesel/rape oil)

Energy density of various fuels

* *** Diesel 100 % = 9.86 kWh/l**



GTL = Gas to liquid

BTL = Bio to liquid

CTL = Coal to liquid

LPG = Liquid Petroleum Gas

LNG = Liquid Natural Gas

DME = DiMethyl Ether

CNG = Compressed Natural Gas

LH_2 = Liquid Hydrogen

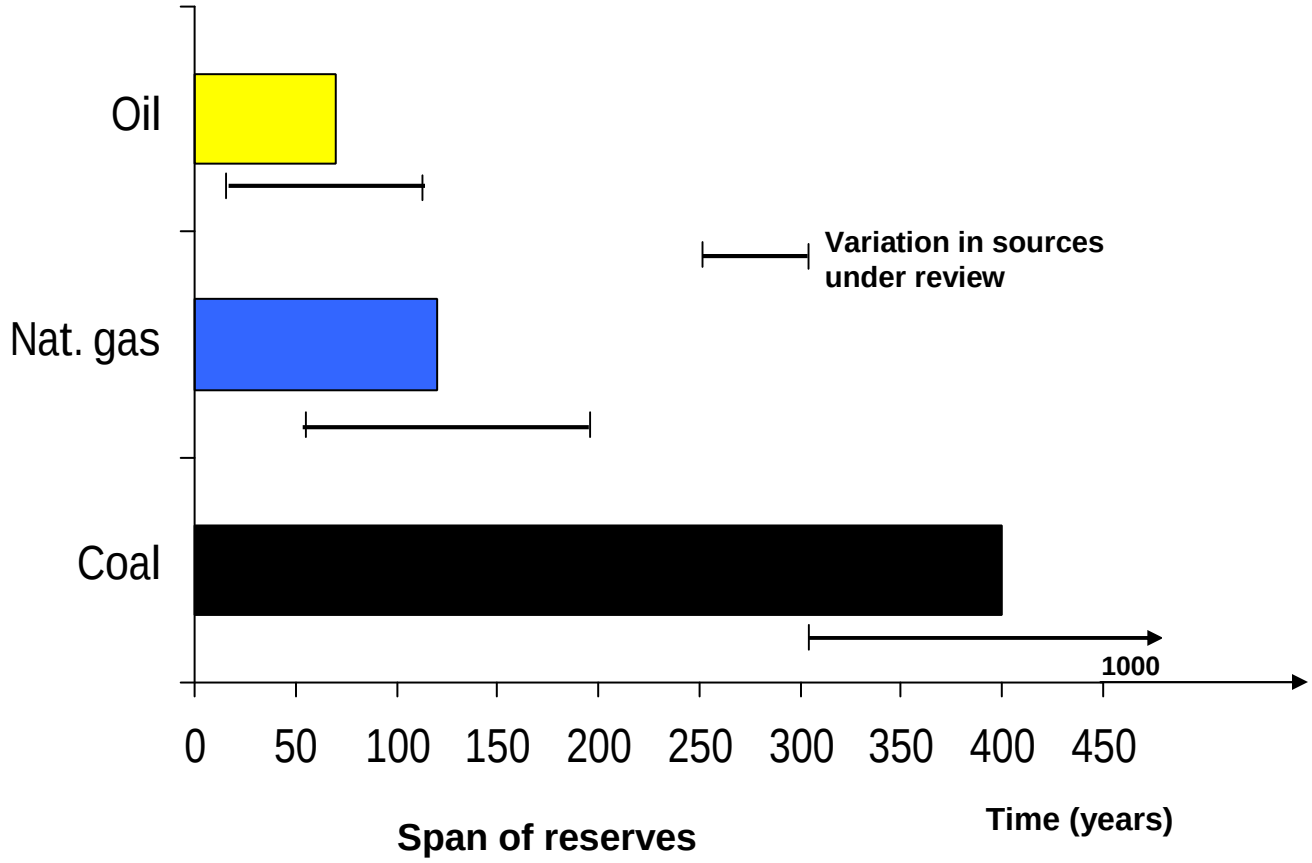
CH_2 = Compressed Hydrogen

Availability

- Fuels from fossil energy sources
- Fuels from regenerative energy sources

The earlier regenerative energies are used in the highest possible quantities, the longer reserves of fossil energy sources will last.

