ICSAT Conference – Chiemsee/Bavaria – 24-26 February 2010

Build-up strategies for a hydrogen supply and refueling infrastructure including a comparative outlook on battery-electric vehicles and their infrastructure requirements

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Resource Situation

The switch from a fuel to an electricity based energy system

Conventional energy supply and IEA Outlook

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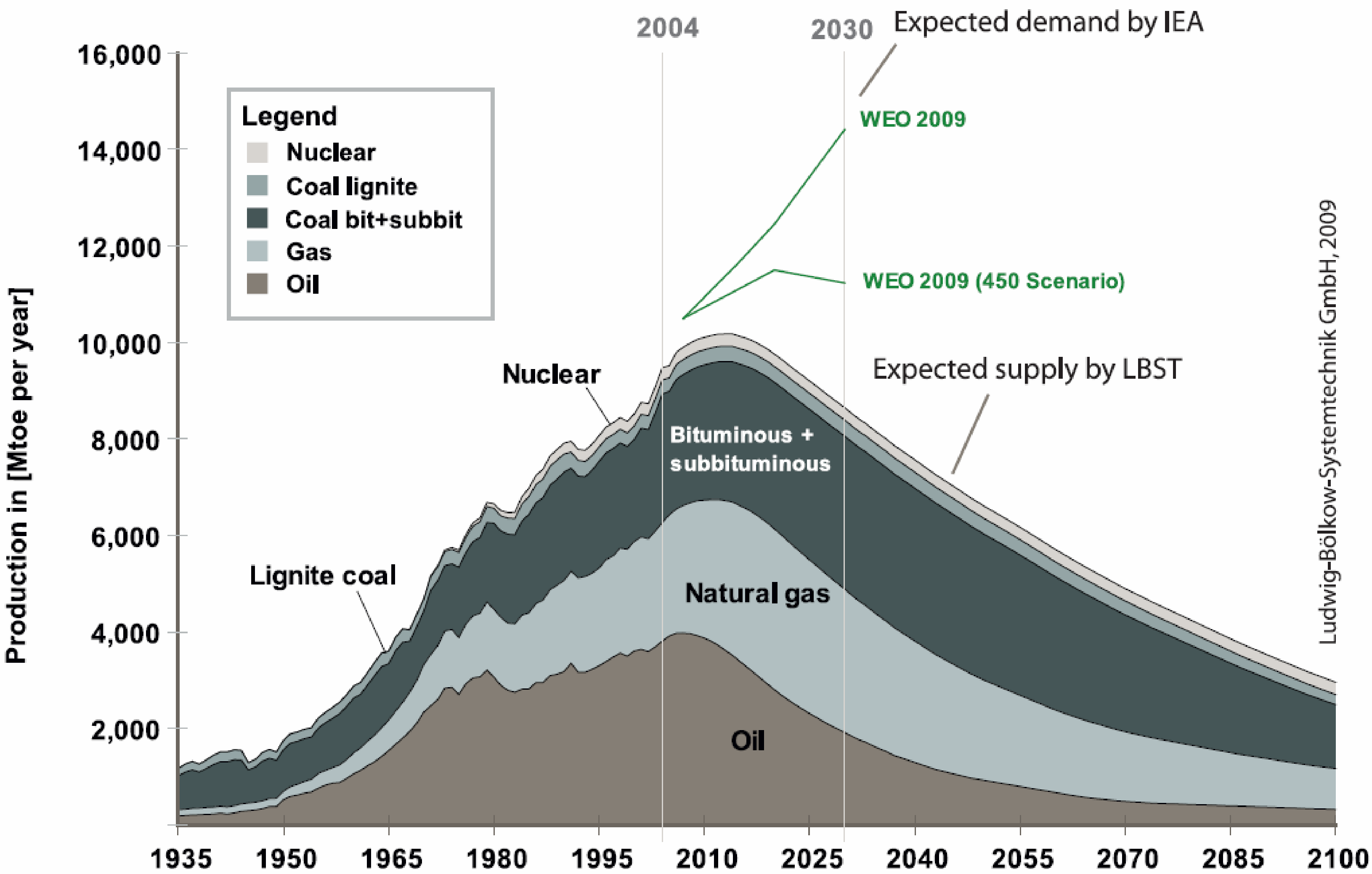
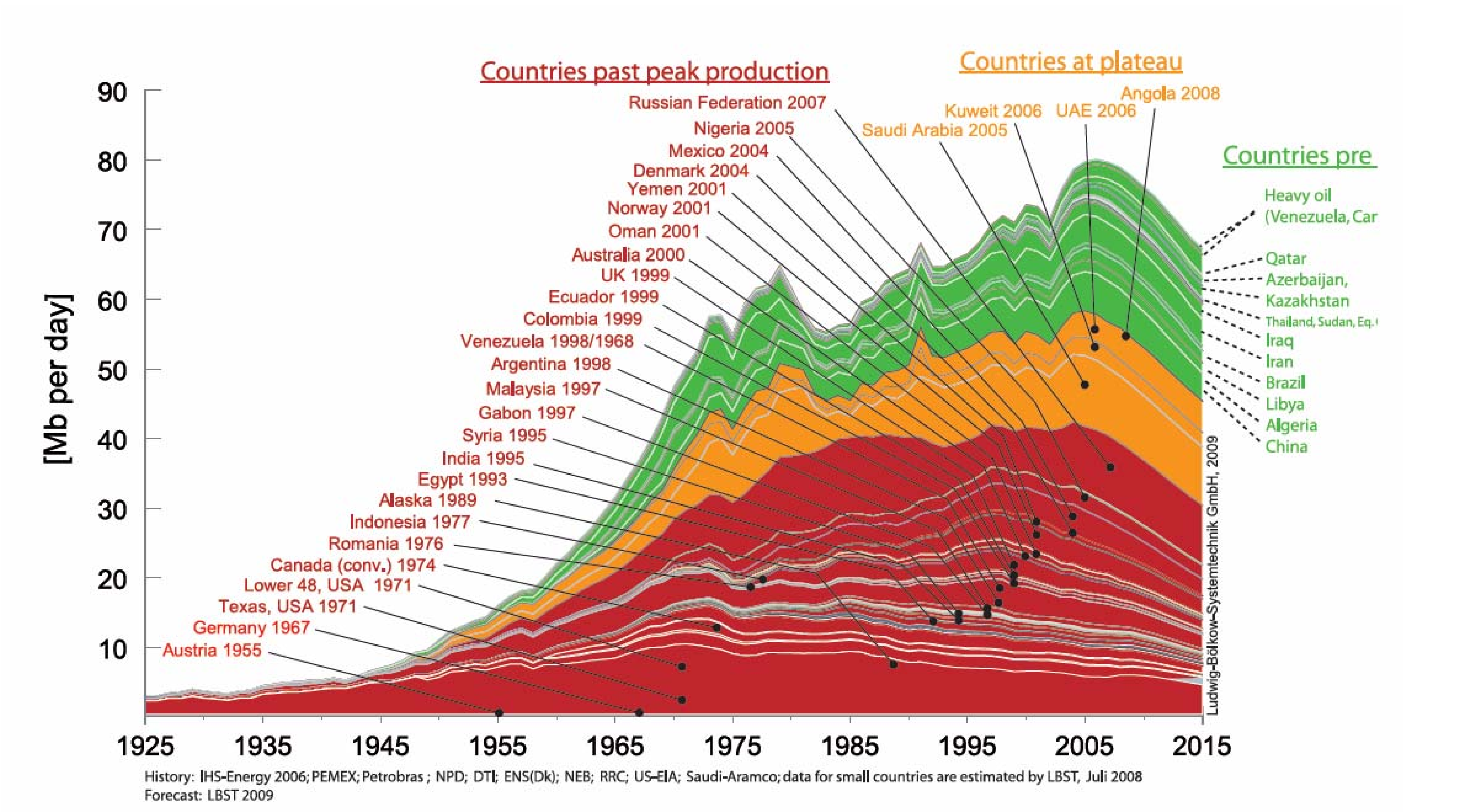
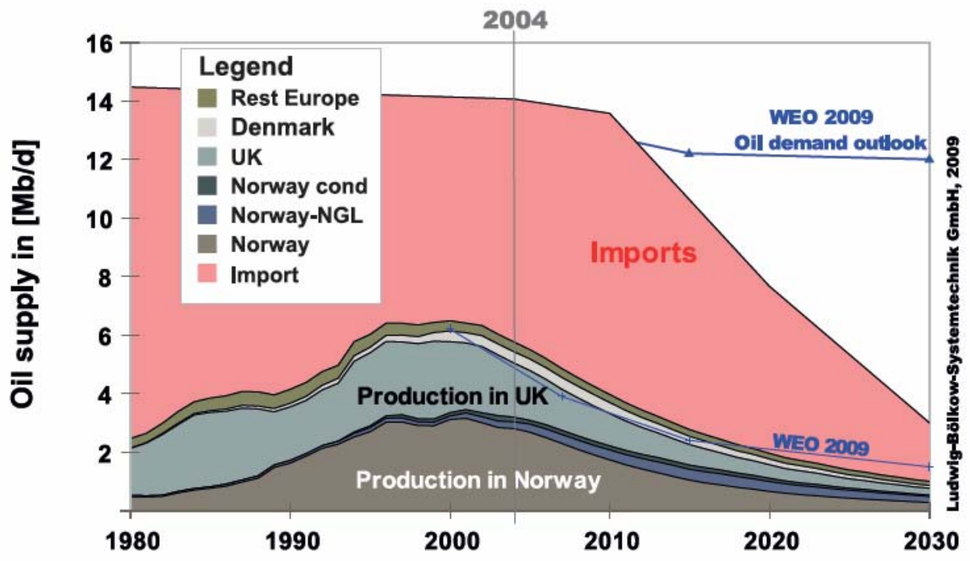


Oil producers after, at and before peak

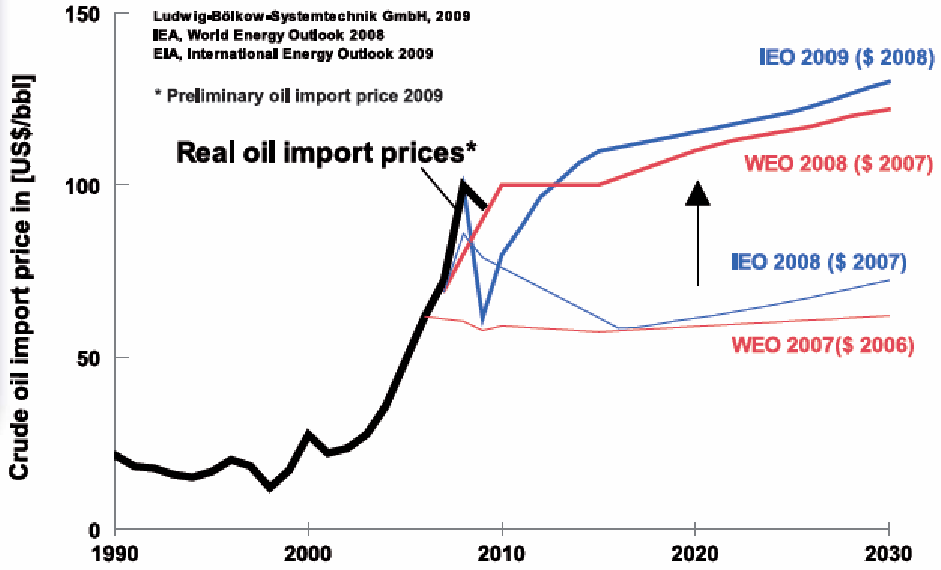


Europe’s crude oil supply situation and oil import prices

Europe’s crude oil supply will decline



Facts 2004 (IEA data)	***LBST Outlook 2030***
Total supply: 14.1 Mb/d	Total supply: 3 Mb/d
Production: 5.8 Mb/d	Production: 1 Mb/d
Imports: 8.3 Mb/d	Imports: 2 Mb/d



IEA’s World Energy Outlook (WEO)
EIA’s International Energy Outlook (IEO)

