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Climate Change and Energy Pathways for the Mediterranean

SESSION III: TRANSPORTATION IN A GREENHOUSE GAS CONSTRAINED WORLD

Nicosia, June 22, 2005

Efficiency in Oil Use and Alternatives to Oil

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Efficiency in Oil Use and Alternatives to Oil

1. Introduction
2. Energy Demand, Reserves and Kyoto
3. Internal Combustion Engines, Hybrid Powertrains and Fuel Cells
4. Alternative Fuels
5. Fundamentals of Energy Systems
6. Conclusions

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- **Energy and water will quite likely be the prevailing problems regarding sustainable development in the decades to come**
- **Transport is the fastest growing energy user in the industrialized world**

A Couple of Numbers

- 80 % of energy use is depending in fossil fuels
- 25 % of the world population use 75 % of the world energy
- Energy consumption will double in the next 30 years
- The world population draws on average 2‘000 Watt of power:
  - China less than 1‘000
  - Europe 6‘000
  - USA 11‘000

How Much Energy Does One Really Need?

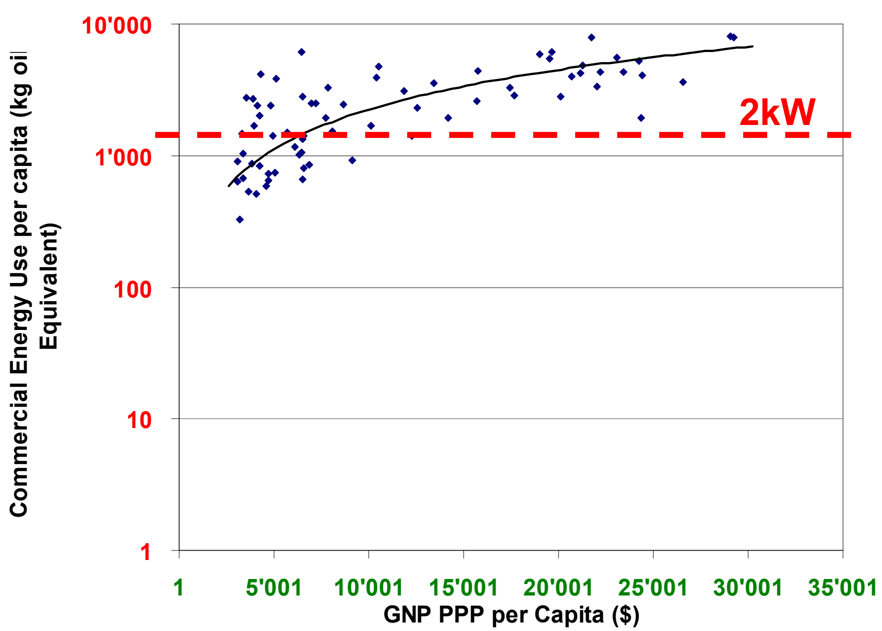
Definition of Human Development Index (HDI)

The HDI is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development:

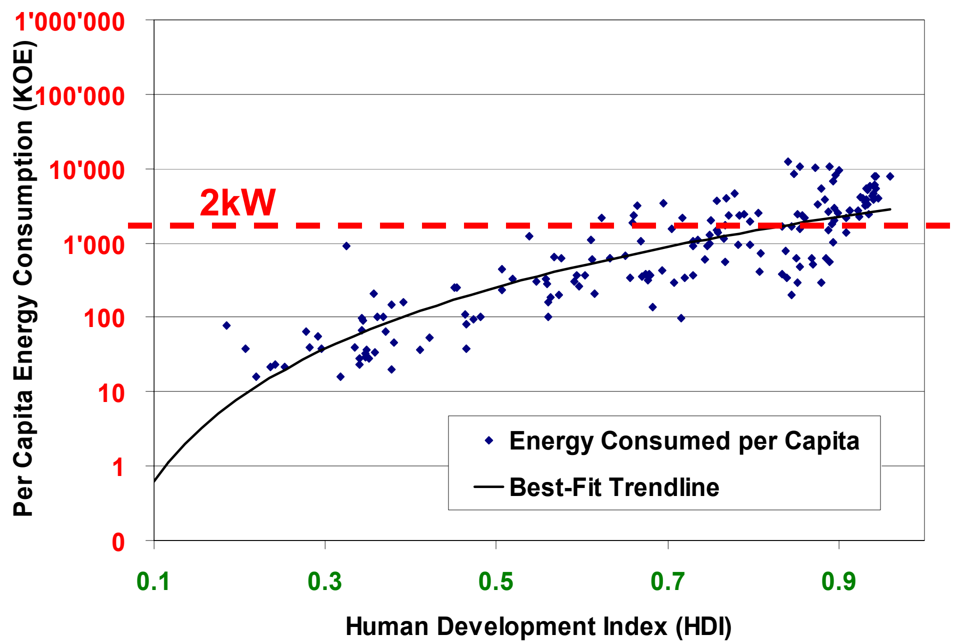
- A long and healthy life, as measured by life expectancy at birth
- Knowledge, as measured by the adult literacy rate and the combined primary, secondary and tertiary gross enrolment ratio
- A decent standard of living, as measured by GDP per capita

The Energy Poverty Linkages

Energy & Economic Growth (GNP)



Energy & Human Development



Source: World Bank

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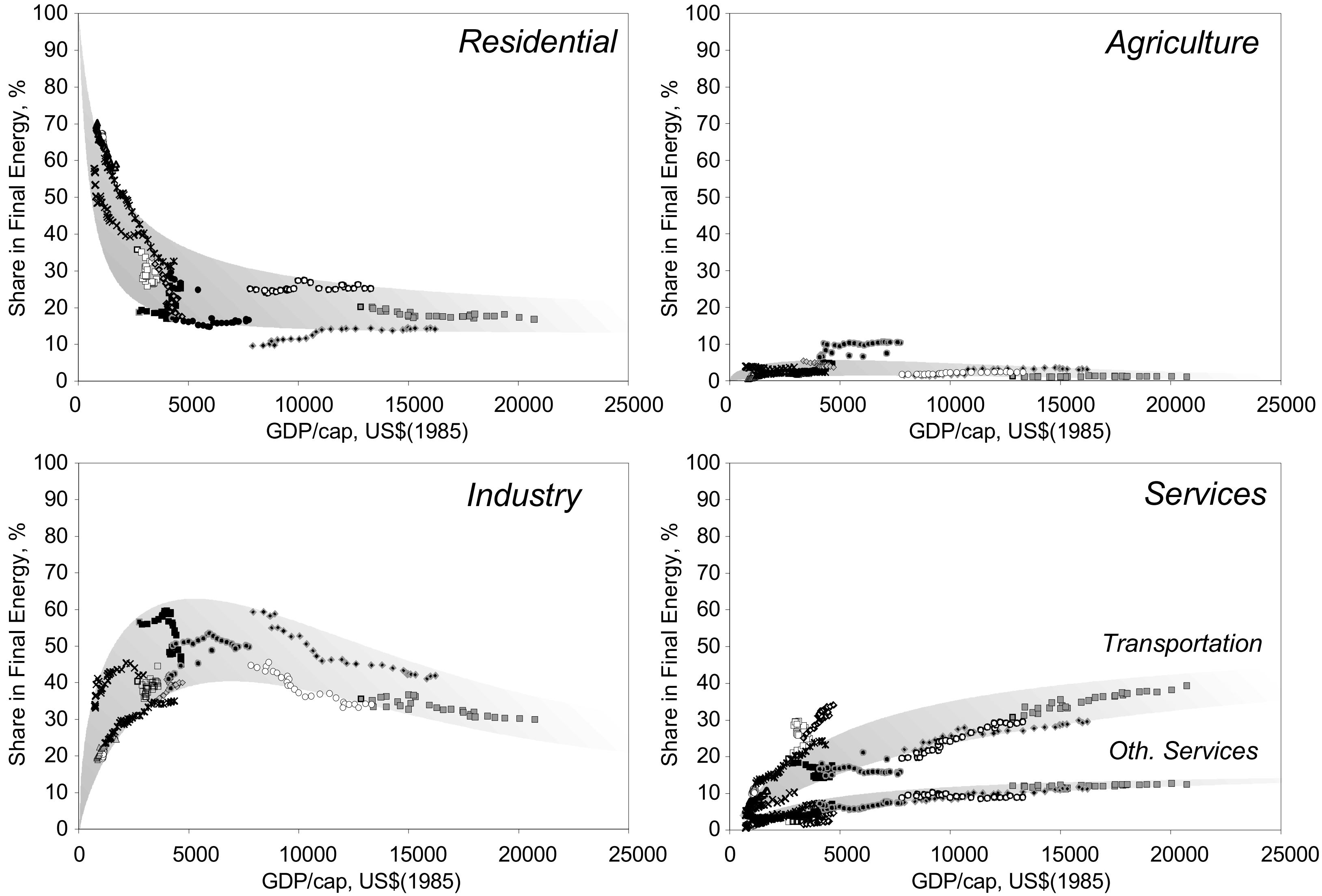
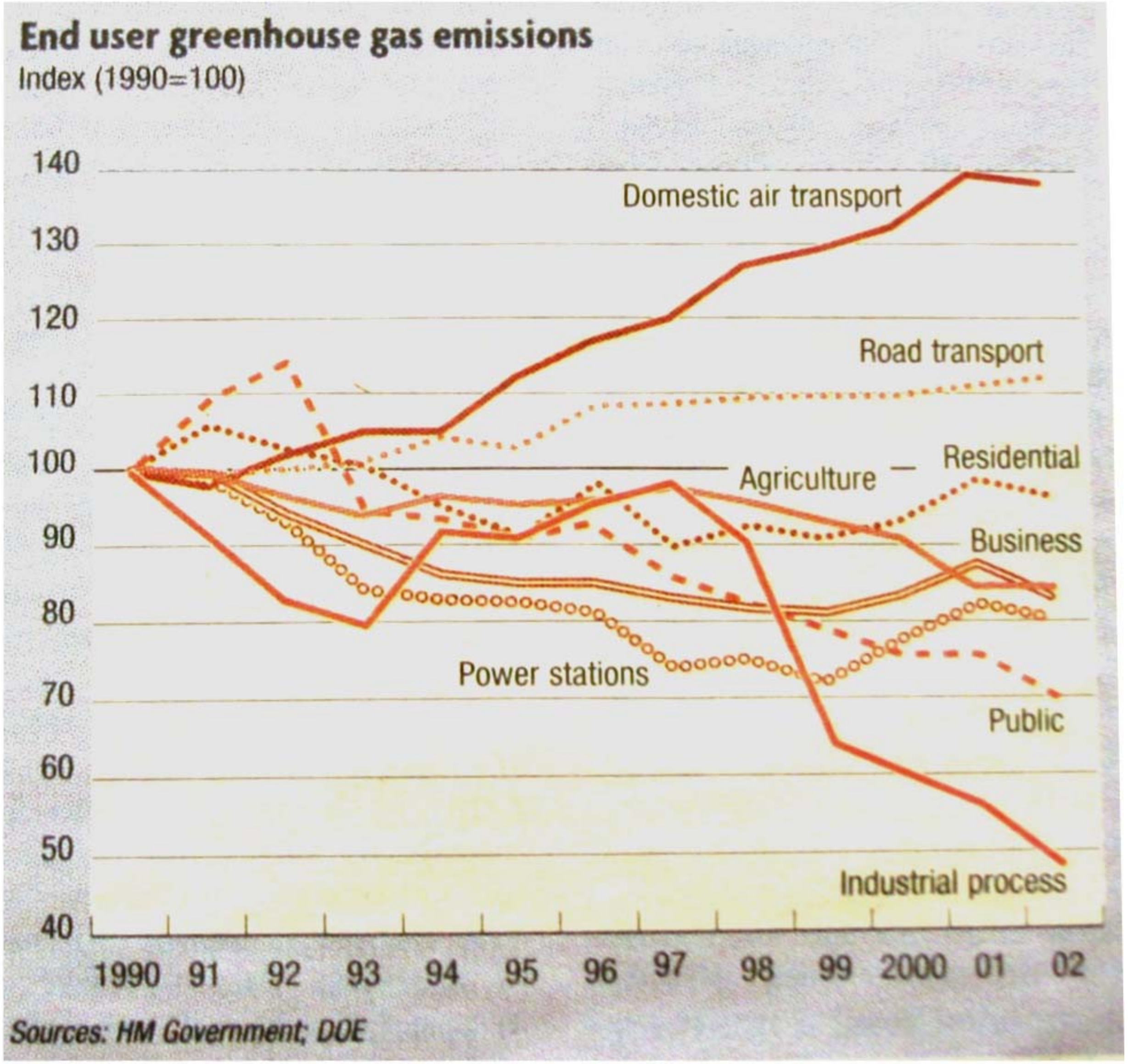
Fundamental Energy System Dynamics