Reserves of fossil energy sources



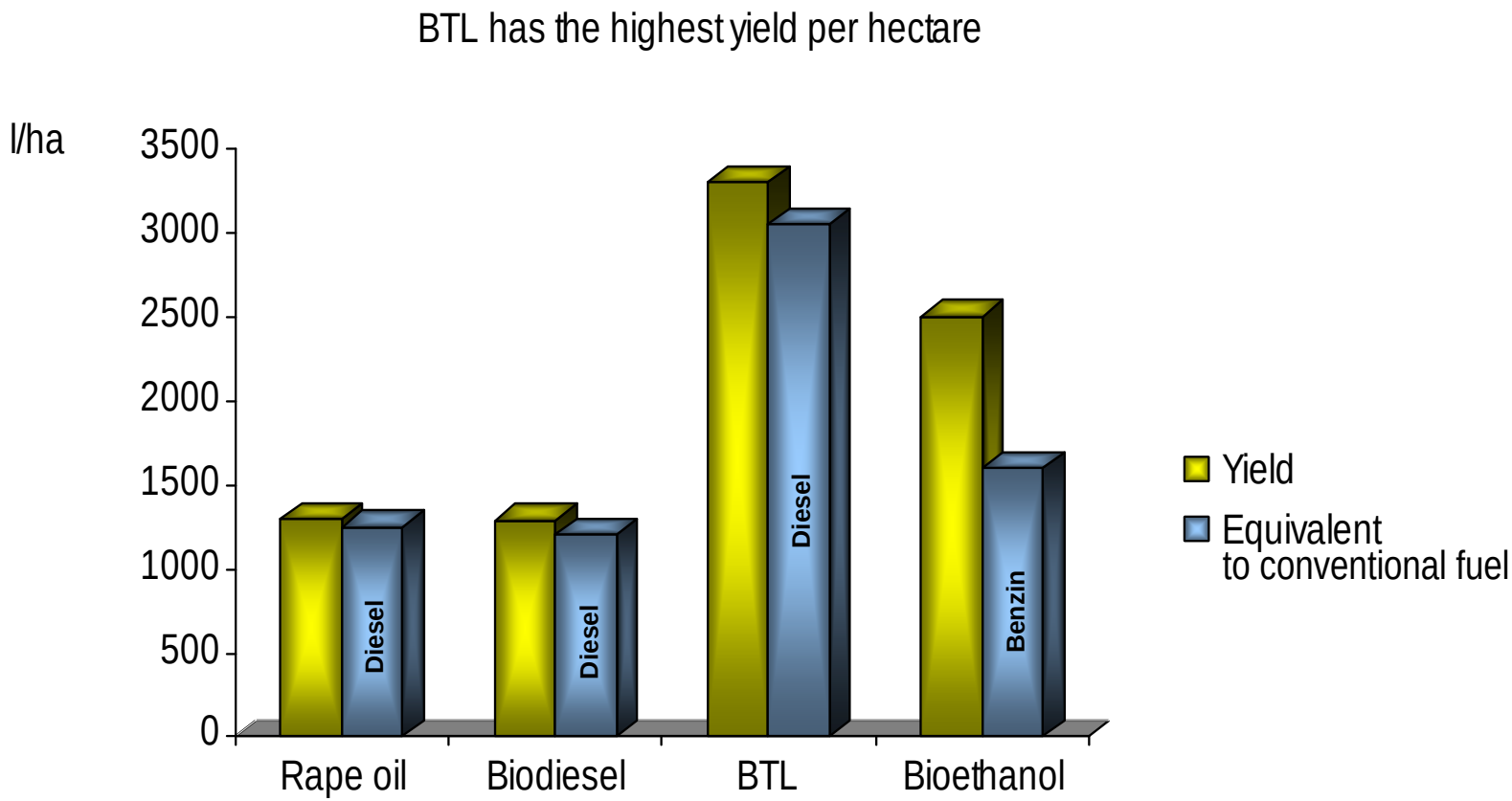
Averages of various sources

Quantity Potential of regenerative energy sources

- Fuel from biomass: Yield depends on fuel type
- Hydrogen: Unlimited availability

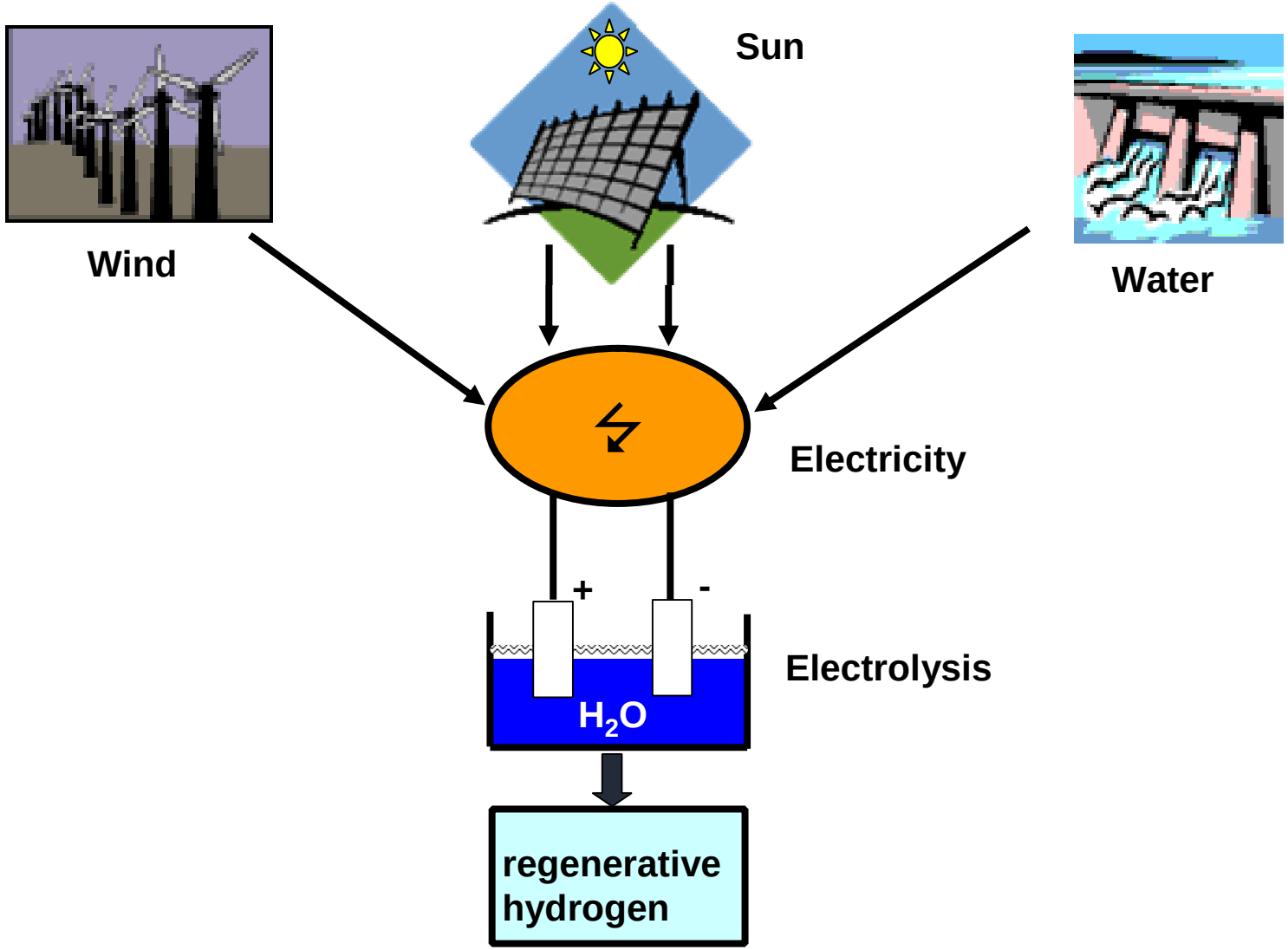
Quantity Potential of regenerative biomass fuels