Europe‘s natural gas supply situation

Europe’s natural gas supply will decline

Facts 2004 (IEA data)

Total supply: 503 Bm^3

Production: 287 Bm^3

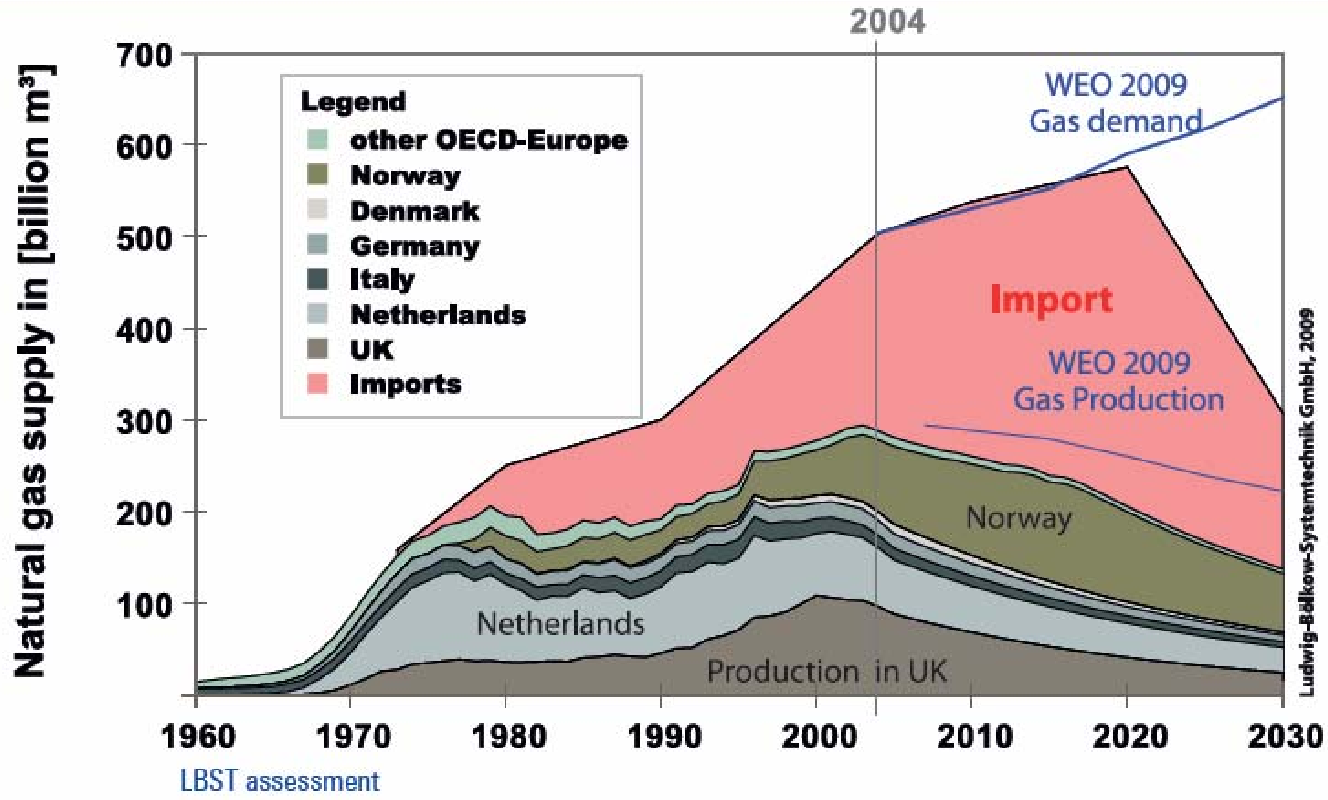
Imports: 216 Bm^3

LBST Outlook 2030

Total supply: 307 Bm^3

Production: 137 Bm^3

Imports: 170 Bm^3



Future primary energy supply

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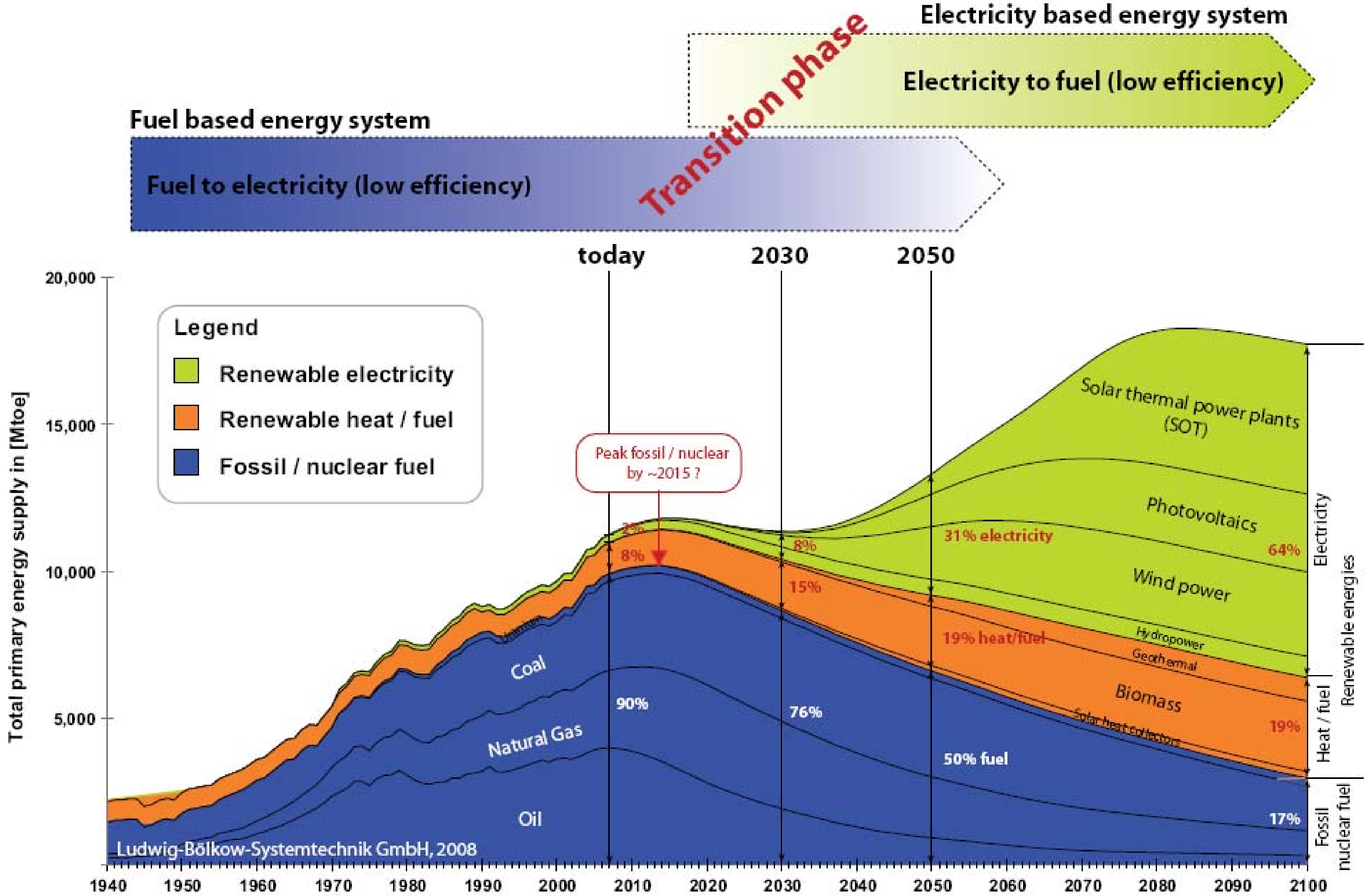
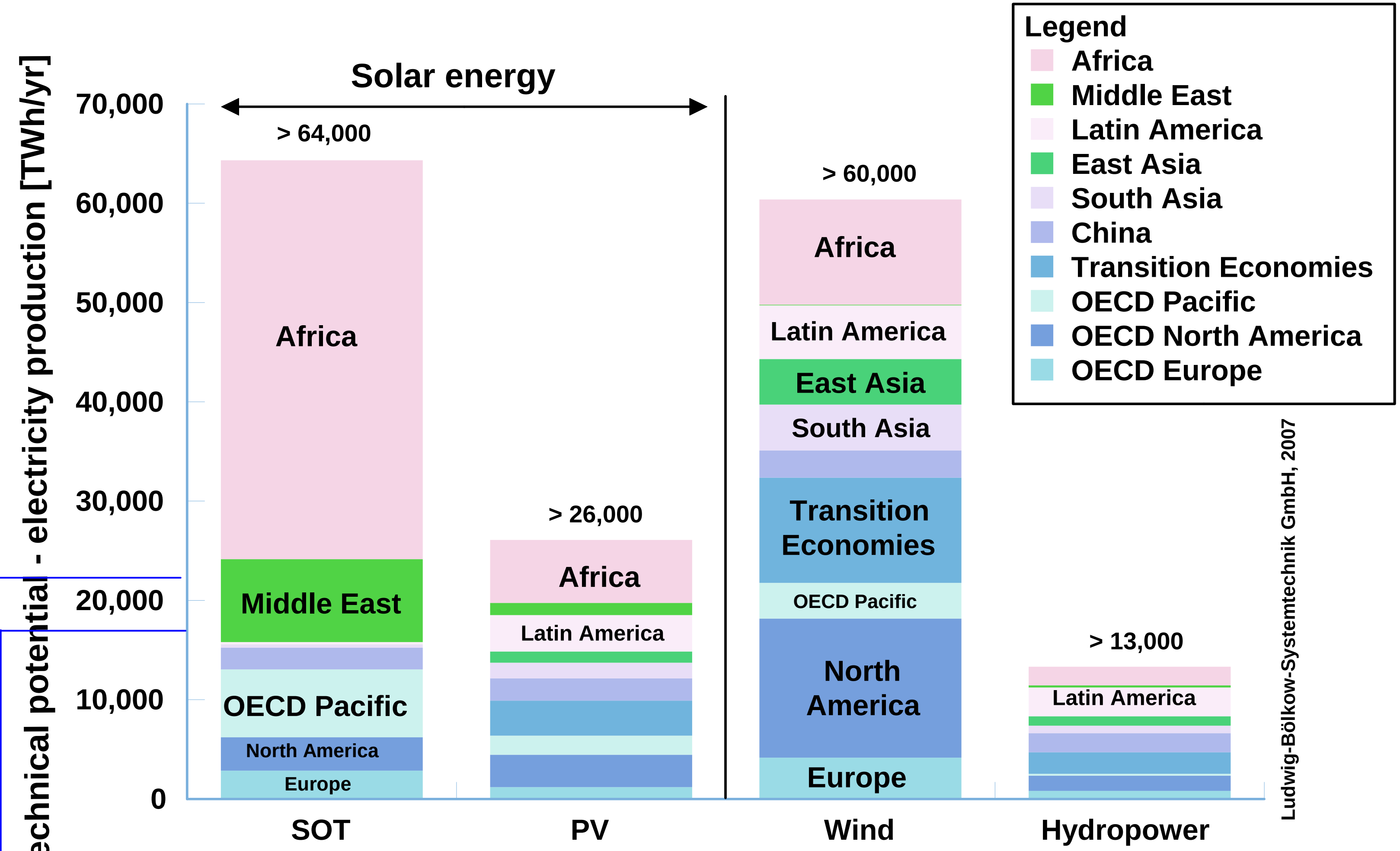