Note: Data series correspond to 11 world regions and range from 1971 through 1998; data source: IEA (2000), additional references describing biomass consumption

End User Greenhouse Gas Emissions



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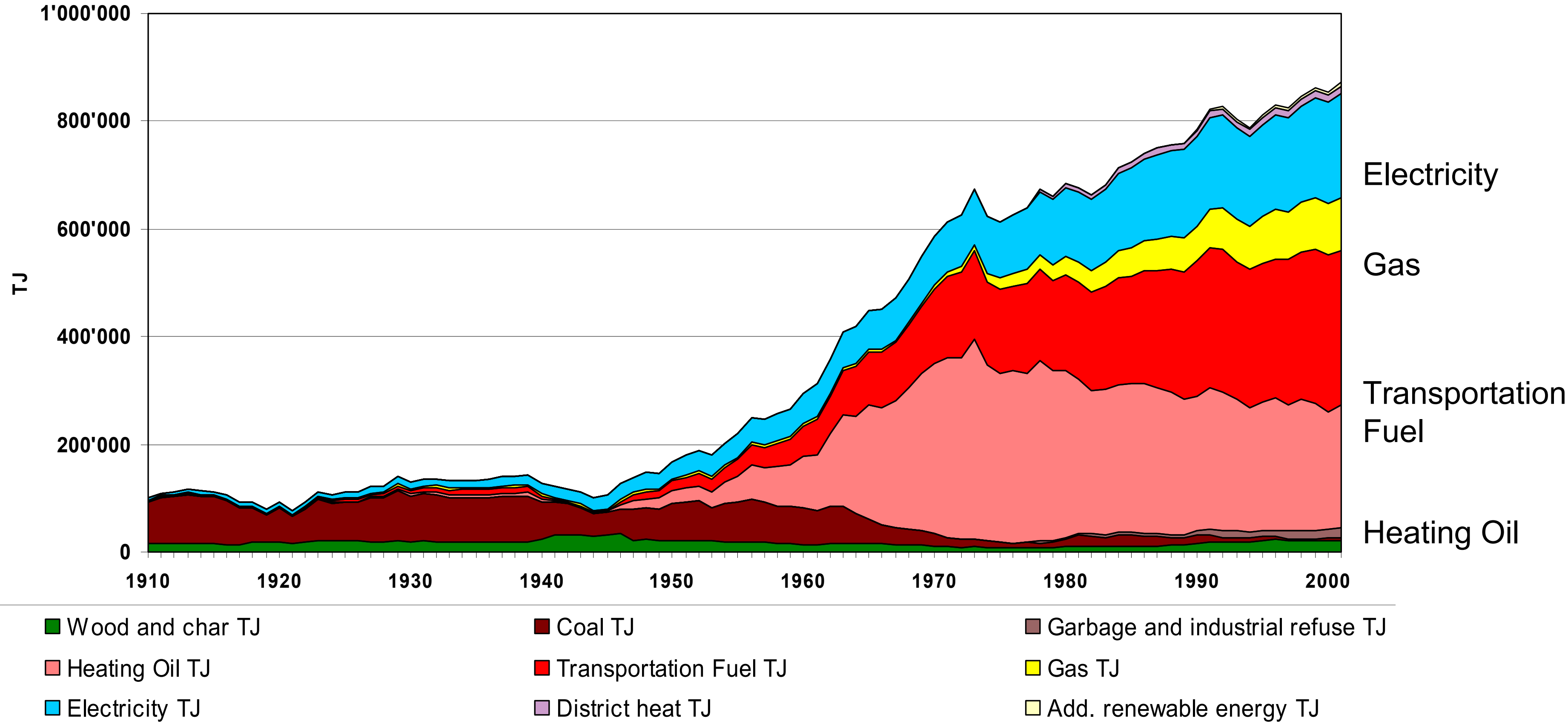
Final Energy Consumption Switzerland, 1910-2001

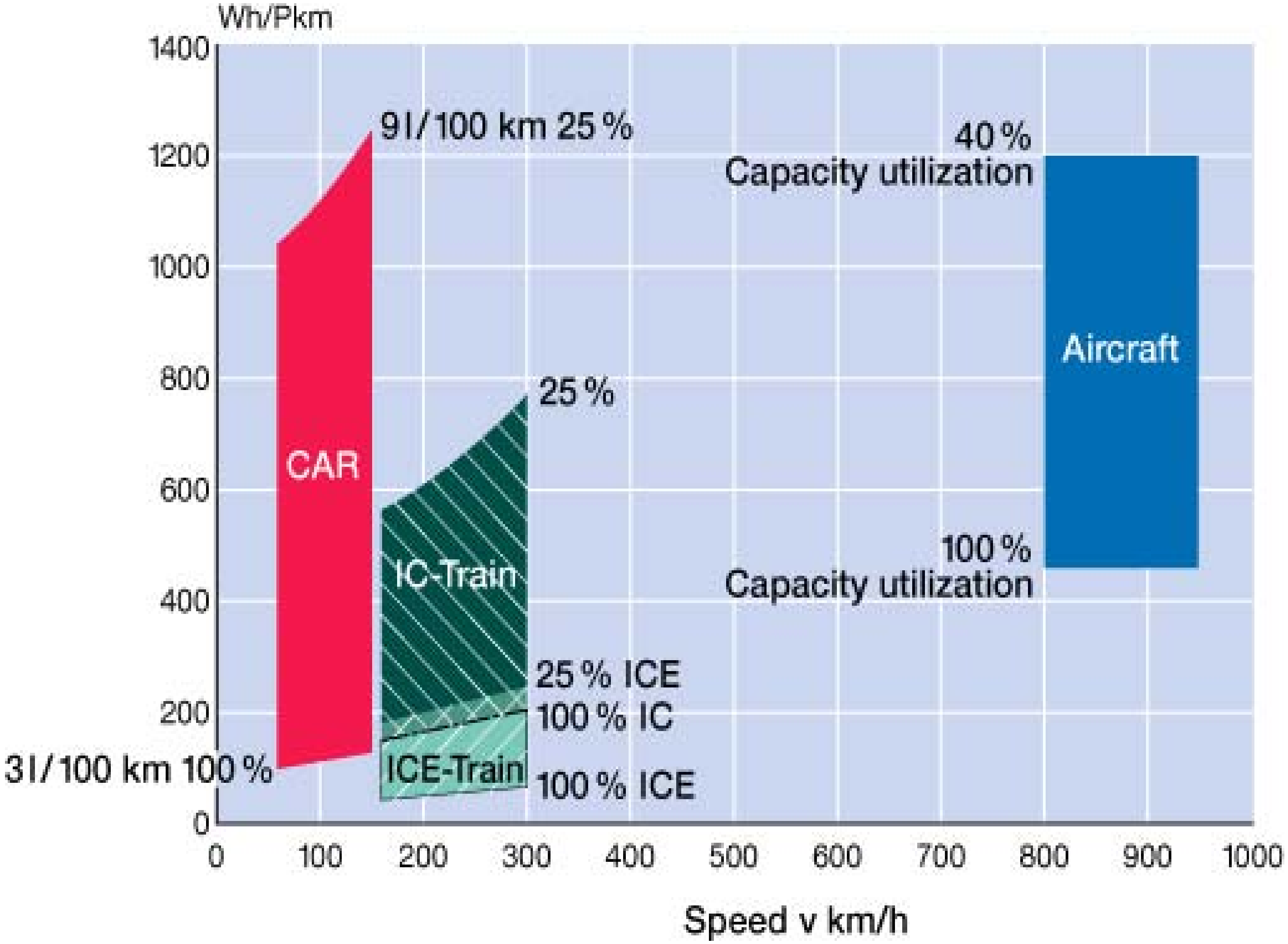


Quelle: BFE

Oil for Heating and/or Transportation

- In a first priority reduce primary energy consumption of both, heating and transportation
- Secondly, replace fossil based heating systems by heat pumps – use fossil fuels for transportation in a first priority. This means: more electricity is required – nuclear becoming again a valid option.