Comparison of yield of various bio fuels

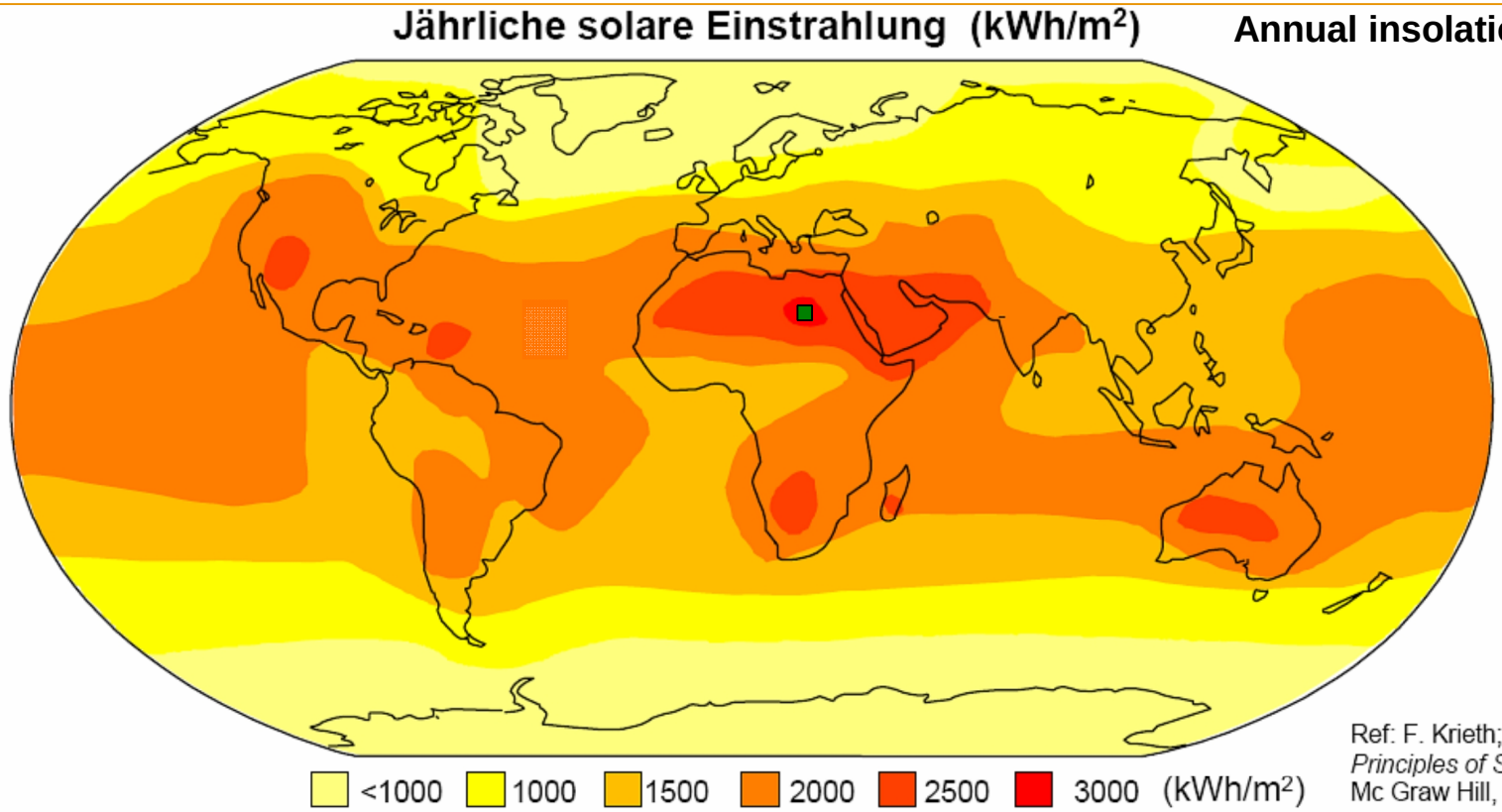


Quelle: BMVEL Okt. 2004

Preferred regenerative production of hydrogen



Solar potential



Ref: F. Krieth; J. Krieger,
Principles of Solar Engineering
Mc Graw Hill, 1978.

Jährlicher Weltenergiebedarf ~ $1{,}2 \cdot 10^{14}$ kWh
Annual world energy requirement