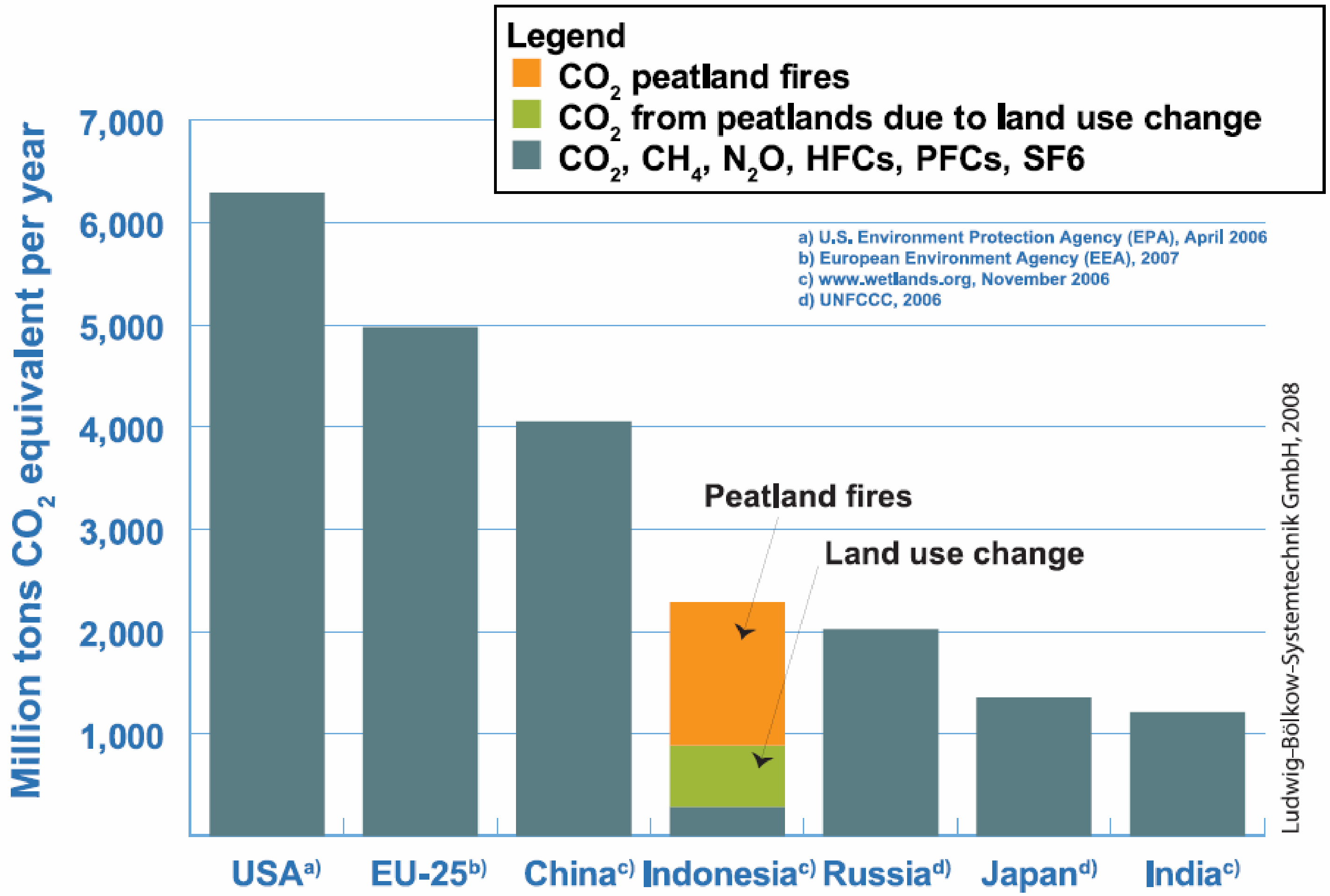
Technical potential of renewable electricity - worldwide



World Electricity Production 2004:
17,500 TWh

World Fuel Demand 2004:
22,100 TWh total transport sector
18,250 TWh road transport

Non-sustainable fuel production ....



Greenhouse gas (GHG) emission in different regions and pressure on ecosystems

Furthermore the expansion of biofuels increases the pressure on natural ecosystems outside the EU (loss of biodiversity due to the conversion of natural forests, contamination of water from pesticides) and also leads to extremely high GHG emissions

Large-scale storage of electricity

Electricity storage technologies and characteristics

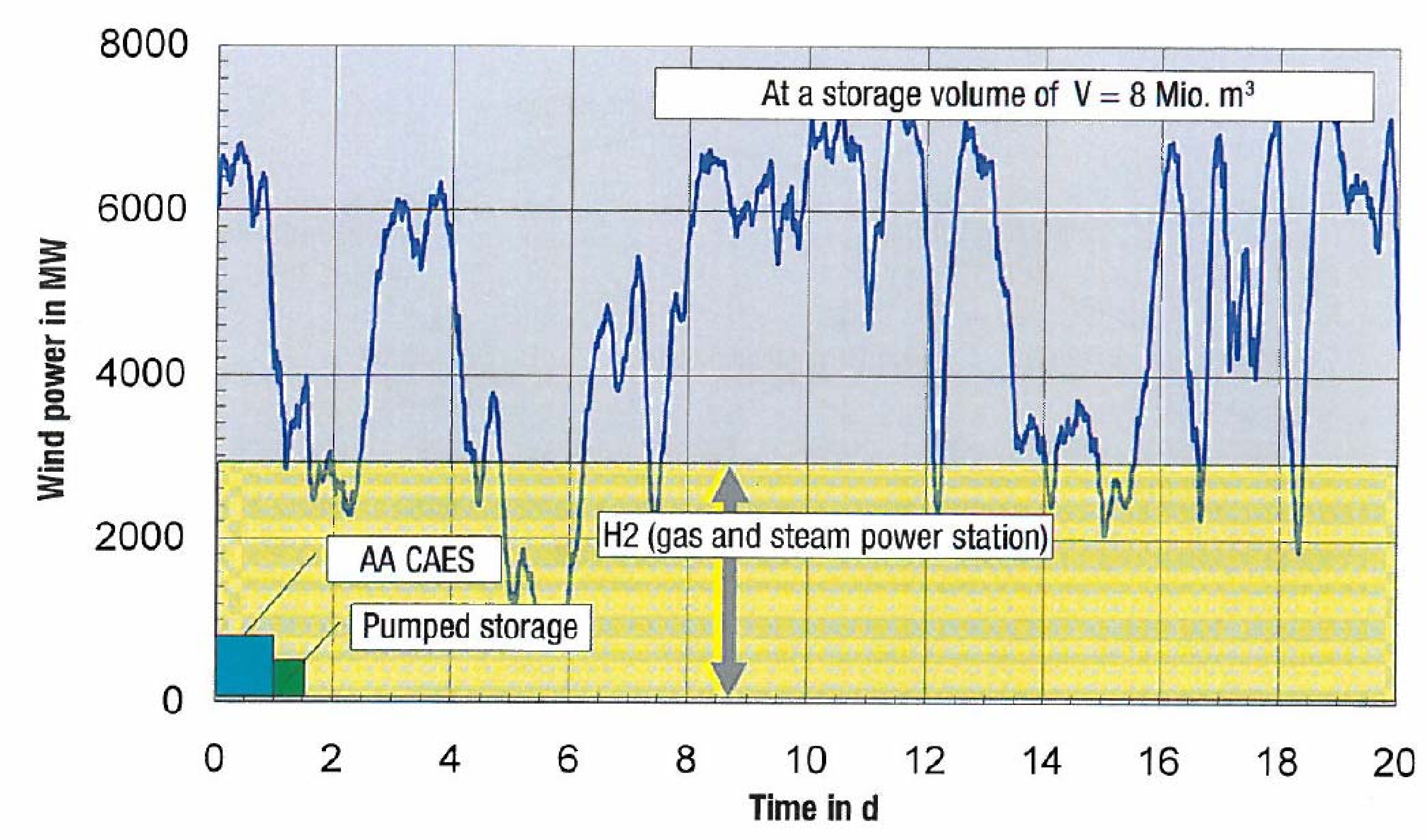
Designation	Brief description	Power	Energy	Discharging time	Cycles per day	Response time
Long-term storage	Storage energy from renewable sources over a period of weeks (no seasonal compensation)	500 MW	100 GWh	200 h	0.06	1-15 min.
Load levelling in the transmission grid (high voltage	Typical rating of a large pumped storage hydro-electricity power station	1 GW	8 GWh	8 h	1	90-120 s
		1 GW	8 GWh	8 h	1	< 1 s
Peak shaving in the medium voltage grid	Storage system on the municipal utility level, particularly for peak shaving	10 MW	40 MWh	4 h	2	< 1 s
Peak shaving in the low voltage grid	Storage system in low voltage grid for peak shaving and load levelling	100 kW	250 kWh	2.5 h	2	< 1 s

l storage technologies:

Pumped storage, CAES, hydrogen
Pumped storage; longer response times for CAES (15 min) and hydrogen (15 min)
Lead acid, NiCd, Li ion, NaS/NaNiCl, redox flow (vanadium), zinc bromine
Lead acid, NiCd, Li ion, NaS/NaNiCl, redox flow (vanadium), zinc bromine
Lead acid, NiCd, Li ion, NaS/NaNiCl, redox flow (vanadium), zinc bromine

Source:
Energy storage in power supply systems with a high share of renewable energy sources, VDE Association for Electrical, Electronic & Information Technologies, December 2008

Capacities and Durations for Electricity Storage

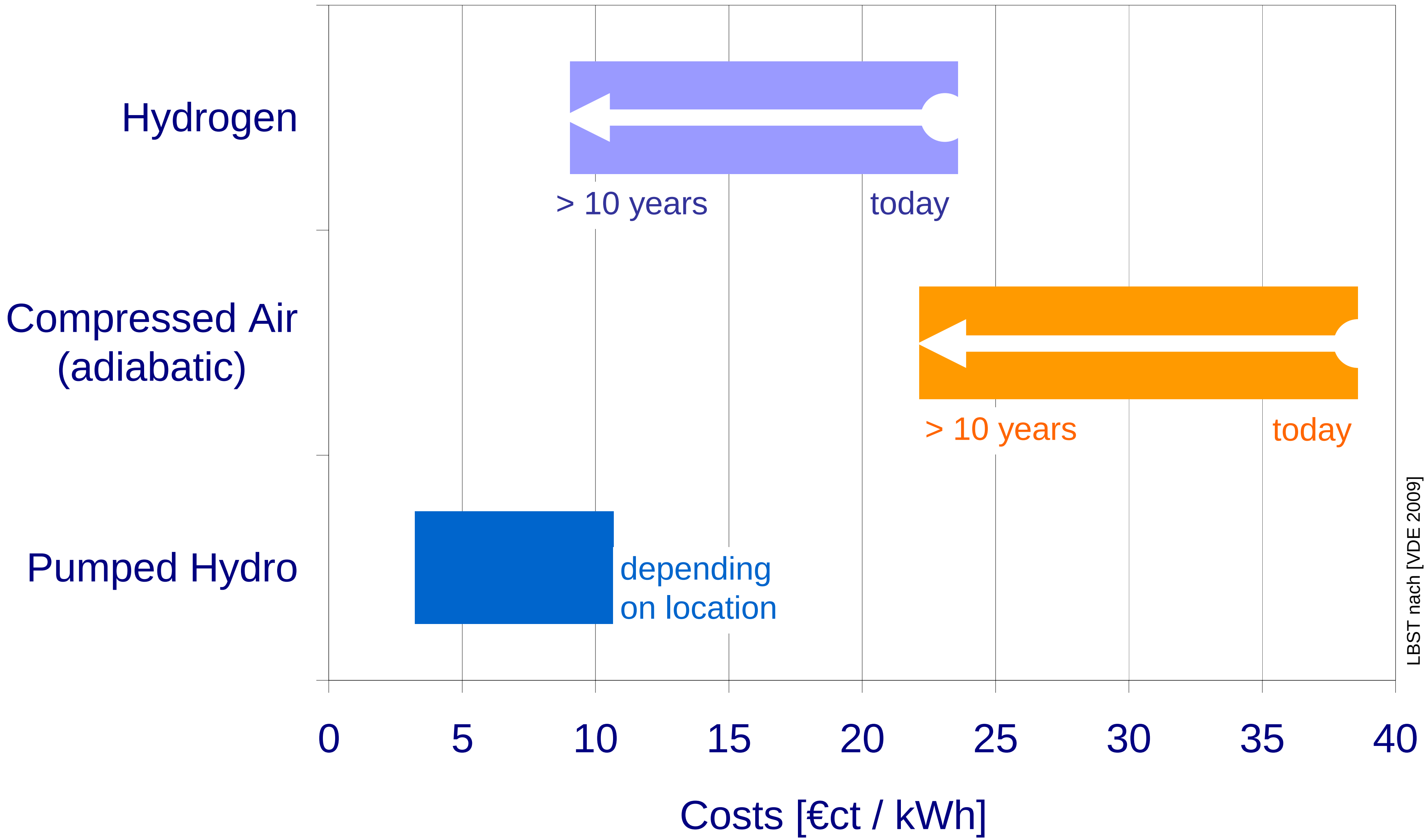


Comparison of the volumetric storage capacities

	Specific net storage capacity	Efficiency level
Pumped storage power station	0,7 kWh/m³	80%
Adiabatic compressed-air storage power station	2,9 kWh/m³	70%
Hydrogen storage (electrolysis storage reconversion)	187 kWh/m³	40%