End-Energy Consumption, Transport of Passengers



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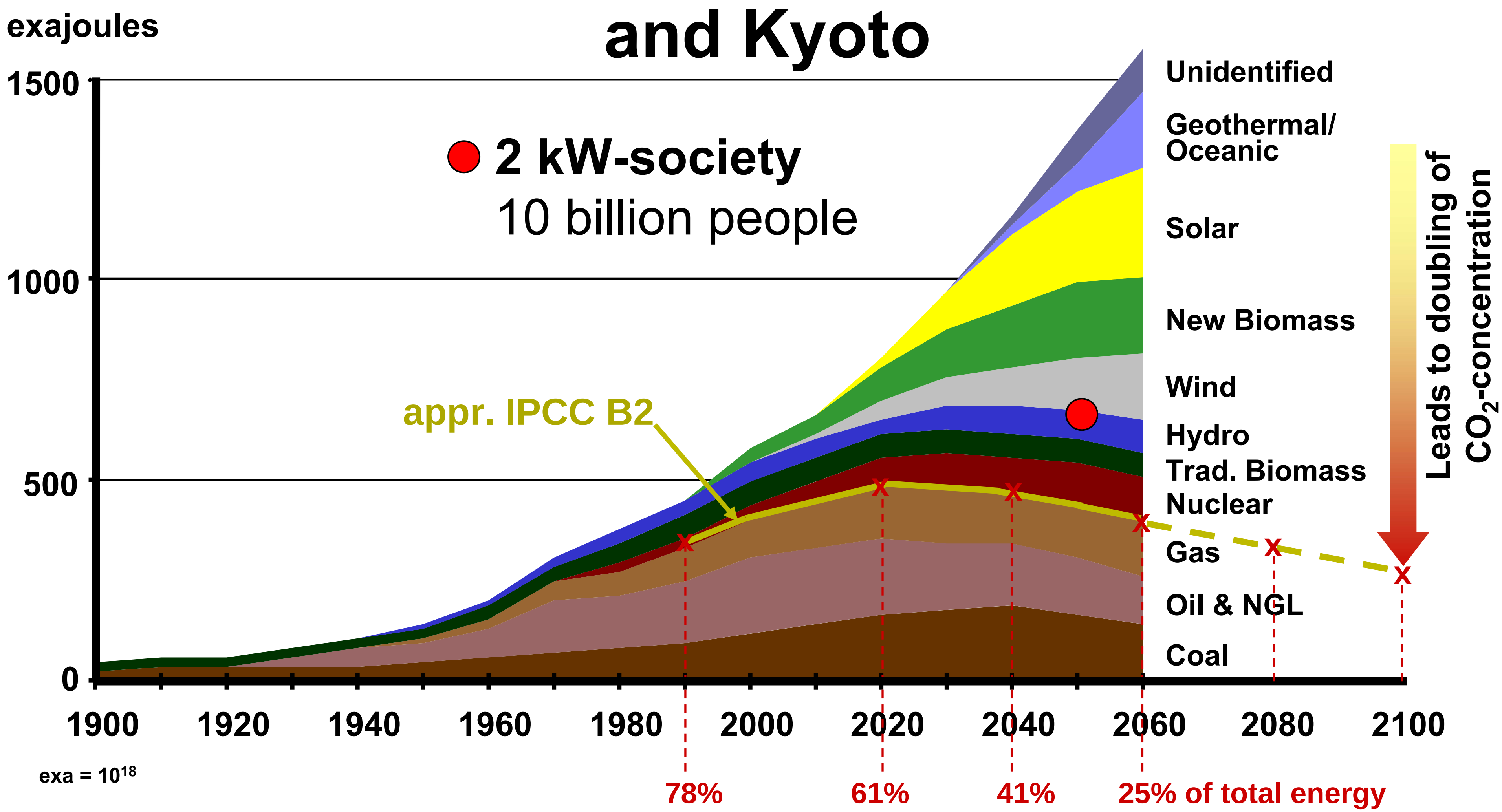
World Energy Supplies up to 2060 and Kyoto



Source: Deutsche Shell AG, ETHZ

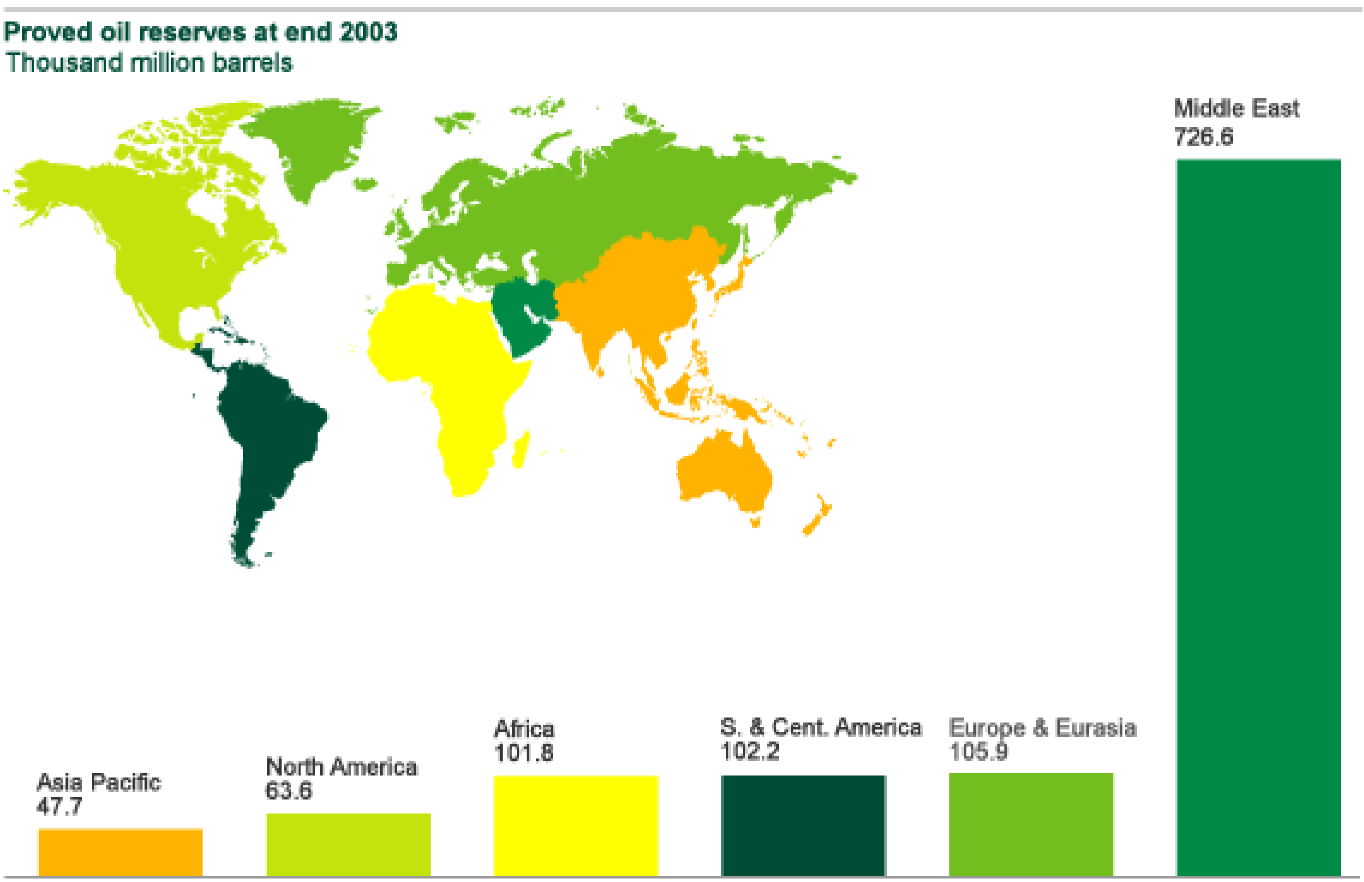
Fossil Fuels for How Long?
Measured in 1999 consumption

	Proven reserves years	Ultimate reserves years
Coal	200	>1000
Oil	50	>100
Gas	80	>200
Uranium[1]	200	1000

Remember: These data are highly unreliable (confidentiality, poor reporting practices, financial and political reasons).
But: Quite likely oil production will have declined around 2020, when substitutes will be needed in large quantities (J. Laherrere 2003)

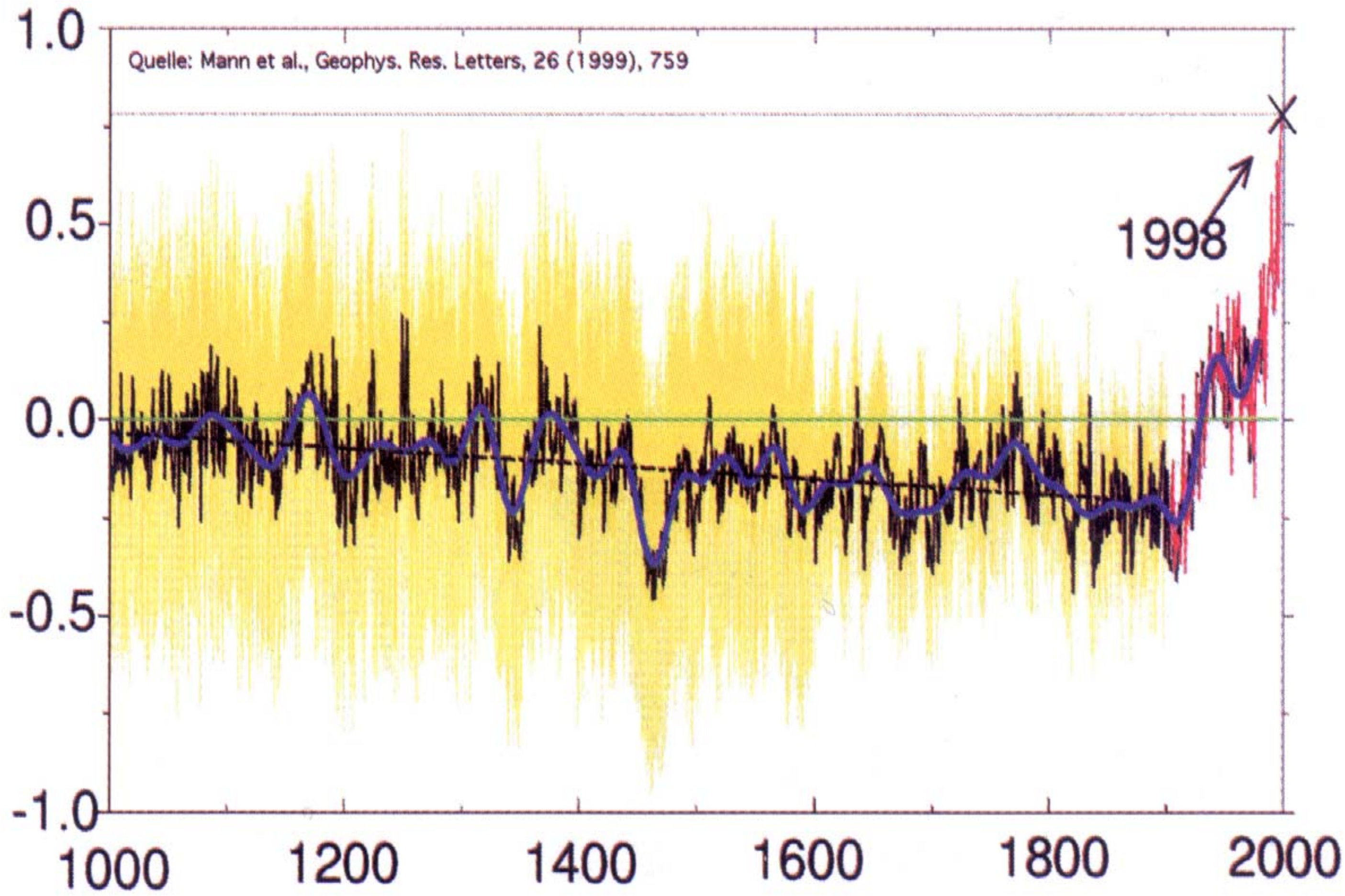
1) Without breeding

Proven Oil Reserves End of 2003



Sorce: BP Statistical Review of World Energy

Mean Air Temperature Close to Soil for the Last 1000 Years, Northern Hemisphere



Why Do We have to Reduce Our Dependence on Fossil Fuels Drastically?