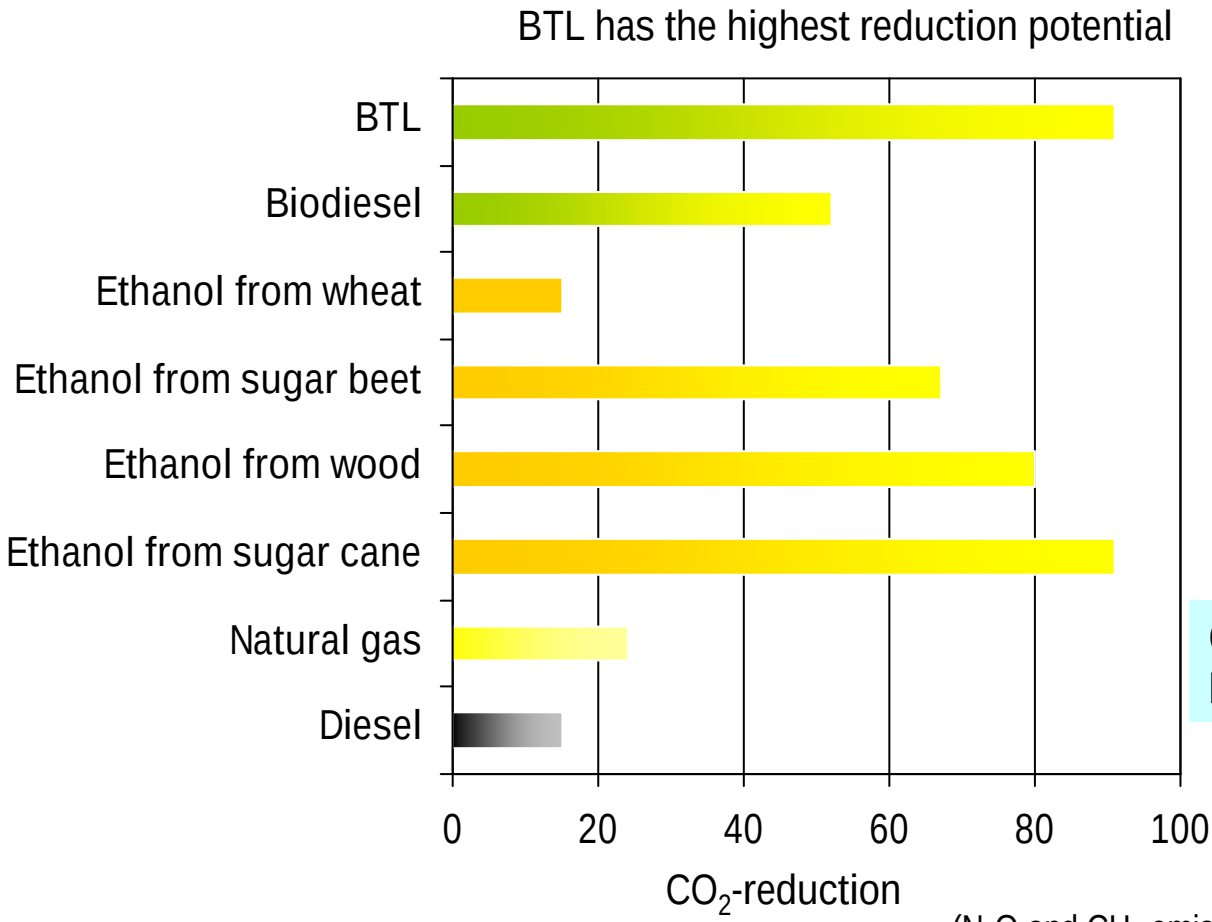
Vorhandene Solarenergie ~ 2350 kWh/m²
Available solar energy