Source:
Energy storage in power supply systems with a high share of renewable energy sources, VDE Association for Electrical, Electronic & Information Technologies, December 2008

Long-term Storage Costs for Electricity



Source:
Based on Energy storage in power supply systems with a high share of renewable energy sources, VDE Association for Electrical, Electronic & Information Technologies, December 2008

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Comparison of sustainable road transportation concepts

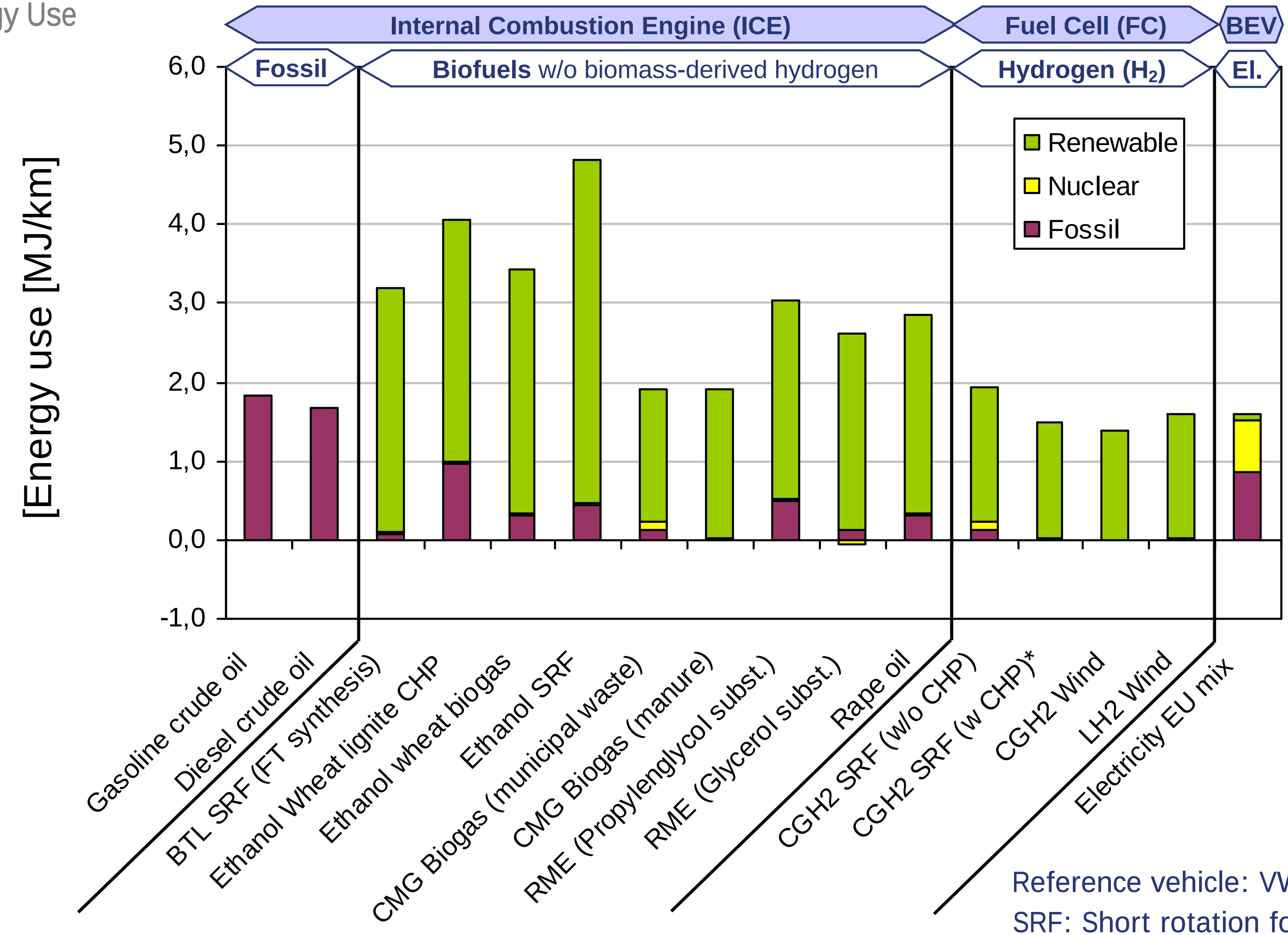
[Well-to-Wheel Supply Pathways to a Sustainable and Feedstock-flexible Automotive Fuel]

Automotive Energy Supply Pathways

Crude Oil	Gasoline
	Diesel
Natural Gas	Compressed Natural Gas (CNG)
	Methanol
	FT-Diesel, FT-Naphtha
	Hydrogen (CGH_2, LH_2)
Electric Power (fossil, nuclear)	Hydrogen (CGH_2, LH_2)
	Electricity
Electric Power (renewable)	Hydrogen (CGH_2, LH_2)
	Electricity
Biomass (Lignocellulosis)	Hydrogen (CGH_2, LH_2)
	Methanol
	Ethanol
	FT-Diesel, FT-Naphtha (BTL)
Biomass (Sugar Beet, Wheat)	Ethanol
Biomass (Oil Plants)	Plant Oil
	FAME
	BTL-like fuel (NExBTL)
Biogas	Methane from Biogas
	Hydrogen (CGH_2)

Well-to-Wheel Analyses – H_2-FCV – ICE – BEV

Energy Use

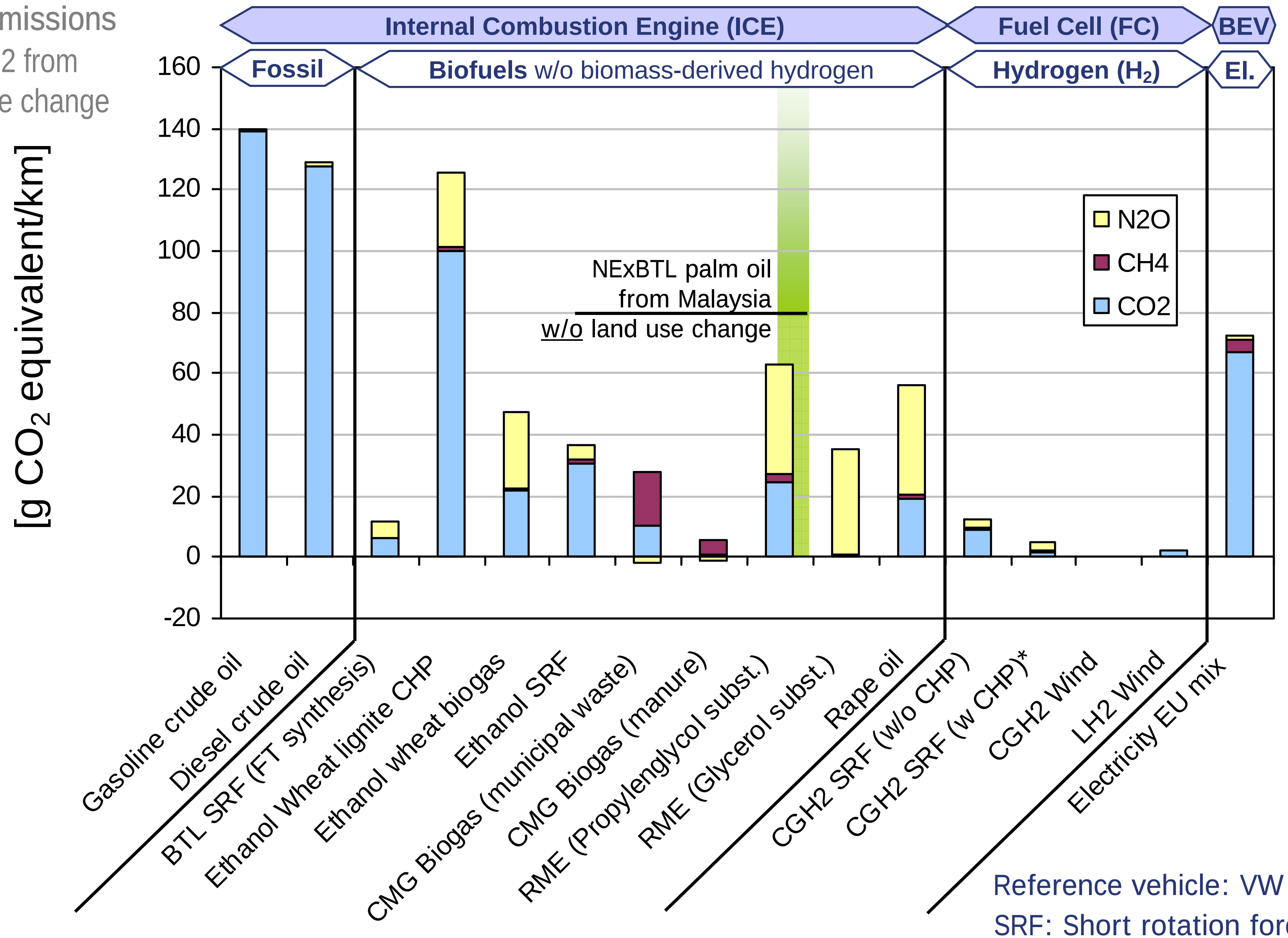


* Excess heat from gasifier and gas engine is fed into a district heating grid

Reference vehicle: VW Golf
SRF: Short rotation forestry
Sources: JEC 2009, LBST E3database