- Today's **energy supply** is dependent on **fossil** energy to the tune of **about 80%**
- **Fossil fuels are finite** but still sufficient for the next decades
- The **large oil supplies** lie in a politically **unstable world region**
- The danger of a **climate change** as a result of green house gas emissions is increasingly getting bigger

Even without climate change, we do have to act now

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Main Elements to Improve Thermal Efficiency of SI-Engines

- Variable intake valve timing, cylinder de-activation
- Downsizing and supercharging
- Start-stop automatic
- Gasoline direct injection
- Reduced friction

- Potential: > 30 %

Main Elements to Improve Thermal Efficiency of CI-Engines

- Improved supercharging
- Start-stop automatic
- Improved combustion characteristics
- Reduced friction

- Potential: > 20 %

Development of Emission Standards of Passenger Cars

Since 1970 reduction of

- Nitric oxides NO_x by 99.0 %
- Hydrocarbons by 99.8 %
- Carbon monoxide by 93.0 %

SULEV-Standard

The *C*lean *E*ngine *V*ehicle Project

- **Goals**
  - SULEV / Euro 4
  - 108 g CO_2/km NEFZ (-30% compared to1.4 lit. Polo: 44 kW)
  - Power: 44 kW (base engine: gasoline 1.0 lit.: 37 kW)
- **Base vehicle**
  - VW Polo 1.0 lit. Gasoline: 37 kW 149 g CO_2/km

    Reference vehicle with 1.4 lit.-engine: 155 g CO_2/km
- **Partners**
  - EMPA
  - ETH Zurich
    - IET-LAV, IMRT
  - VW, Bosch, Corning, Engelhard
  - FOGA, DVGW, ÖVGW
  - AMAG, ASTRA, Post, BFE, BUWAL
- **Concept of *CEV***
  - Natural gas, high CR, AGR, TC, new transmission and catalysator

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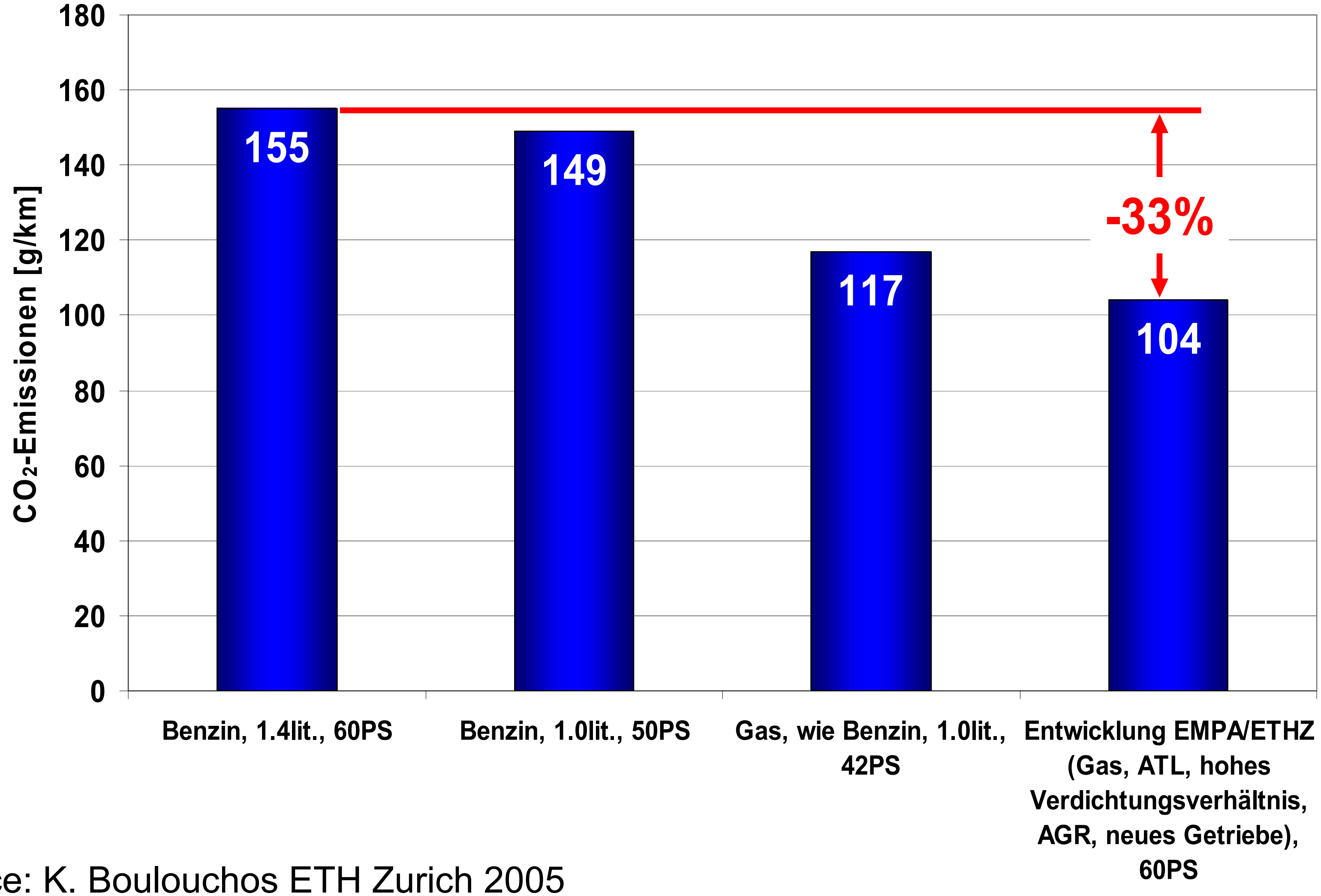
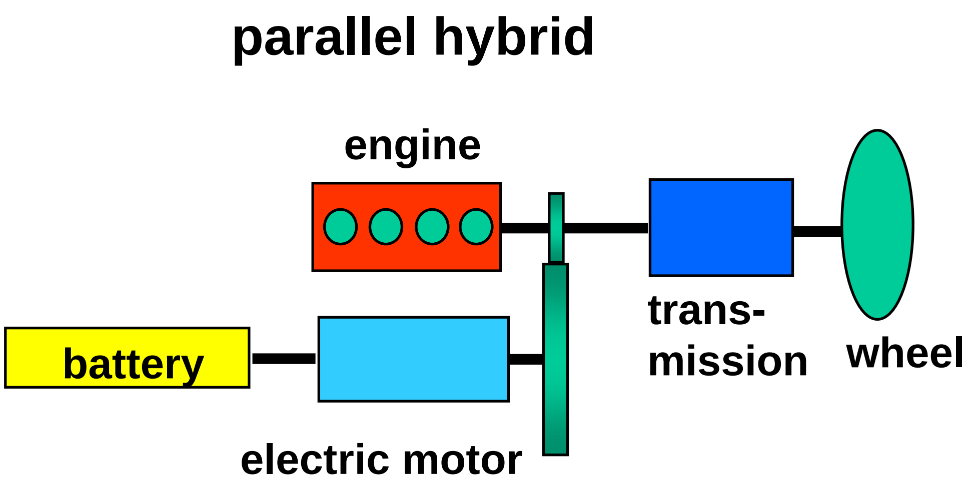
Comparison of Gasoline and Gas (CH_4), Different Processes and Catalysts, NEFZ-Cycle



Source: K. Boulouchos ETH Zurich 2005

Hybrid Powertrain



- CI or SI engine
- engine with start/stop automatic
- electric motor for deep part load
- no ZEV-operation
- recuperation
- different types of batteries
  - NiMH
  - supercap
- no battery charging from grid
- 5-speed transmission for engine
- 1-speed for electric motor

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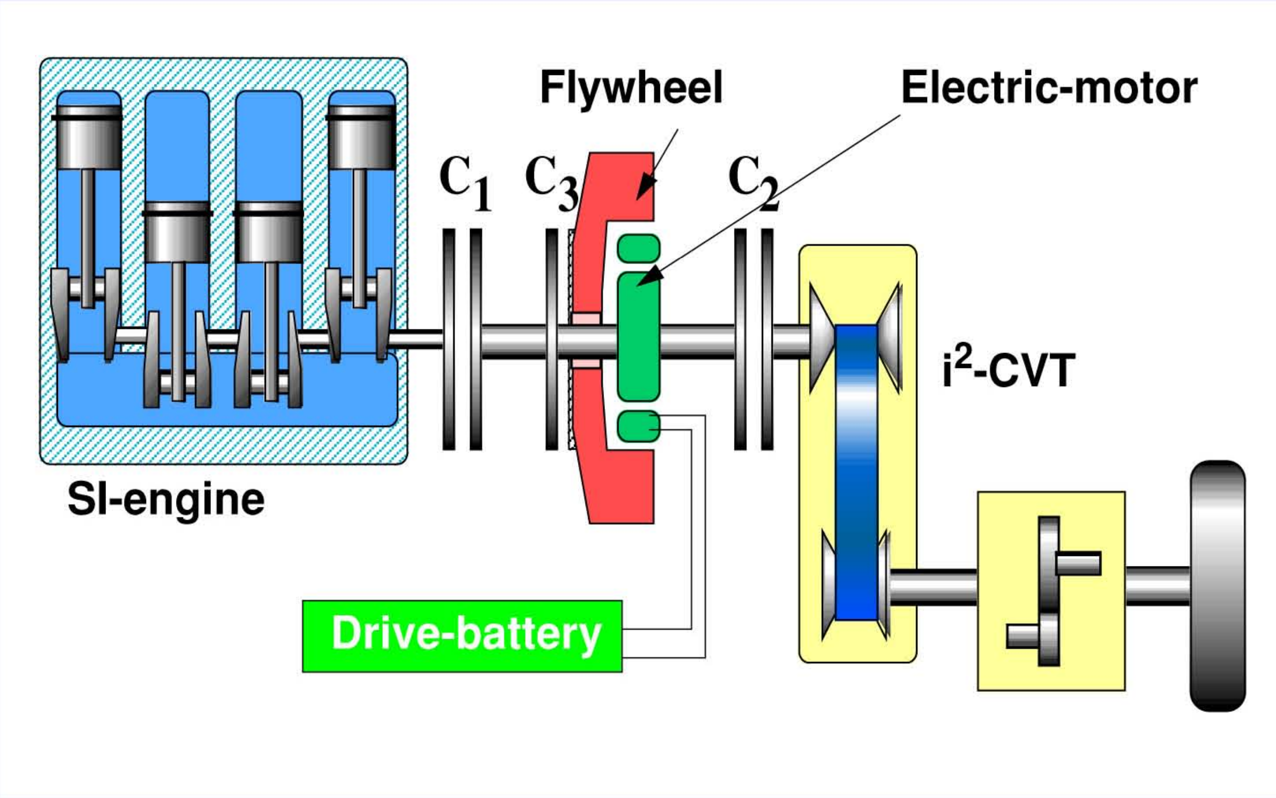
ETH Zurich Hybrid III
Arrangement of Powertrain



Key data

Nominal power:

SI-engine 53 kW
Electric 6 kW

Components:

Vehicle +350 kg
Battery 5 kWh
Flywheel 245 kJ
48 kg
CVT i_{range} 5.5

Design-consumption:

ECE-R15/04
Gasoline 4.4 l/100km
Electric 18 kWh/100km

Hybrid III / Results Reference Vehicle

Constant vehicle speed

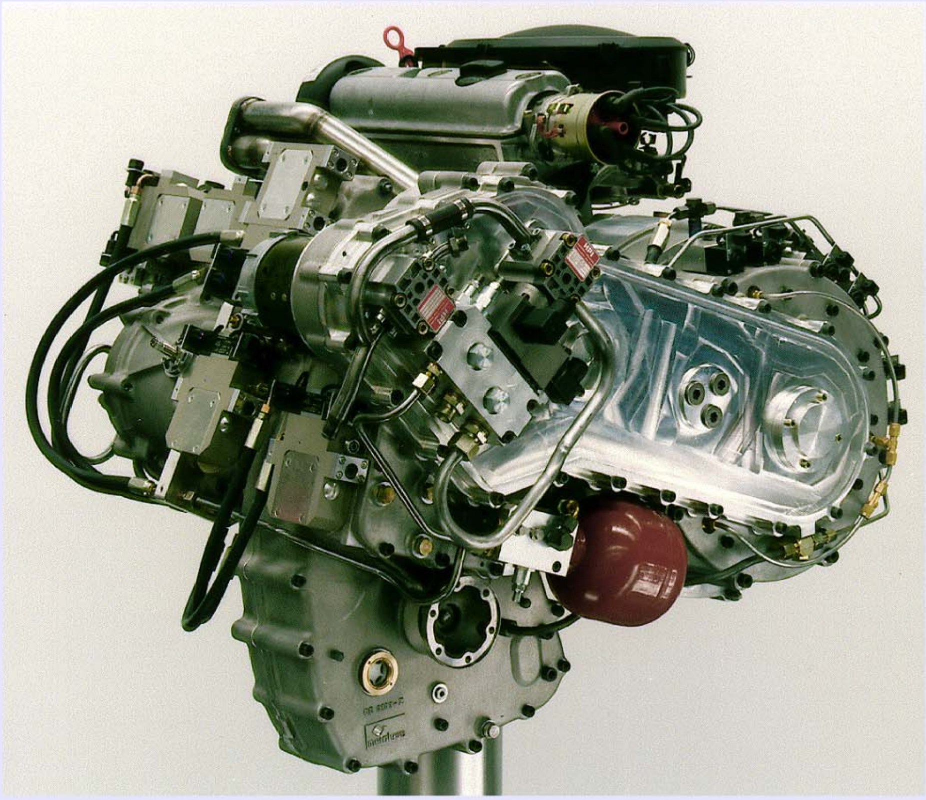
■ 30 km/h	Measured	3.46 l/100 km
	Simulation	3.39 l/100 km (+ 2.1 %)
■ 50 km/h	Measured	3.35 l/100 km
	Simulation	3.48 l/100 km (- 3.7 %)

ECE-Cycle fuel consumption

Measured	4.72 l/100 km
Simulation	4.53 l/100 km (+ 4.2 %)
Reference vehicle	8.90 l/100 km

Improvement in fuel consumption: 47 %

Powertrain and Its Integration in a Vehicle



Volkswagen Sharan

Front-end enlarged in total +180 mm

Hybrid Powertrain Toyota Prius

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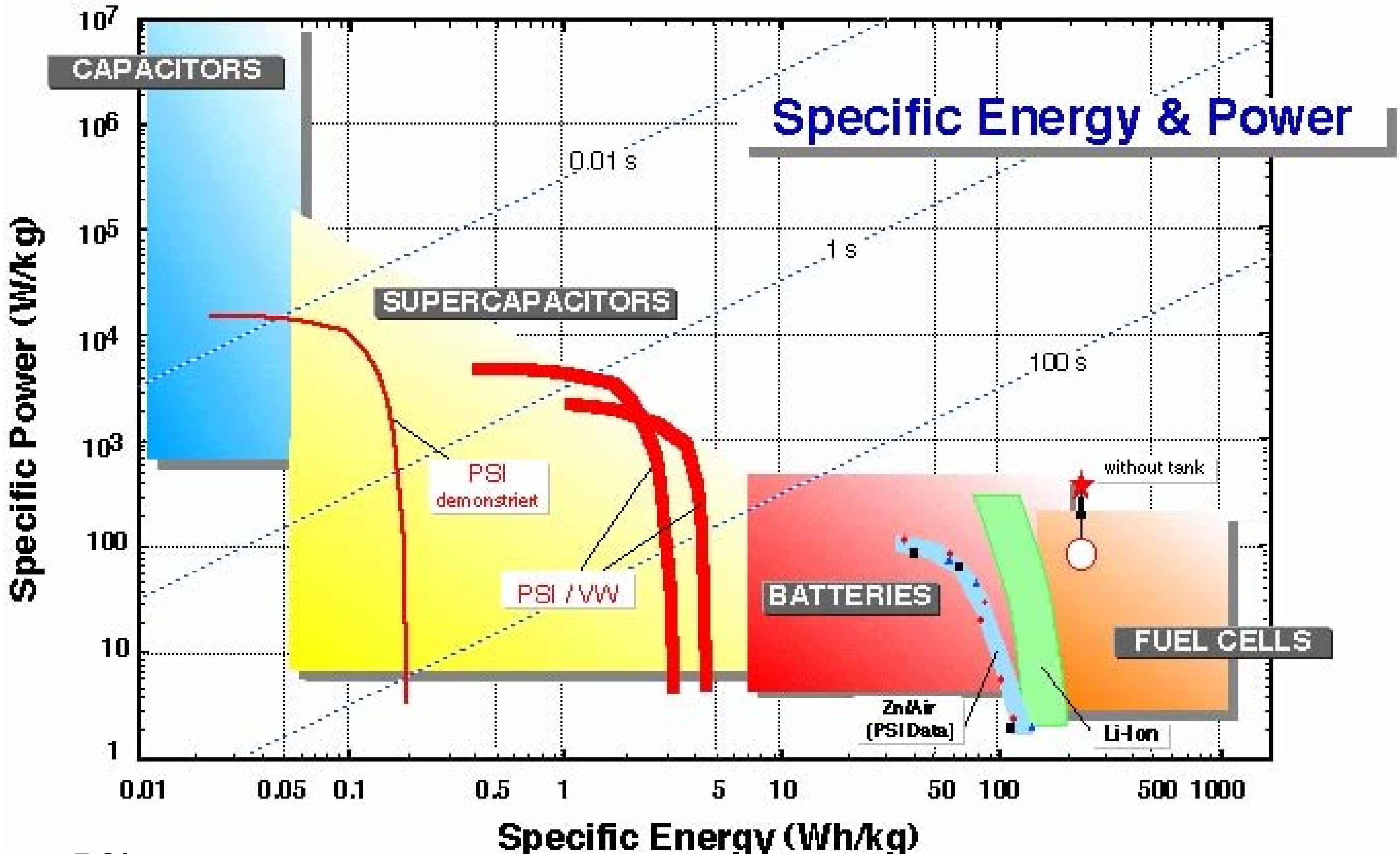
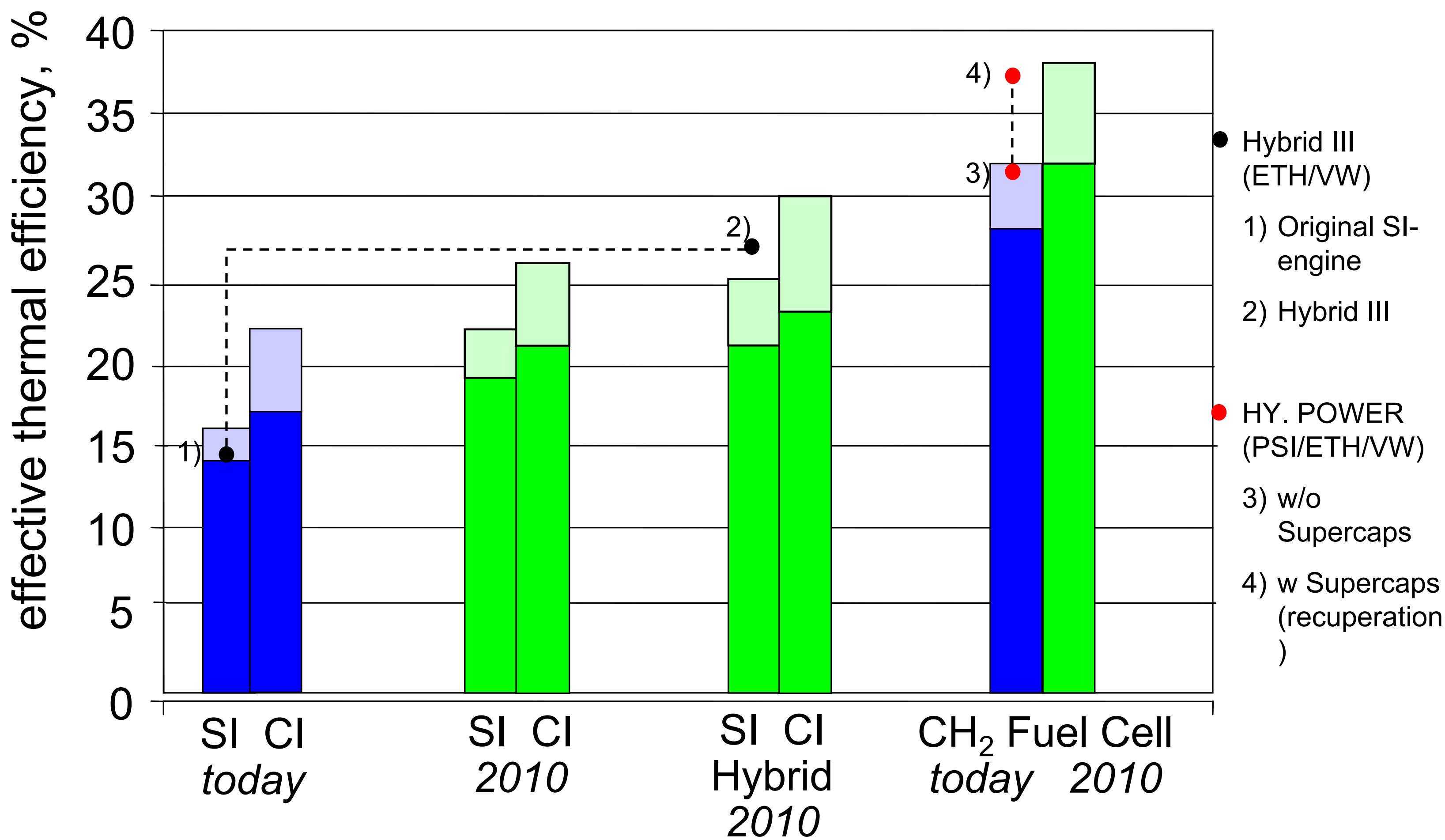
Main Characteristics of Electric Energy Storage Systems