Wirkungsgrad eines solaren Prozesses ~ 20%
Efficiency of a solar process

Area required
~ 500 km x 500 km

CO_2 reduction potential

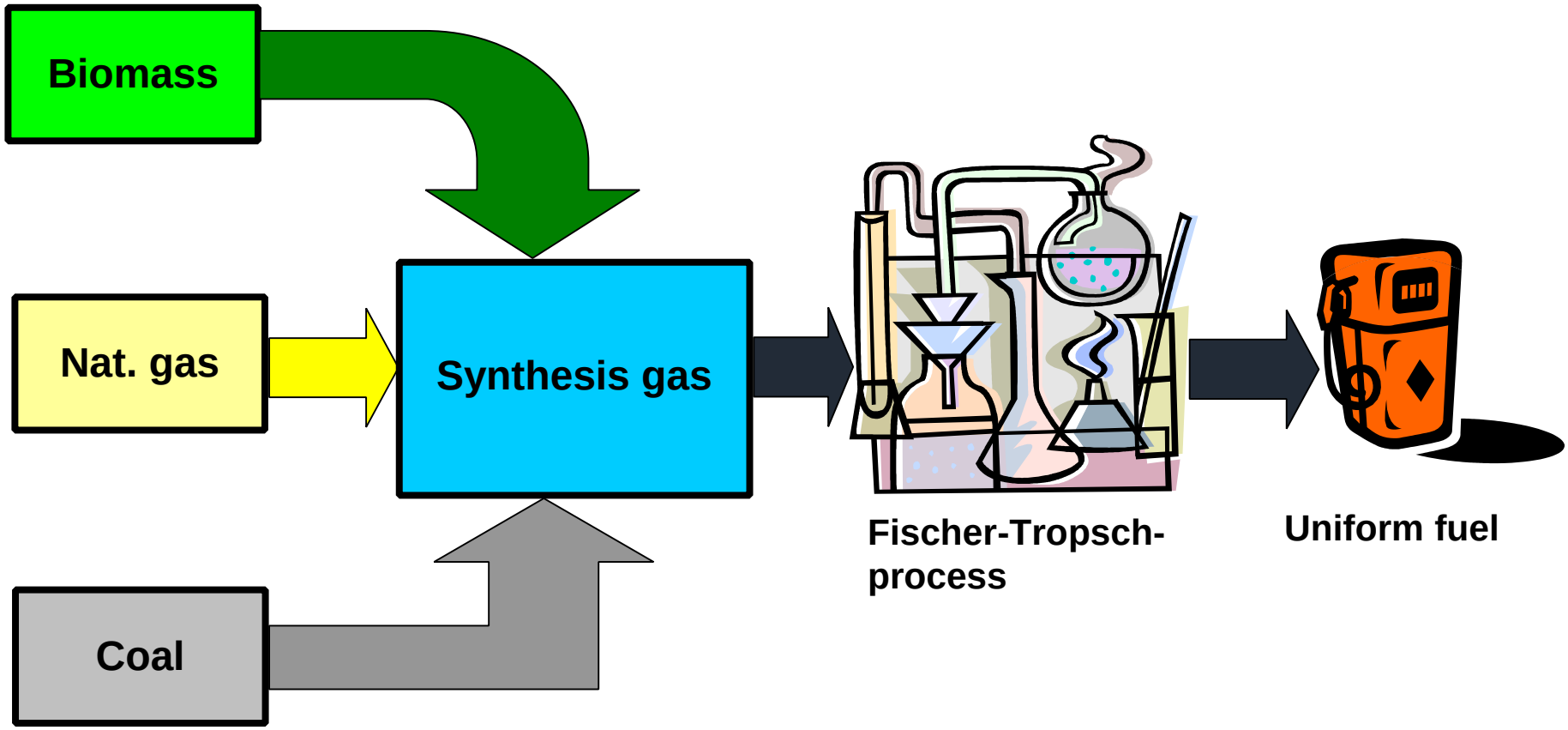
Greenhouse gas reduction potential



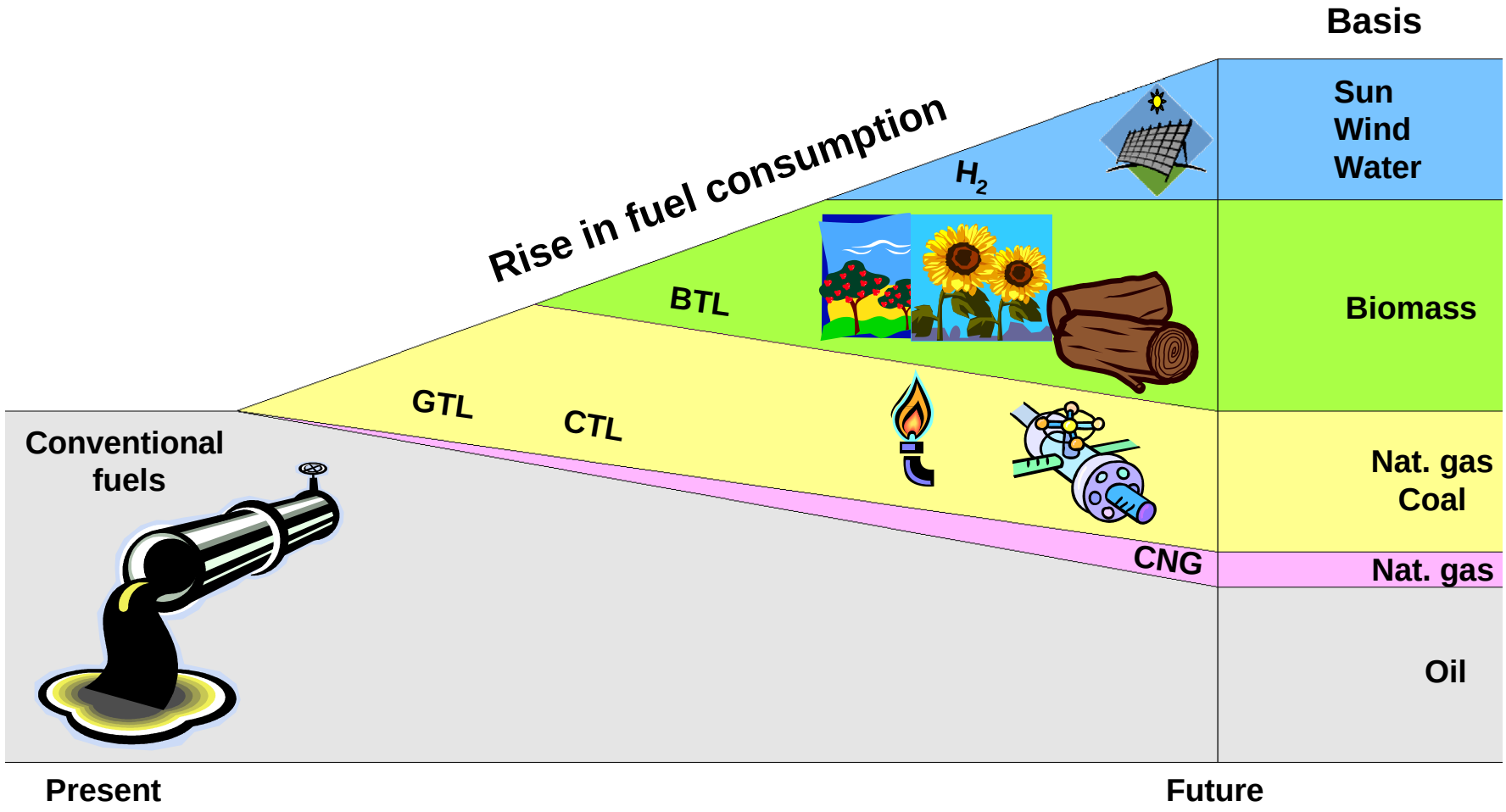
CO_2-free production and use of hydrogen is possible!

(N_2O and CH_4 emissions considered as CO_2 equivalent)