Well-to-Wheel Analyses – H_2-FCV – ICE – BEV

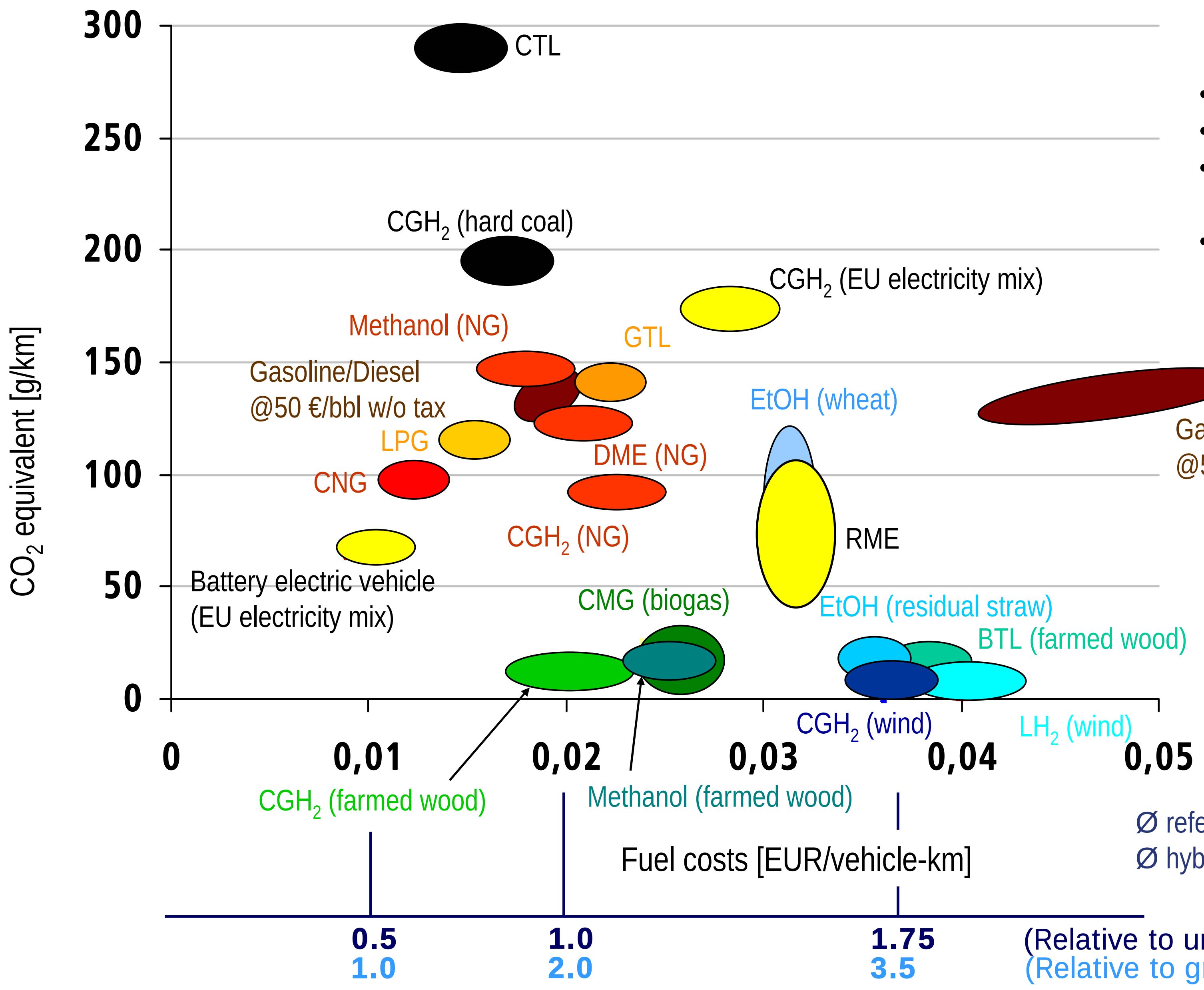
GHG Emissions
w/o CO2 from
land use change



* Excess heat from gasifier and gas engine is fed into a district heating grid

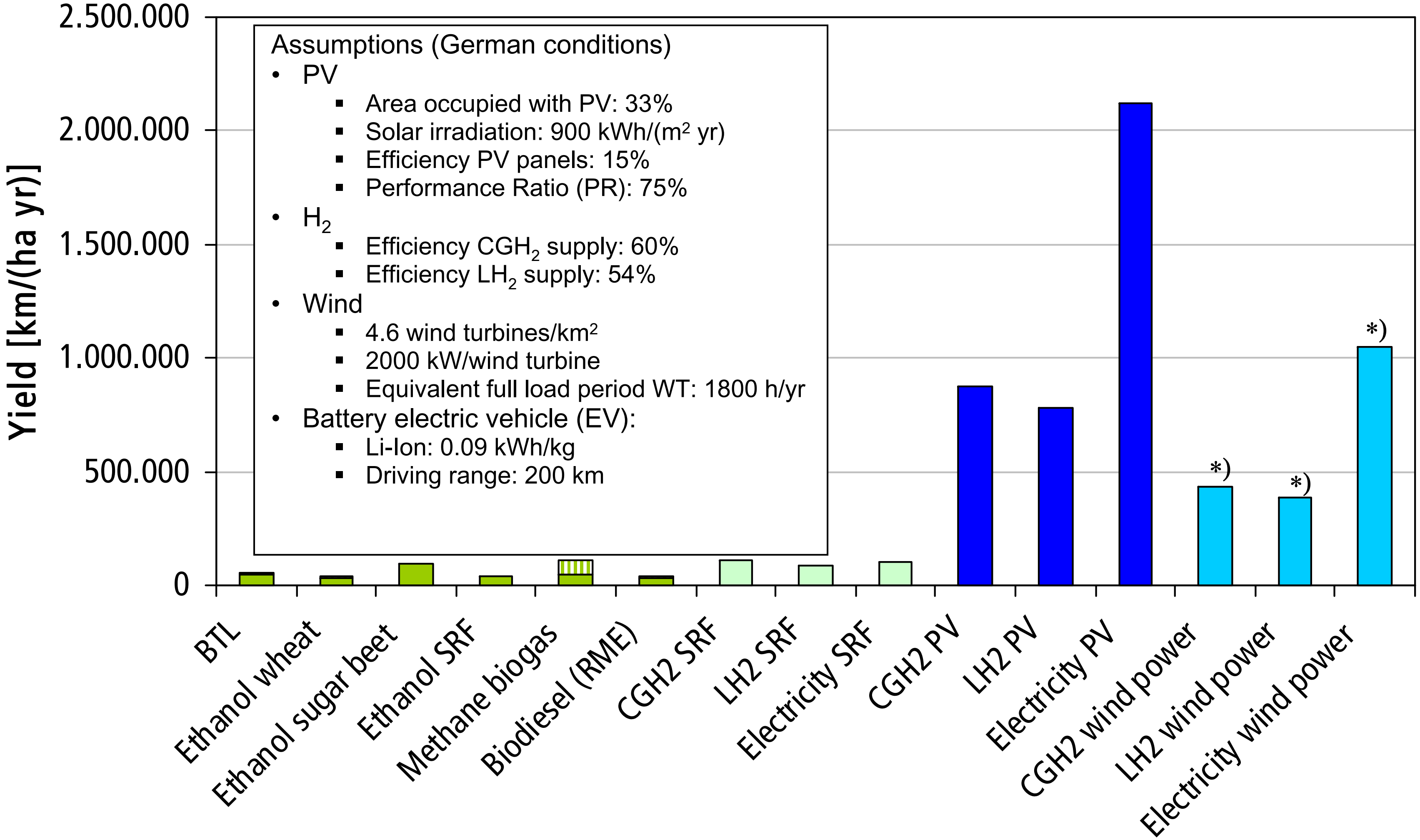
Reference vehicle: VW Golf
SRF: Short rotation forestry
Sources: JEC 2009, LBST E3database

Fuel costs versus GHG emissions "Well-to-Wheel", hybridized powertrains



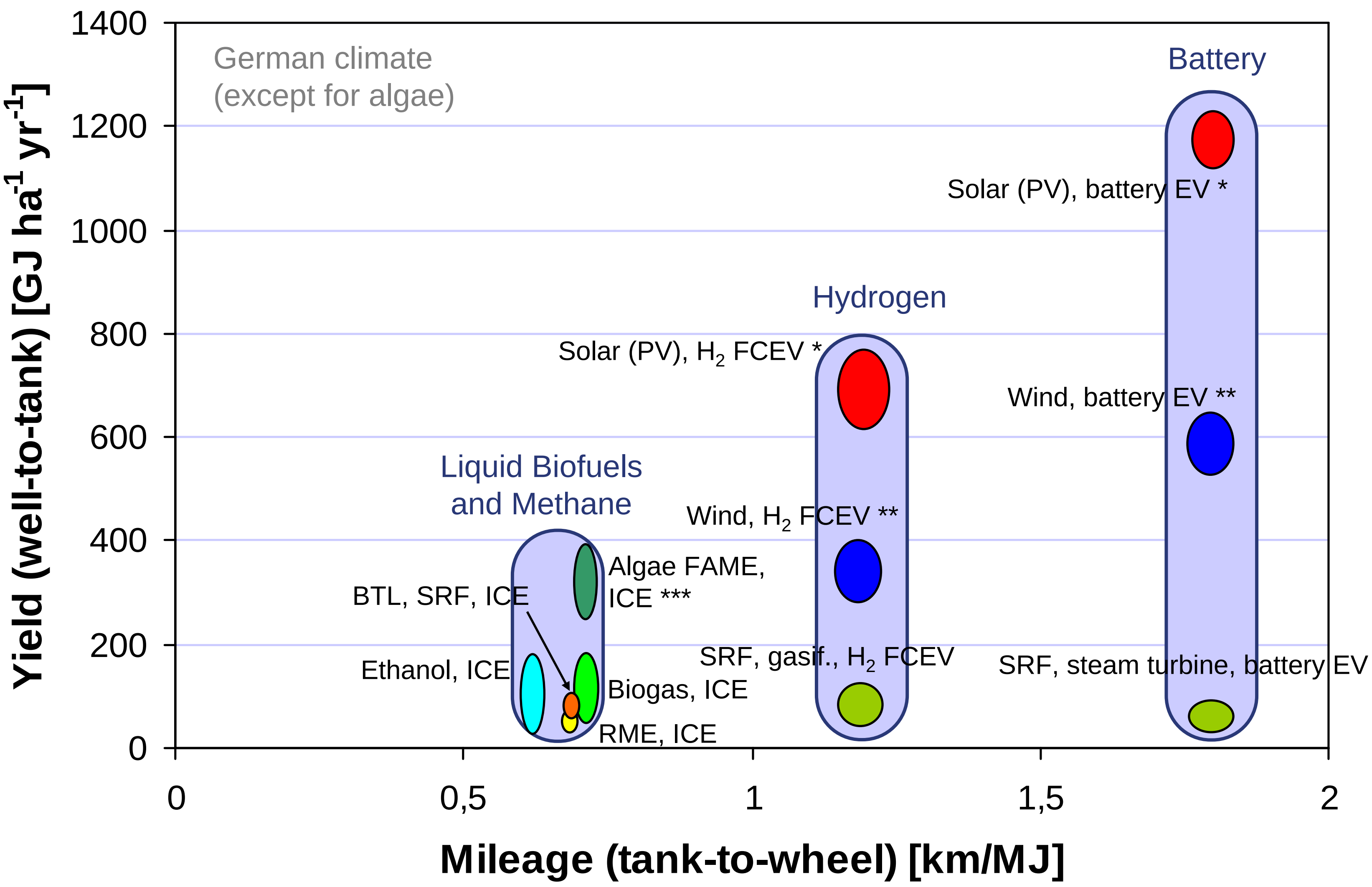
- CGH_2, LH_2: FC
- Methanol: FPFC
- Diesel, RME, BTL, GTL, CTL, DME: Diesel ICE
- Gasoline, ethanol, CMG: Otto ICE

Kilometers travelled per ha



*) more than 99% of land area can still be used for other purposes e.g. agriculture

Mapping of key performance criteria: “mileage” vs. “yield”