Source: PSI

Efficiencies of Different Powertrains Tank-to-wheel



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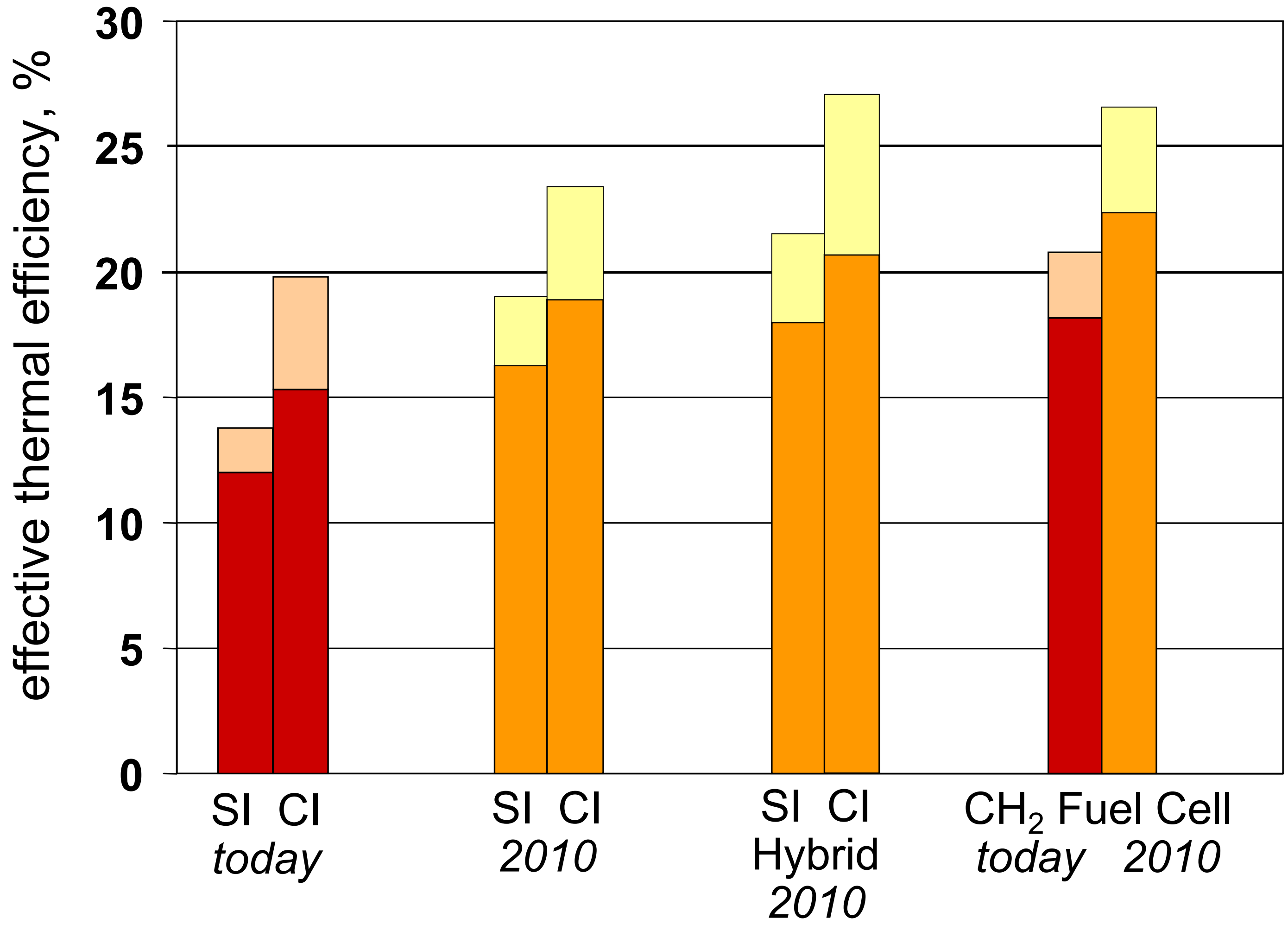
Efficiencies of Different Powertrains
Well-to-wheel



Energy Consumption of Cars: The Psychology Drives the Consumption

- Fun to drive means: high power-to-weight ratio resulting in steep acceleration
- A car is increasingly a means of self-expression satisfying emotional needs

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Helmut Newton‘s Dream Machine

The Consumer Decides about Fuel Consumption

Vehicle	Mass Kg	Power kW	Spec. power kW/100 kg	Consumpt. l B,D/100 km
A	1250*	107	8.6	4.3
B	1320*	110	8.3	7.4
C	2480*	220	8.9	14.9
D	12‘000*/40‘000	330	2.8/0.8	35

A: Hybrid; B: reg. Car; C: SUV. (A, B, C: All cars with 5 seats)
Accel.: 8.9-10.9 s for 0-100 km/h
D: Heavy truck (Diesel). *: weight empty

The PAC-Car Project of ETH Zurich: Shell Eco-Marathon in Nagoro/F May 21/22 2005

- 200 teams from 17 countries – the winner is ETH Zurich with 3836 km per litre of gasoline equivalent
- Car: L 2.78 m, W 0.57 m, H 0.61 m
  - Weight: 30 kg
  - C_d 0.09, Frontal area 0.254 m2, Rolling res. 0.0015
  - PEM fuel cell of 900 W (PSI)

The PAC-Car Project of ETH Zurich

Source: IMRT ETH Zurich, 2005

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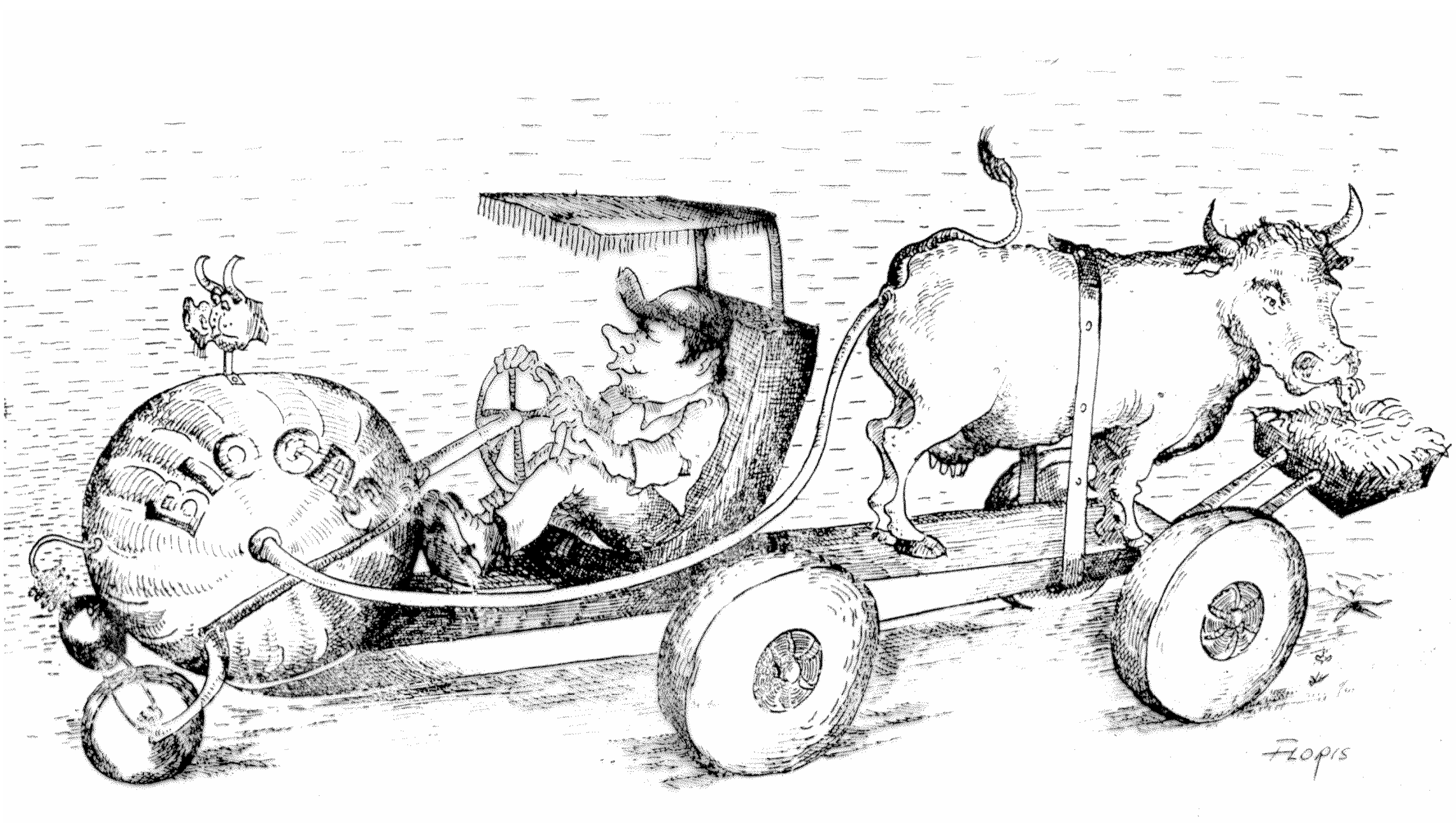
Sustainable Mobility

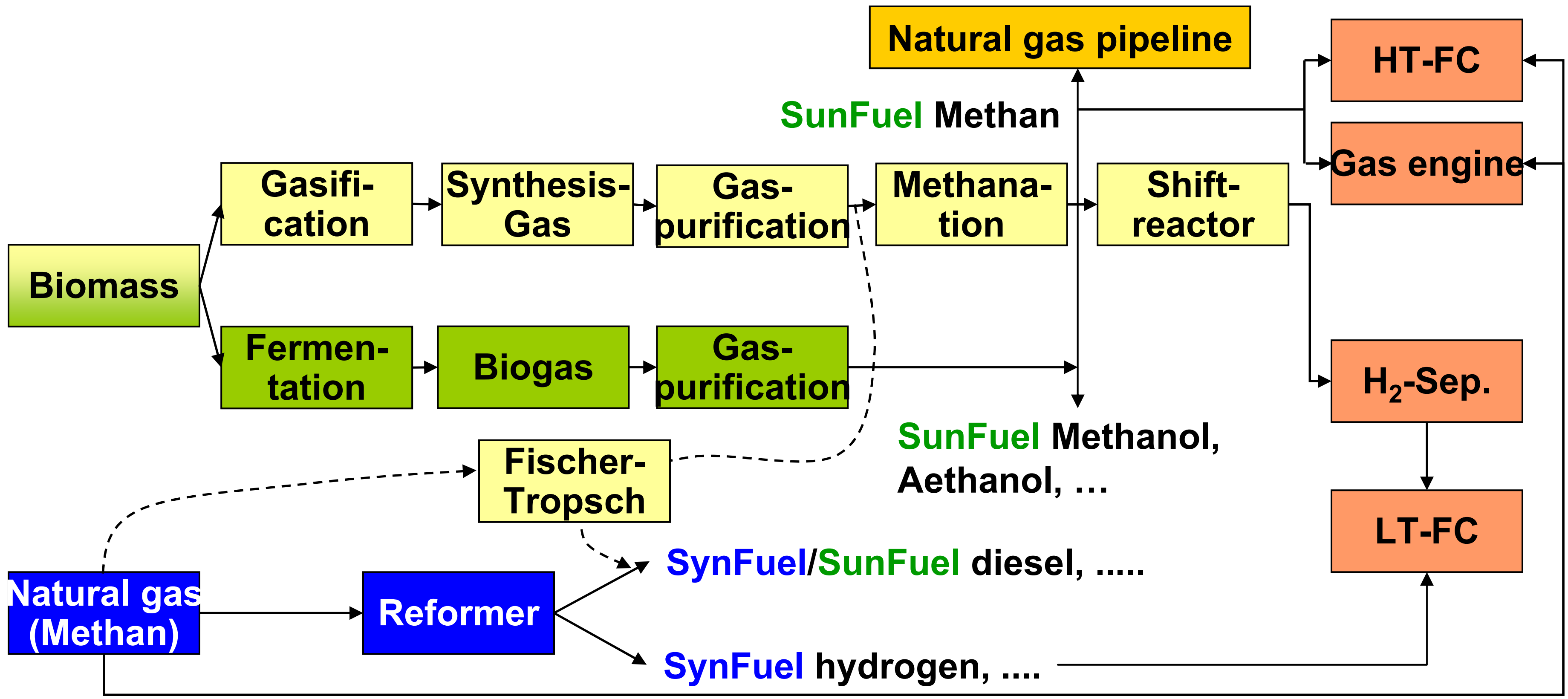


What Kind of Fuels Do We Talk about?