Base substances for uniform fuel



Fuel strategy



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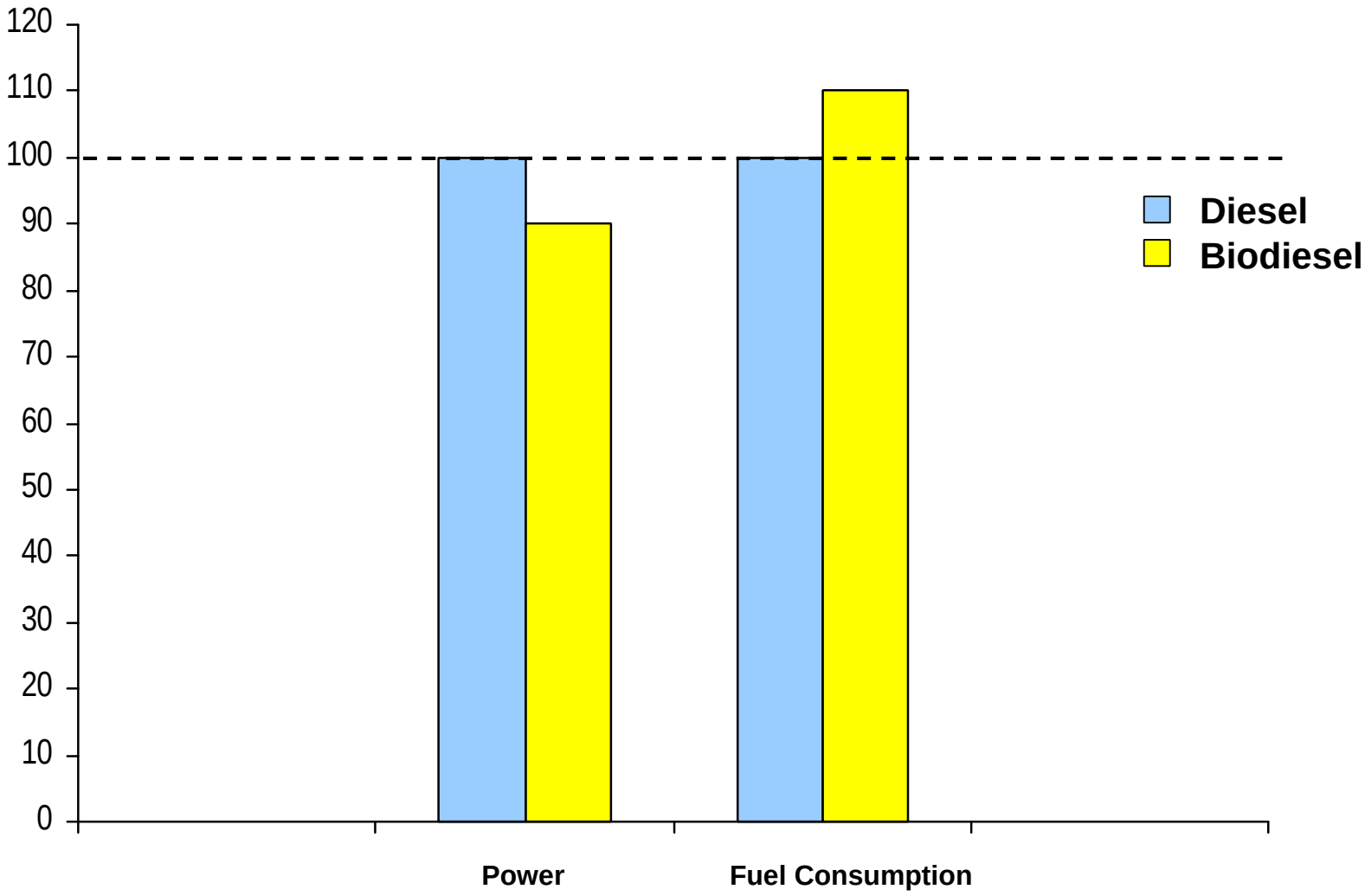
Comparison of Specifications

Specifications	Unit	Fossile Diesel Fuel EN 590		Biodiesel (FAME) EN 14214	
		min.	max.	min.	max.
Density @ 15°C	g/ml	0,82	0,86	0,875	0,900
Kinematical Viscosity @ 40° C	mm^2/s	2,00	4,50	3,5	5,0
Flame Point (Pensky Martens)	°C	55		110	
Boiling Point	°C	160		200	
Sulphur Contents	mg/kg		10,00		10
Heating Value	MJ/kg	ca. 42		36,4	
	MJ/l	ca. 35,3		32,4	
Cetan Number		49		49	
Water Contents	mg/kg		200		300
Neutralization Number	mg KOH/g				0,5
Total Glycerin	%				0,250
Free Glycerin	%				0,020
Phosphorus	mg/kg				10
Methanol	%				0,300

Biodiesel Characteristics

- higher viscosity → increased strain on injection system
- higher boiling point → oil dilution / reduced oil-change intervals
- increased water contents → microorganisms (algea) in fuel system
- lower heating value → reduced power / increased fuel consumption
- Phosphor contents → reduced durability of aftertreatment systems
- not frost-resistant below -20°C

Biodiesel
Power and Fuel Consumption



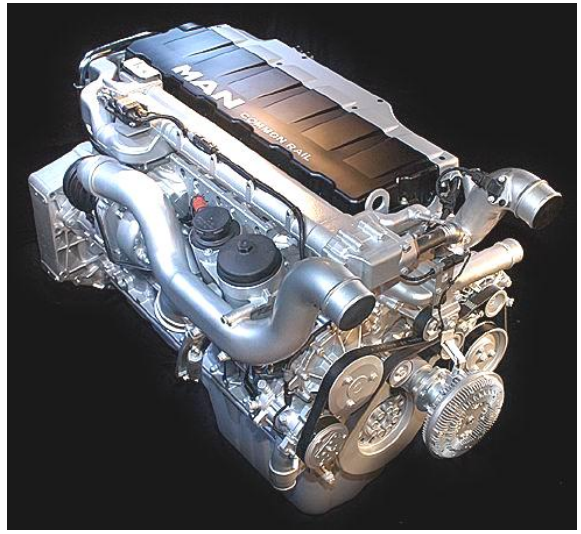
Biodiesel
Engine Releases

- MAN started to customize engines for use of FAME in 1995
- all D 08 and D 28 engines with rotary or in-line injection pumps are released since 1998
- D 20 and D 28 engines with Common Rail Systems are released in connection with the purchase of an extended OEM warranty package

Biodiesel
Extended Warranty for Common Rail Engines

- duration is 48 month or 600.000 km, which ever occurs first
- this warranty package has to be ordered with the vehicle
- Oil-change intervals have to be shortened (engine-oil and oil-filter)
- the change of the fuel-filter is not subject of this extended warranty
- the fee for this extended warranty is 930,- €

Biodiesel
Service Requirements / 1



- oil-change intervals:

  driving distance up to 45.000 km/year:
  every 20.000 km or 400 hours

  driving distance over 45.000 km/year:
  every 30.000 km or 600 hours

- the oil, the oil-filter and fuel-filter must be changed by MAN or by a service outlet authorized by MAN
- the changes have to be documented in the service booklet

Biodiesel
Service Requirements / 2

- only fuel to the European standard EN 14214 is to be used

- if the vehicle was out of operation for more than four weeks, the fuel system has to be flushed with at least two fill-ups of normal diesel fuel

- for stationary heaters, the service recommendations of the suppliers have to be regarded

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Specification of Rape Seed Oil