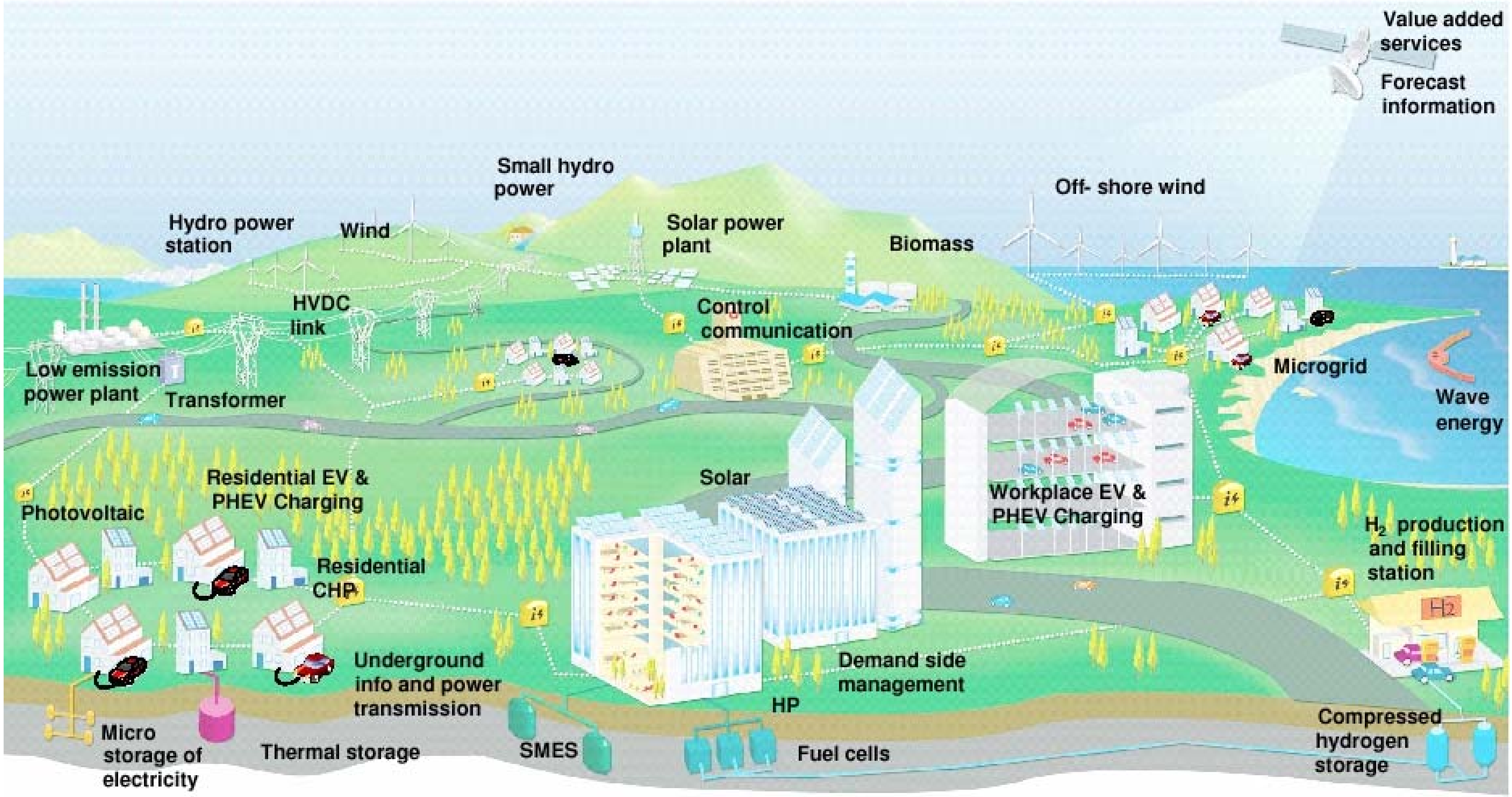
*) One third of the area is occupied with PV panels

**) more than 99% of the land area can still be used for other purposes e.g. agriculture

***) region with high solar irradiation

Hydrogen Demand, Supply and Infrastructure Build-up

Future Energy Landscape will contain a variety of decentralized sources and an intelligent transmission grid increasingly integrated with transport requirements



Legend: SMES = Superconducting Magnetic Energy Storage System, H VDC = High Voltage Direct Current, CHP = Combined Heat and Power, HP: Heat Pump

Source: European Smart Grids Technology Platform: Vision and Strategy for Europe s'Electricity Networks of the Future, European Commission, 2006 & Ricardo

Source: Prof. Neville Jackson, Ricardo plc., June 2009

Hydrogen Demand and Supply - the HyWays case

The European Hydrogen Energy Roadmap

Roadmap and Action Plan for Europe

HyWays
The European Hydrogen Energy Roadmap

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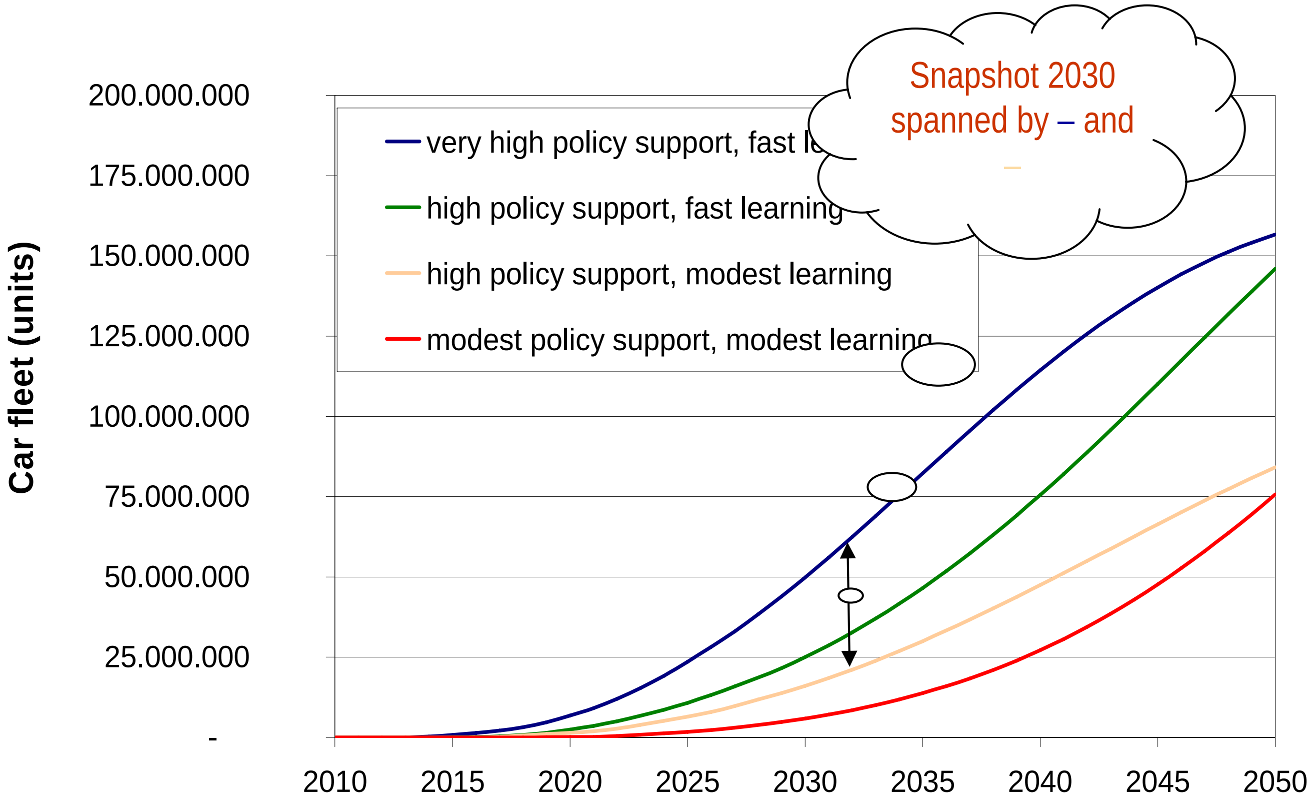

Vehicle fleet targets: Snapshots 2020 & 2030

HyWays passenger car fleet targets for EU15	"Snapshot 2020" (HFP)	"Snapshot 2030" (HyWays Proposal)
Lower bound Requires high policy support!	1 million	15 million
Upper bound Requires extreme policy support!	5 million	50 million
What could happen with modest policy support	*0.1 million*	*5 million*

Spatial coverage of fuelling stations in Europe

HyWays
The European Hydrogen Energy Roadmap

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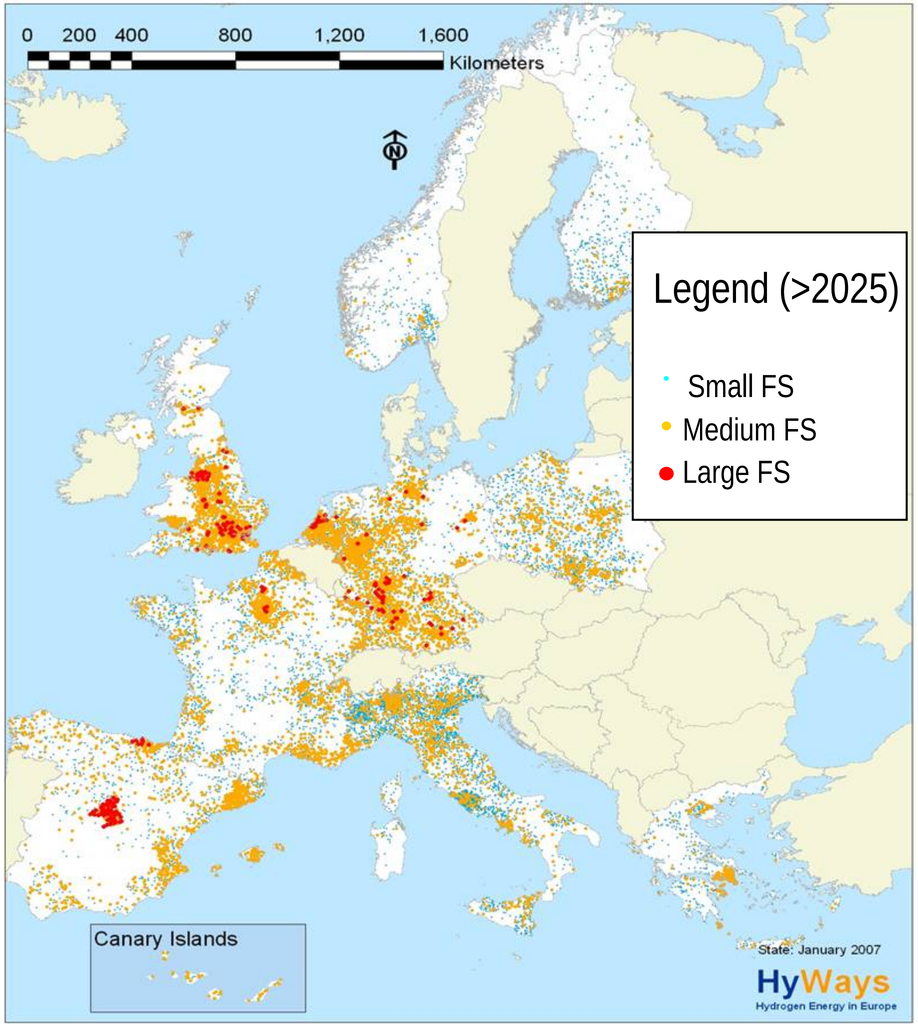

Example: fuelling stations spatial coverage for 8% vehicle penetration

- First phase (2010-2015):
  - A limited number (400) of small H_2 stations
  - serving around 10.000 H_2 cars (25 cars/station in average)
  - for corridors another app. 500 small fuelling stations would be required
- Demand develops (2015 – 2025):
  - also bigger filling stations will come in
  - between 13,000 and 20,000 H2 stations and 10 mill. H_2 vehicles in Europe.
- Massive rollout of H_2 (post 2025):
  - Gradually, same patterns as today's conventional refuelling network is reached