Non-renewable	SynFuel	SunFuel
CNG	Natural Gas	Gas
LPG		
DME	DME	DME
Naphtha	GTL Naphtha	GTL Naphtha
Kerosene	GTL Kerosene	GTL Kerosene
Diesel	GTL Diesel	GTL Diesel
Gasoline	Gasoline	
	Methanol	Methanol
	Hydrogen	Ethanol
		RME
		Hydrogen

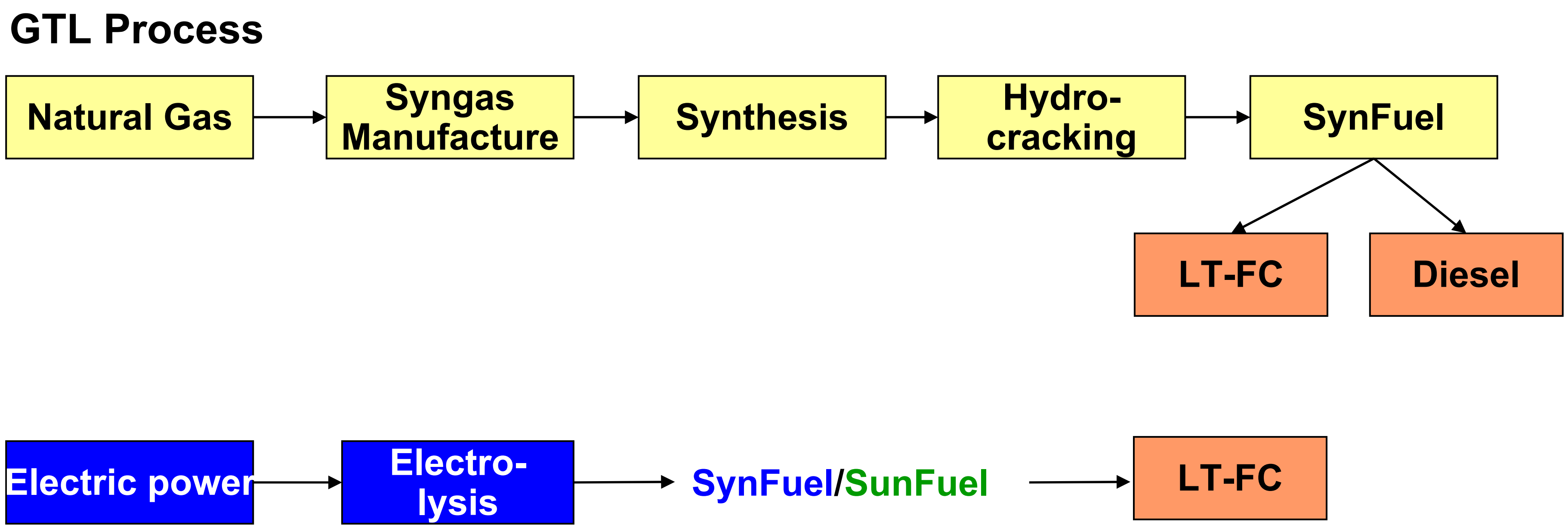
Source: ETHZ GTL: Gas-to-liquid

Energy Conversion Chain



Source: ETHZ

Energy Conversion Chain (cont.)



Source: Shell Gas & Power

SynFuel (Gas-to-liquid): A Possible Bridge to SunFuel

- SynFuel (Gas-to-liquid): A possible bridge to SunFuel
- Gas-to-liquid conversion in Fischer-Tropsch plant
- Resulting ultra clean fuels: naphtha, kerosene, diesel, etc.
- Characterization: no sulphur, no aromatics, narrow boiling range; can be mixed with ordinary fuels
- Combustion: excellent trade-off NO_x-PM in diesels
- Same infrastructure as diesel
- Well-to-wheel CO_2: better than gasoline, worth than diesel; candidate fuel for HCI
- More expensive than diesel, cheaper than bio-mass fuel
- Plants in operation: Shell in Indonesia, ExxonMobil in USA

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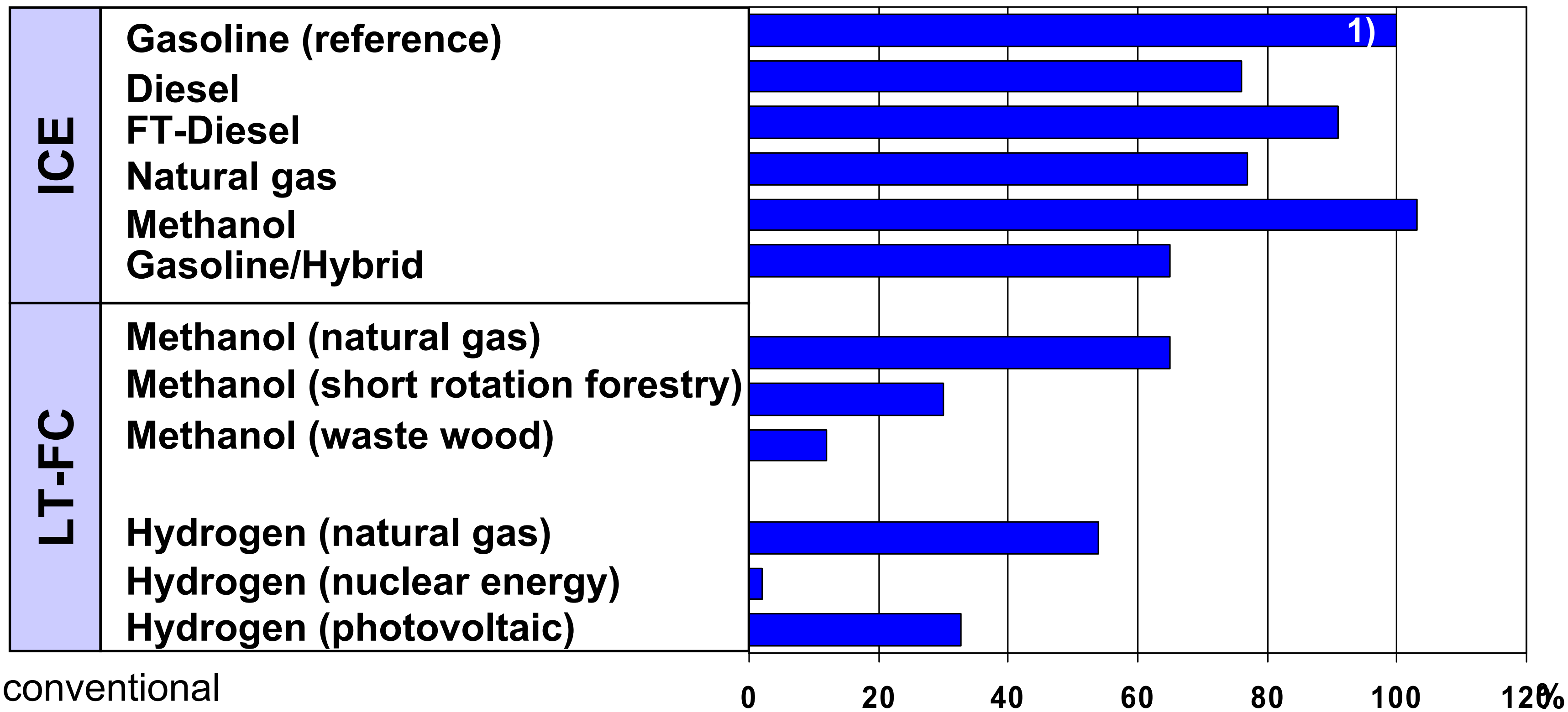
Relative well-to-wheel Emissions of Cars Equipped with Internal Combustion Engine (ICE) and Low Temperature Fuel Cells (LT-FC)