		Fossile Diesel Fuel		Biodiesel (FAME)		Rape Seed Oil	
Specifications	Unit	EN 590		EN 14214			
		min.	max.	min.	max.	min.	max.
Density @ 15°C	g/ml	0,82	0,86	0,860	0,900	0,9	0,930
Kinematical Viscosity @ 40° C	mm^2/s	2,00	4,50	3,5	5,0		36,0
Flame Point (Pensky Martens)	°C	55		120		220	
Boiling Point	°C	160		200		300	
Sulphur Content	mg/kg		10,00		10		10
Heating Value	MJ/kg	ca. 42		36,4		36,0	
	MJ/l	ca. 35,3		32,4		33,1	
Cetan Number		49		51		39	
Water Content	mg/kg		200		500		750
Total Glycerin	%				0,250		
Free Glycerin	%				0,020		
Phosphorus	mg/kg				10		12
Methanol	%				0,300		

- a fuel standard for rape seed oil does not exist
- the quality of rape seed oil has an extremely large tolerance band

Rape Seed Oil / System Requirements

- only 2-Tank systems are to be used
- the engine has to be started with diesel fuel and before shut down the system has to be switched back to diesel fuel to rinse the system
- it has to be ensured that no rape seed oil will enter the diesel fuel tank
- at low loads, the system has to switch automatically to diesel fuel
- during rape seed oil operation, the system has to ensure a fuel temperature of 65 - 70 °C at the injection pump
- additional equipment, like stationary heaters, have to be operated on diesel fuel

technical problems

- carbon build-up at the valves
- carbon build-up at the injection nozzles
- carbon build-up at the pistons and piston ring grooves
- increase wear of the top rings
- the higher viscosity results in an increased strain on the injection system
- the higher boiling range results in an increased oil dilution
- the increased water content enhances the growth of microorganisma (algea)

Abbildung 36: Ein- und Auslassventile nach Prüflauf 50 % ROE/50 % DK

Abbildung 13: Verkokung an Düse 1 nach Prüflauf mit 50 % ROE/50 % DK

Abbildung 45: Kolben nach Prüflauf mit 25 % ROE/75 % DK

Quelle: Universität Hohenheim, Dipl.-Ing. K. Maurer , 09/2003

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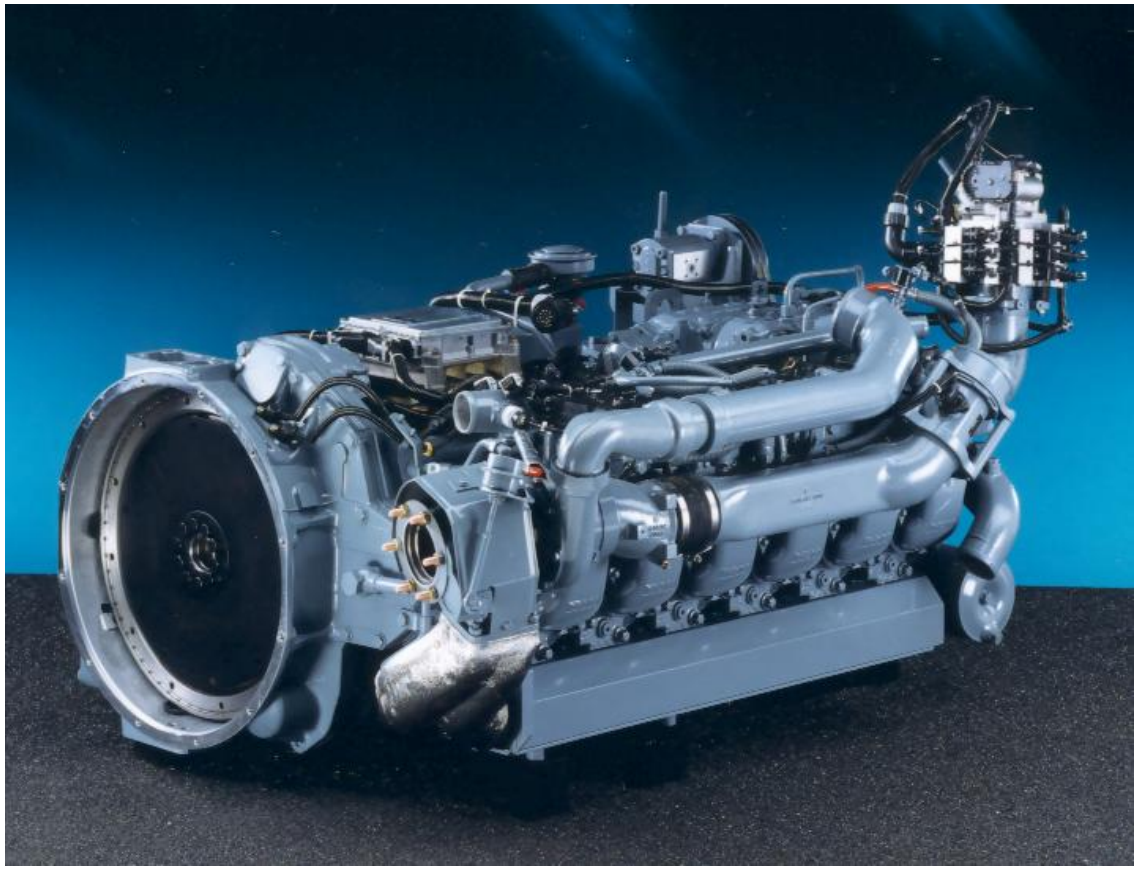
Gas – Engines for Busses

Fuel	Engine type	Engine concept	Mixture	Installation	Power [kW]	Exhaust gas standard
CNG	E 2866 DUH03	naturally aspirated three-way-catalyst	stoichio-metric	horizontal	180	EEV
	E 2876 LUH01/02	turbocharged and aftercooled three-way-catalyst	lean-burn / mix	horizontal	228	EEV *)
LPG	G 2876 DUH01	naturally aspirated three-way-catalyst	stoichio-metric	horizontal	200	EEV
H2	H 2876 UH01	naturally aspirated reduction -catalyst	stoichio-metric	horizontal	150	EEV**)