Costs of infrastructure build-up

HyWays
The European Hydrogen Energy Roadmap
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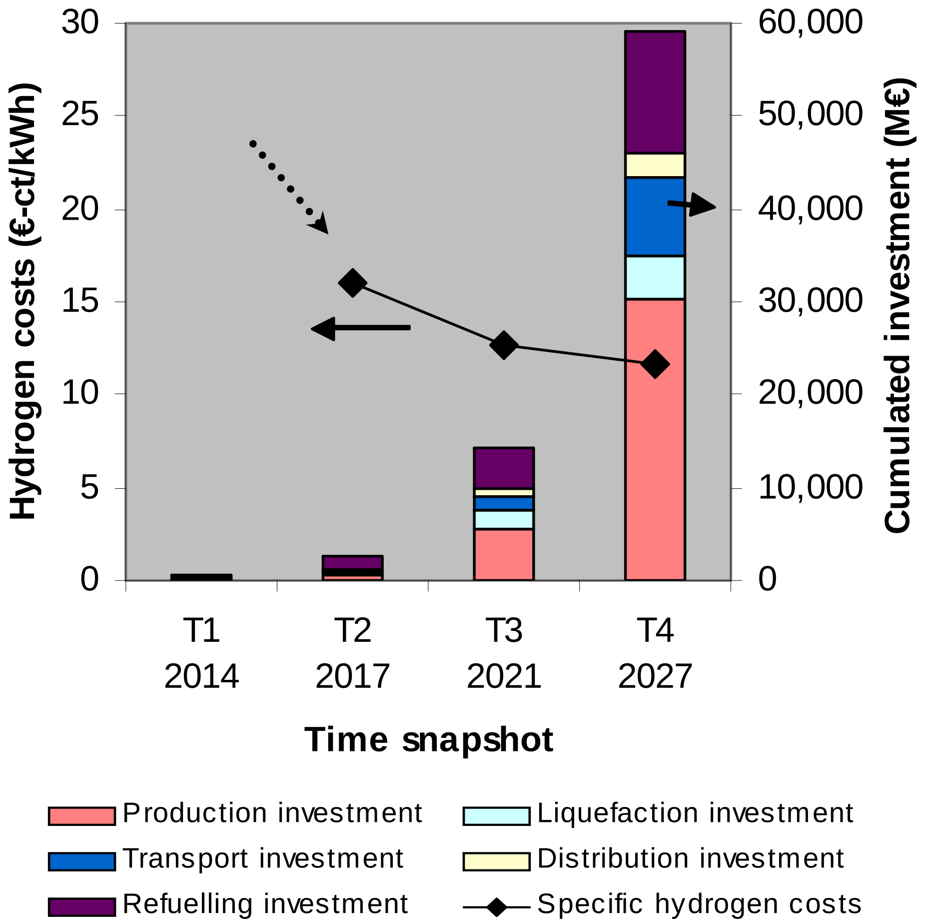
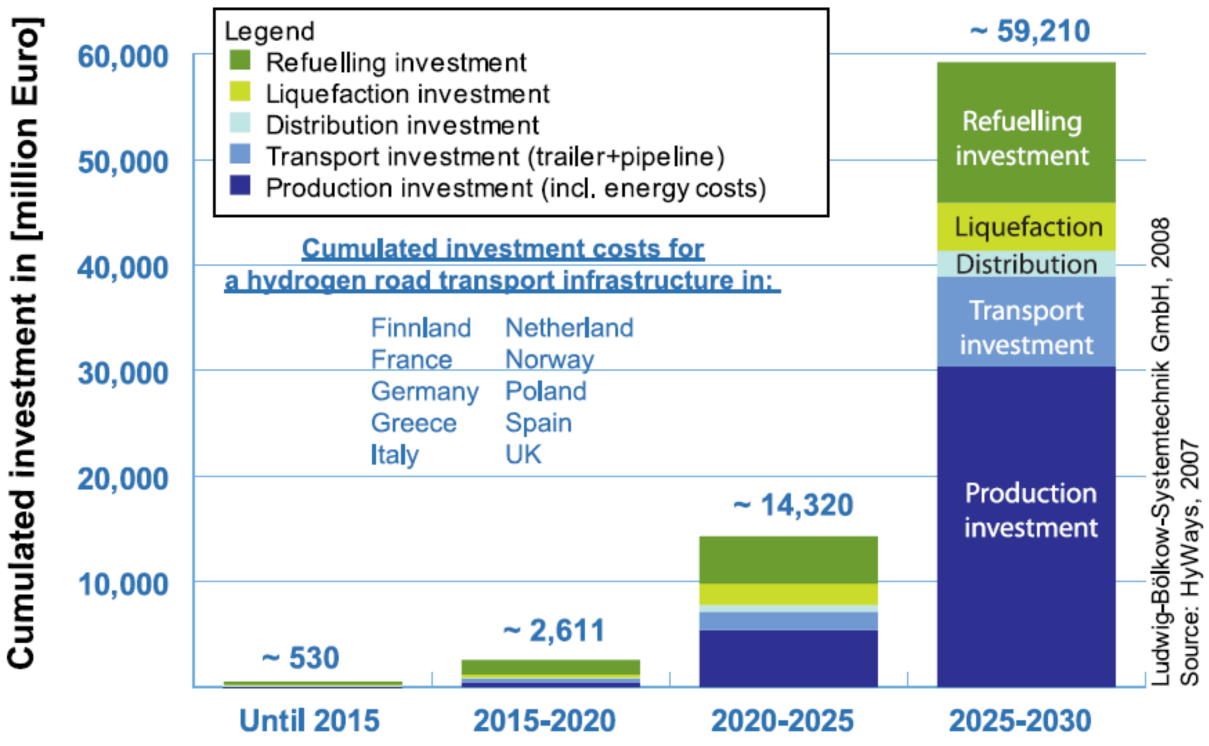
Cumulated investment and specific H_2 costs



- High initial costs (due to under-utilization of plants and fillings stations)
- But: quick reduction to 1.1-1.6 €/ liter$_{\text{diesel equivalent}}$) from second phase
- Relevant variation of cost between countries (depending on availability of feedstock, stakeholder selection of hydrogen pathways, car and population density)
- Transport, distribution and refuelling contribute significantly to investment

Costs of infrastructure build-up

Infrastructure costs



Cumulative Investment Costs for a Hydrogen Road Transport System
in ten European Countries

Structure of the investments in a hydrogen economy of the six HyWays countries

HyWays
The European Hydrogen Energy Roadmap

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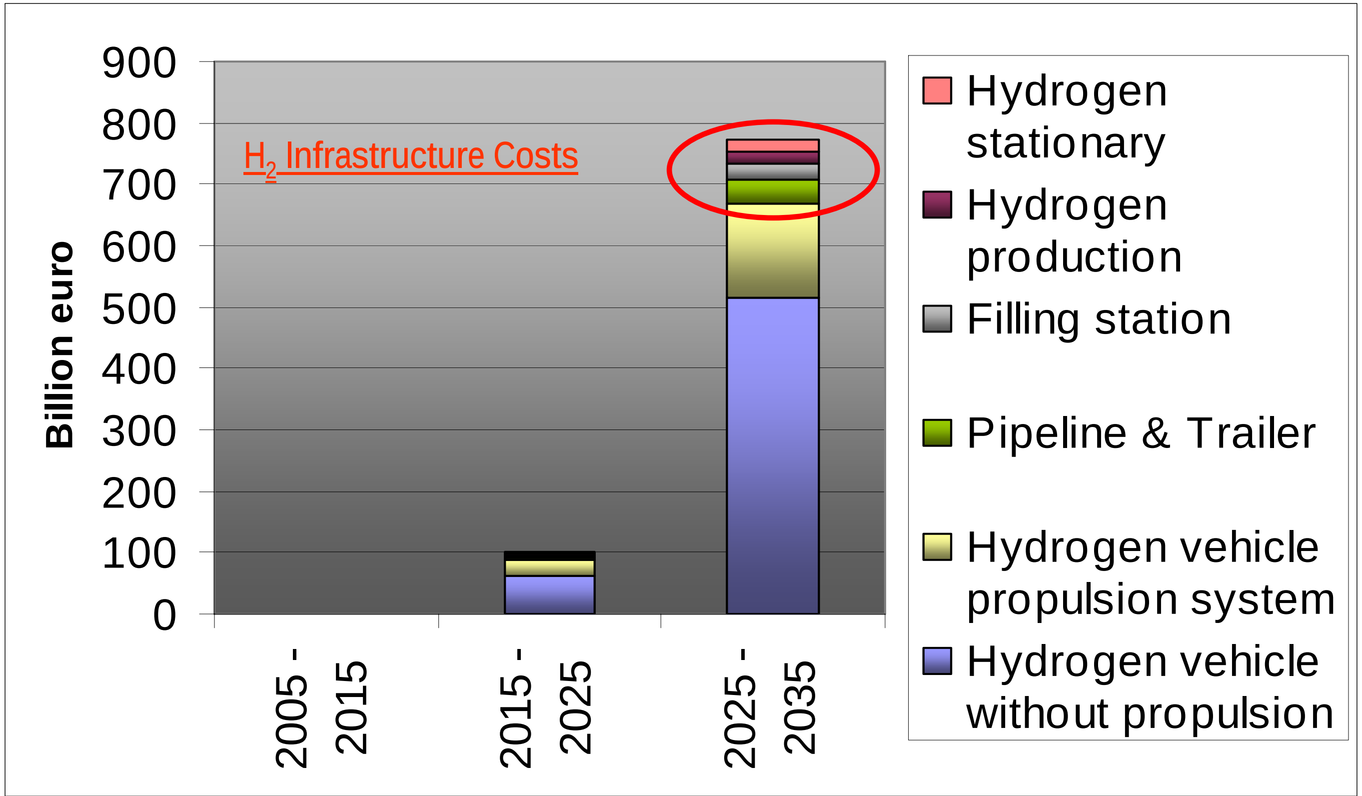

(cumulative investments for a ten-year period, hydrogen high penetration scenario, based on 6 HyWays Phase I member countries: D, F, I, GR, N, NL)

Interpretation of results:

- More than 60% of the invest costs have to be brought up for the conventional part of the vehicle
- about 20% are for the H_2-specific onboard part of the vehicle (e.g. FC and storage)
- about 15% are for the H_2 production, transport, distribution and dispensing