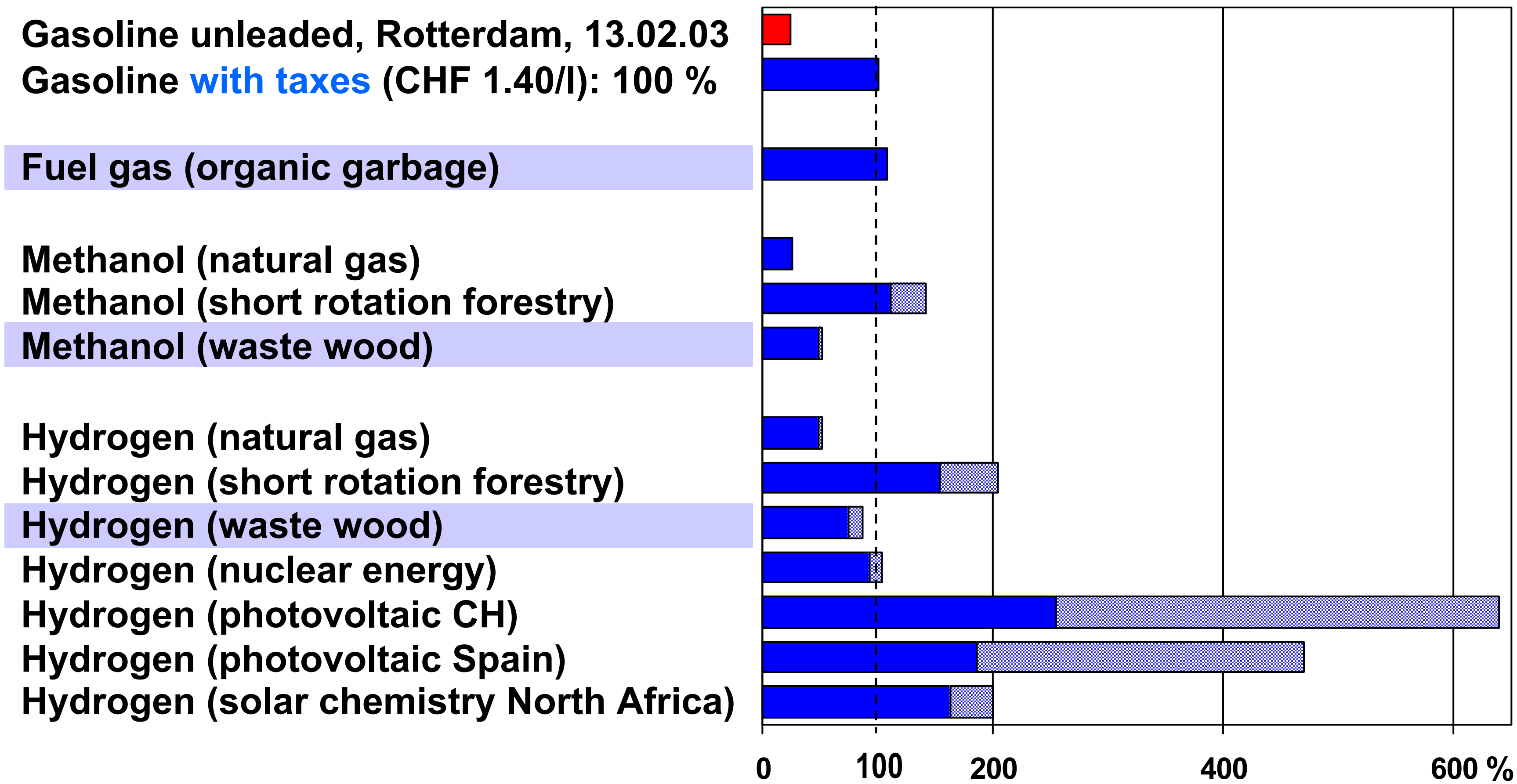
Rel. $CO_{2\text{-aeq.}}$ emissions per unit of distance, FTP-Cycle



1) conventional

Sources: PSI, ETHZ, Opel, etc.

Relative Fuel Costs – without Taxes, Related to Unity of Energy



Sources: PSI, Kompogas

„If all biogenic garbage in Switzerland (grass, household, not wood) would be fermented, about 10% of the passenger cars could be driven with Kompogas“

Source: Kompogas

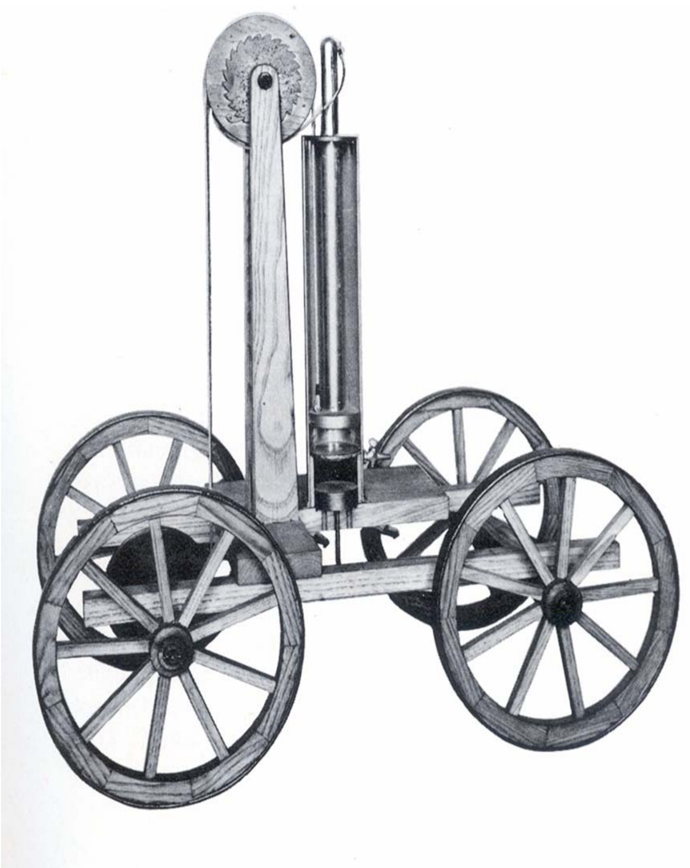
The Opinion of an Agrarian Economist about Agriculture and Energy

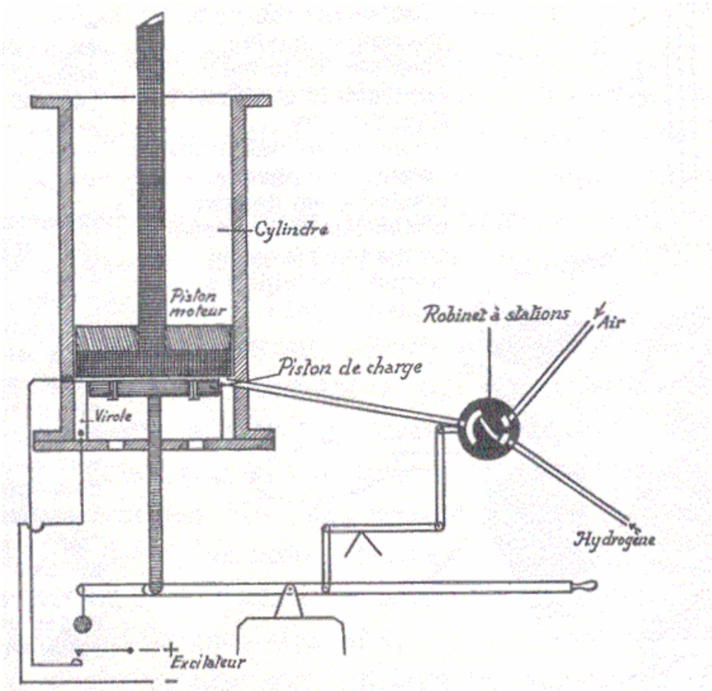
In Switzerland (if fully internationally integrated), the conditions regarding climate, topography, remuneration and structure for an economically justifiable energy production are not given

Political decision if we do it anyway

Source: ETHZ

Isaac de Rivaz (Swiss, 1752-1829) 1805: First „Mechanical Wagon" ever Run on Hydrogen





Sources: H.Michelet, l'Inventeur Issac de Rivaz, Martigny 1965
E.Schmid, Schweizer Autos, Edita SA., Lausanne 1978

A Word of Caution about Hydrogen

Only sensible if produced in a renewable way (LCA), hydrogen is a long term option

Three critical issues to be resolved:

- **Storage for transport applications not satisfactory**
- **Infrastructure not yet available; transport losses from production to user a challenge**
- **Cost of production not yet competitive**

Source: ETHZ

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Fundamentals of Energy System

Each country has its own set of priorities – hardly a common denominator

- Cost of energy
- Security of supply
- Strategic diversification
- Global warming
- Availability of local energy resources
- Local air pollution
- Agricultural surplus
- Availability of sufficient amounts of energy
- Balance of payment
- Renunciation of nuclear energy
- Job creation
- Ability to pay
- Ecological conscience
- Social equity

Source: ETHZ

Fundamentals of Energy System (cont.)

We all agree on:

- Reduce primary energy use in a big way
- Look for energy diversity
- A close collaboration between governments, the public (the user) and energy industries is vital to ensure a sustainable long term energy future“

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- **The primary energy consumption has to be reduced, in particular for cars**
- **Fossil fuels will be the source of energy for years to come with a gradual shift to renewables and fuel cells, natural gas is the most important fuel of transition**
- **Fuel cells to make sense require fuels produced in a sustainable manner**
- **Home heating will have to be switched to heat pumps requiring more electricity with nuclear energy being a viable option**
- **Our dependence on fossil fuels has to be reduced as much as possible in the decades to come**

Conclusions (cont.)

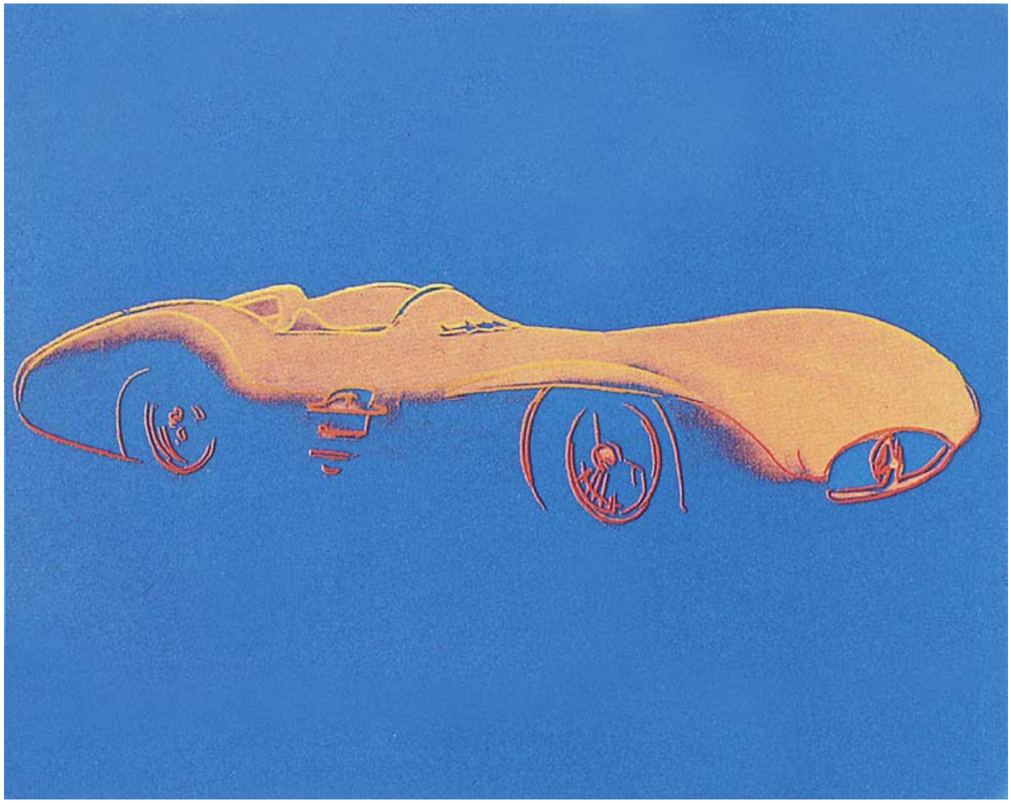
- **The improvement of our energy situation is doable and payable – the technology is there**
- **Universities play an ever more important role to develop leadership, to operate as an honest broker and to educate the younger generation regarding sustainability**

It is up to you, what kind of future you want – choose wisely for the sake of future generations

Energy Pathways for the Mediterranean

- Make use of the sun: solar-thermal (active and passive), think perhaps in terms of chemical storage of solar energy (hydrogen)
- Consider geo-thermal

1954: Mercedes-Benz Formula-1-Race Car W 196 R, D Andy Warhol 1986



Thank you for your kind attention