*) gas group limitation

**) certified in ESC

CNG-Lean Burn Engine E 2866 LUH

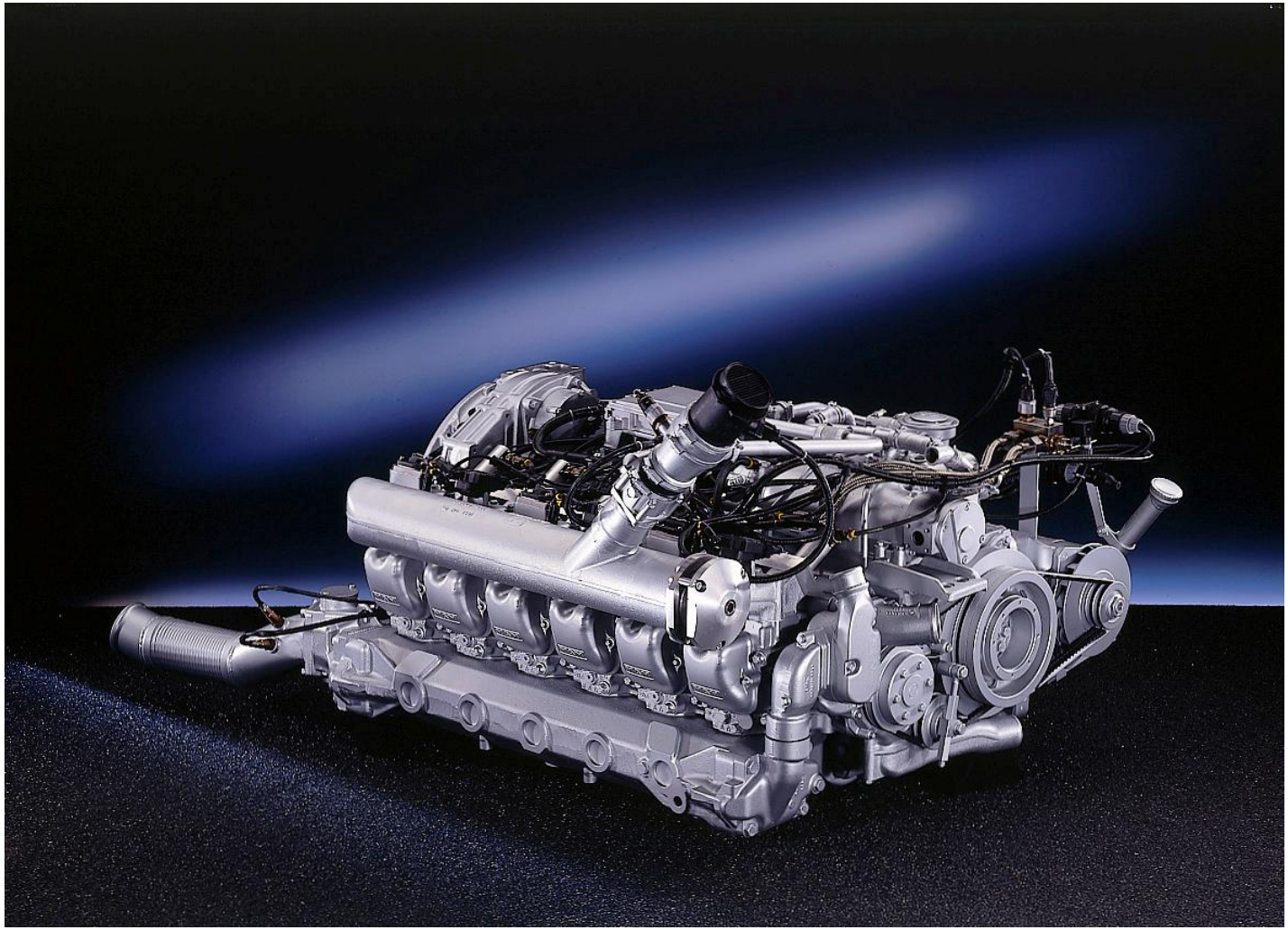


Displacement: 12 l
max. power: 228 kW / 2000 rpm
max. torque: 1250 Nm / 1200 - 1600 rpm

Saarbrücken Transport Authorities 38 Buses

Augsburg Transport Authorities 13 Buses

Hydrogen engine H 2866 UH01



MAN biogas engines- powerful

biogas engines	E 0836 LE 202	E 2876 TE 302	E 2876 LE 302	E 2848 LE 322	E 2842 LE 322
number of cylinders	6	6	6	8	12
bore [mm]	108	128	128	128	128
stroke [mm]	125	166	166	142	142
displacement [l]	6.9	12.8	12.8	14.6	21.9
power output [kW] @ 1500 rpm	110	130	200	265	380
mechanical efficiency [%]	39.0	38.0	39.5	39.5	39.5
power output [kW] @ alternator efficiency of 96 %	106	125	192	254	365
electrical efficiency [%] @ alternator efficiency of 96 %	37.4	36.5	37.9	37.9	37.9
air-fuel ratio	1.4	1.4	1.4	1.4	1.4
emission level	TA-Luft	TA-Luft	TA-Luft	TA-Luft	TA-Luft

MAN biogas engines- high reliability

150 PS
700 Nm

177 PS
830 Nm

272 PS
1270 Nm

520 PS
2430 Nm

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Future Fuels
Summary

- Bio-Fuels should be used to the largest possible amount as soon as possible
- biodiesel saves energy reserves and reduces CO_2-emission
- biodiesel is released for use in MAN vehicles
- a problem with biodiesel can be the large fluctuation of quality
- a synthetic fuel made of biomass, BTL, shows the highest yield per acre
- The CO_2-reduction potential is twice as high as with biodiesel
- Biogas can be produced with high efficiency and is a recommended renewable fuel for stationary engines

Thank you for your attention!