Portfolio Analysis
Hydrogen User Costs vs. GHG Emissions

HyWays
The European Hydrogen Energy Roadmap

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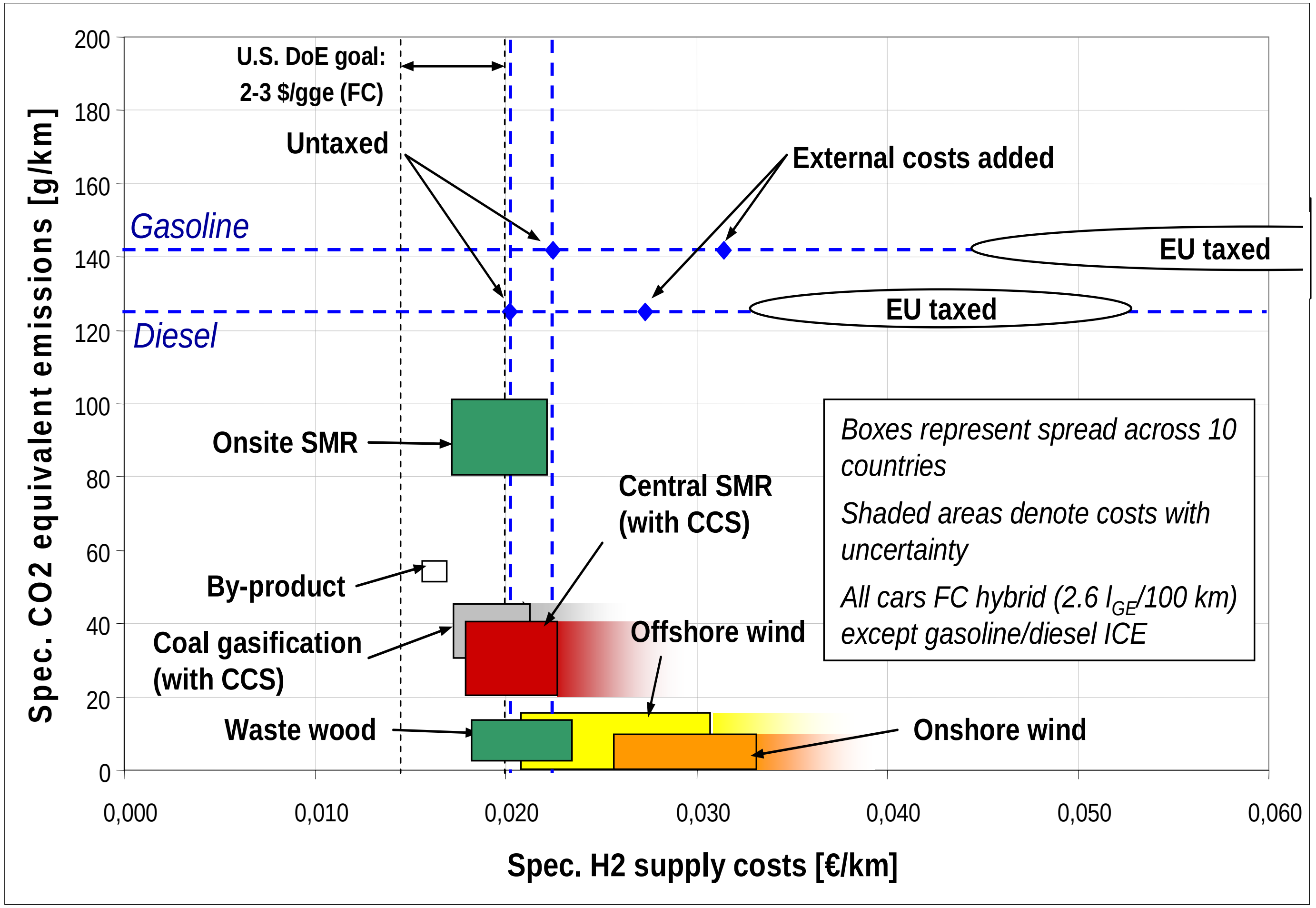
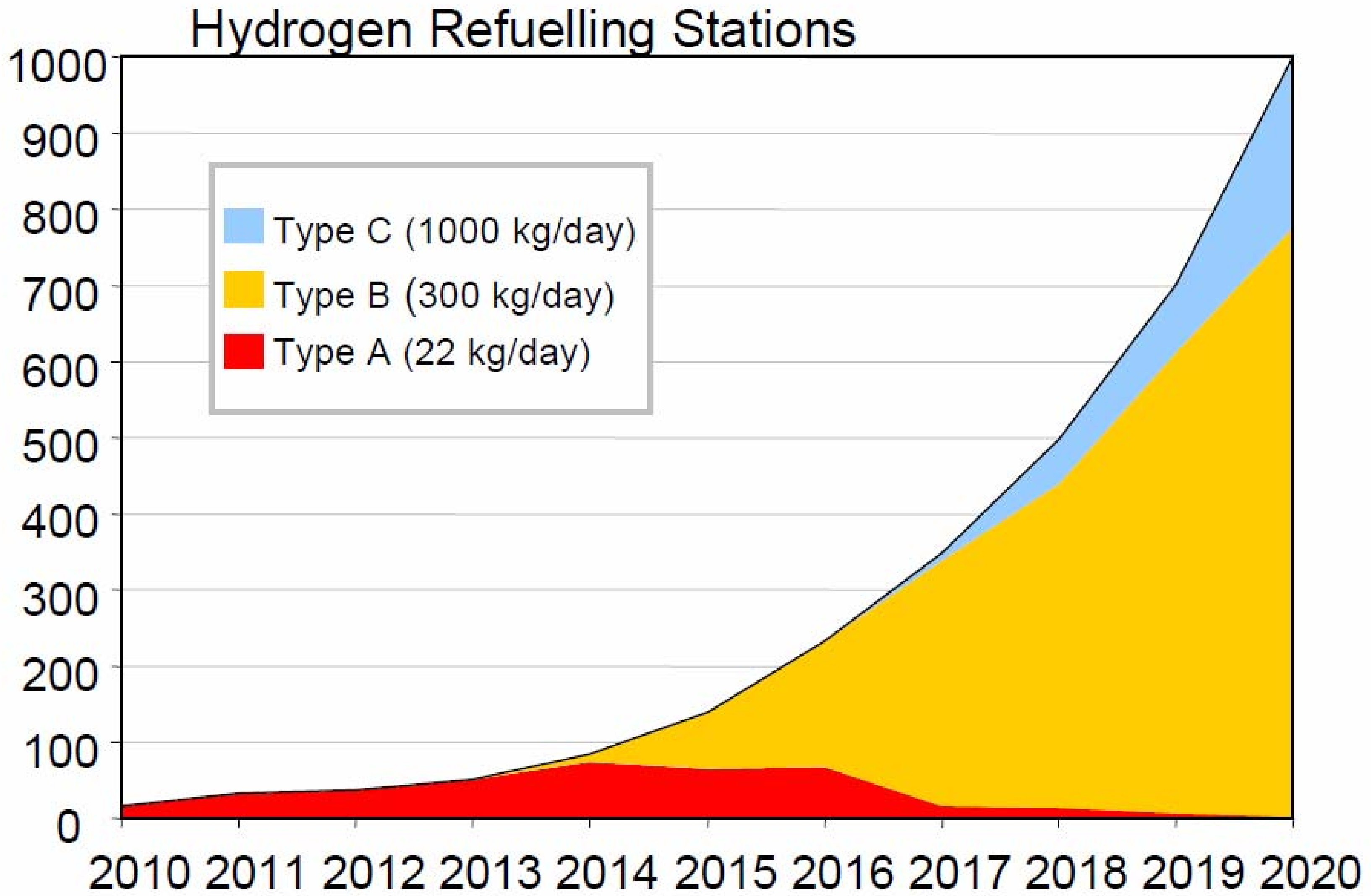
Greenhouse Gas Emissions



Source: HyWays - H_2 Well-To-Wheel pathway portfolio for 10 EU member states (2030)

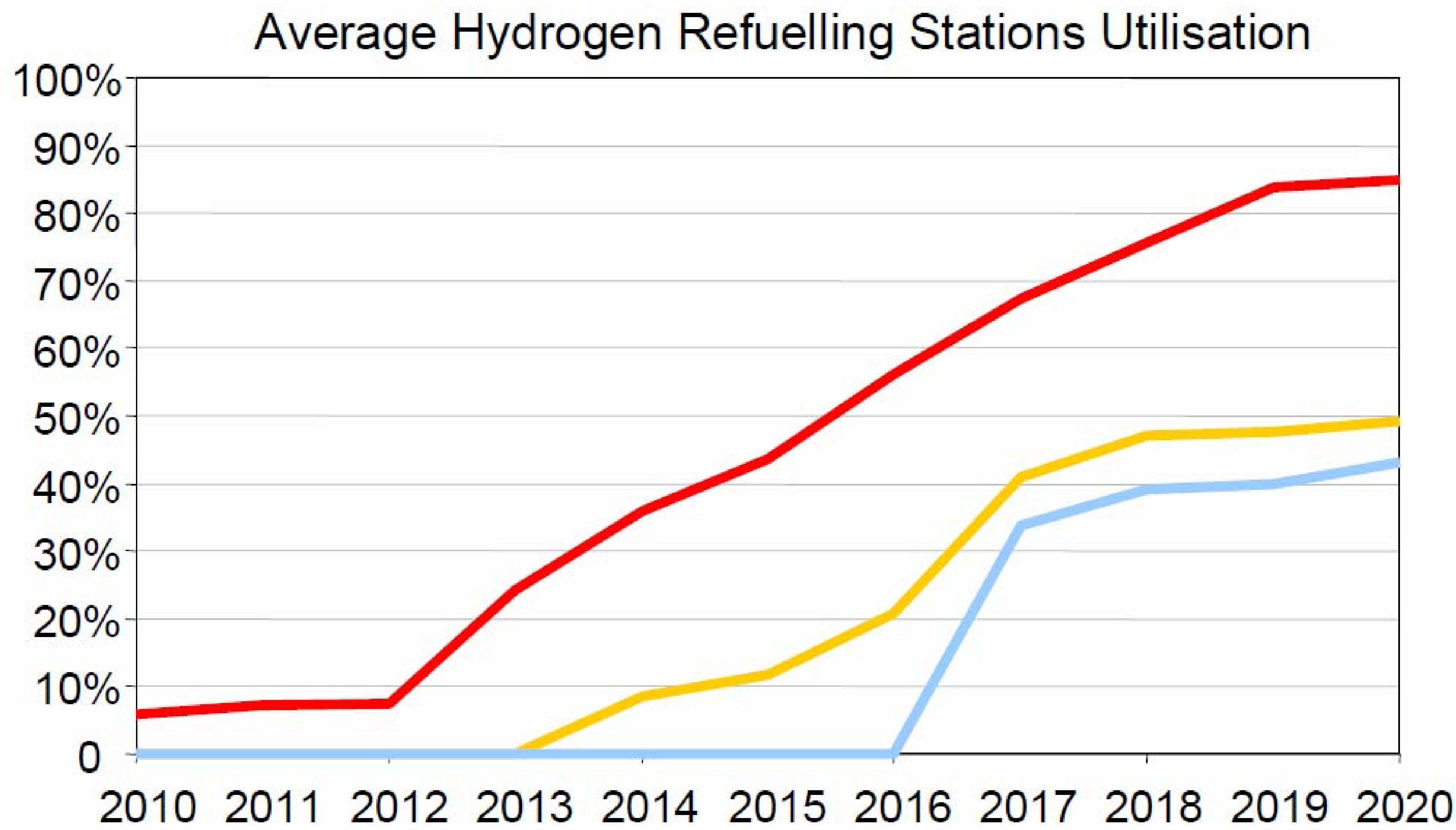
Hydrogen Demand and Supply
- the case for Germany

Estimated share of hydrogen refueling station in Germany



Source: Ulf Hafseld, StatoilHydro, Stavanger May 13, 2009

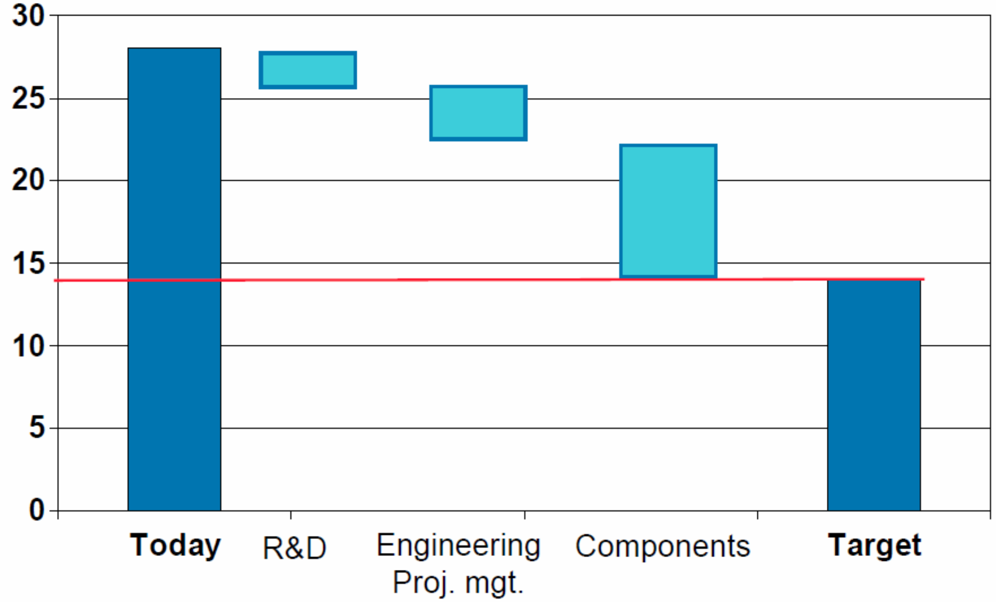
Estimated utilization of hydrogen refueling stations



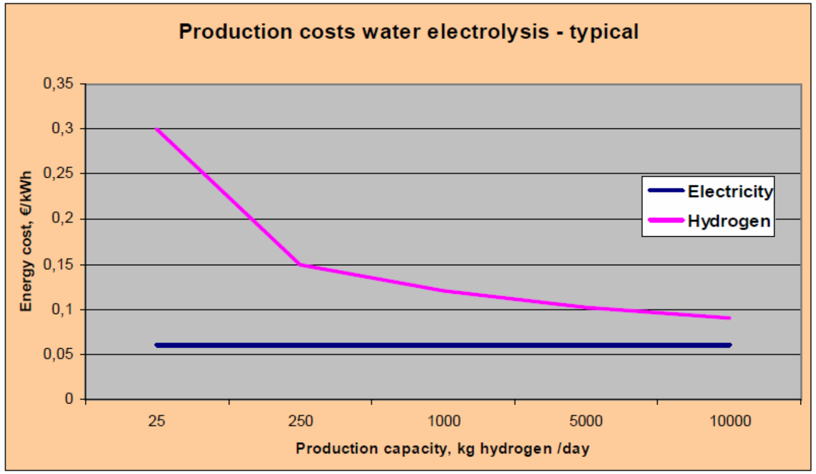
Source: Ulf Hafseld, StatoilHydro, Stavanger May 13, 2009

Cost reduction measures for electrolysers

Ex: cost of a electrolyser production plant on-site



Production cost of hydrogen will draw nearer electricity costs as plants get larger



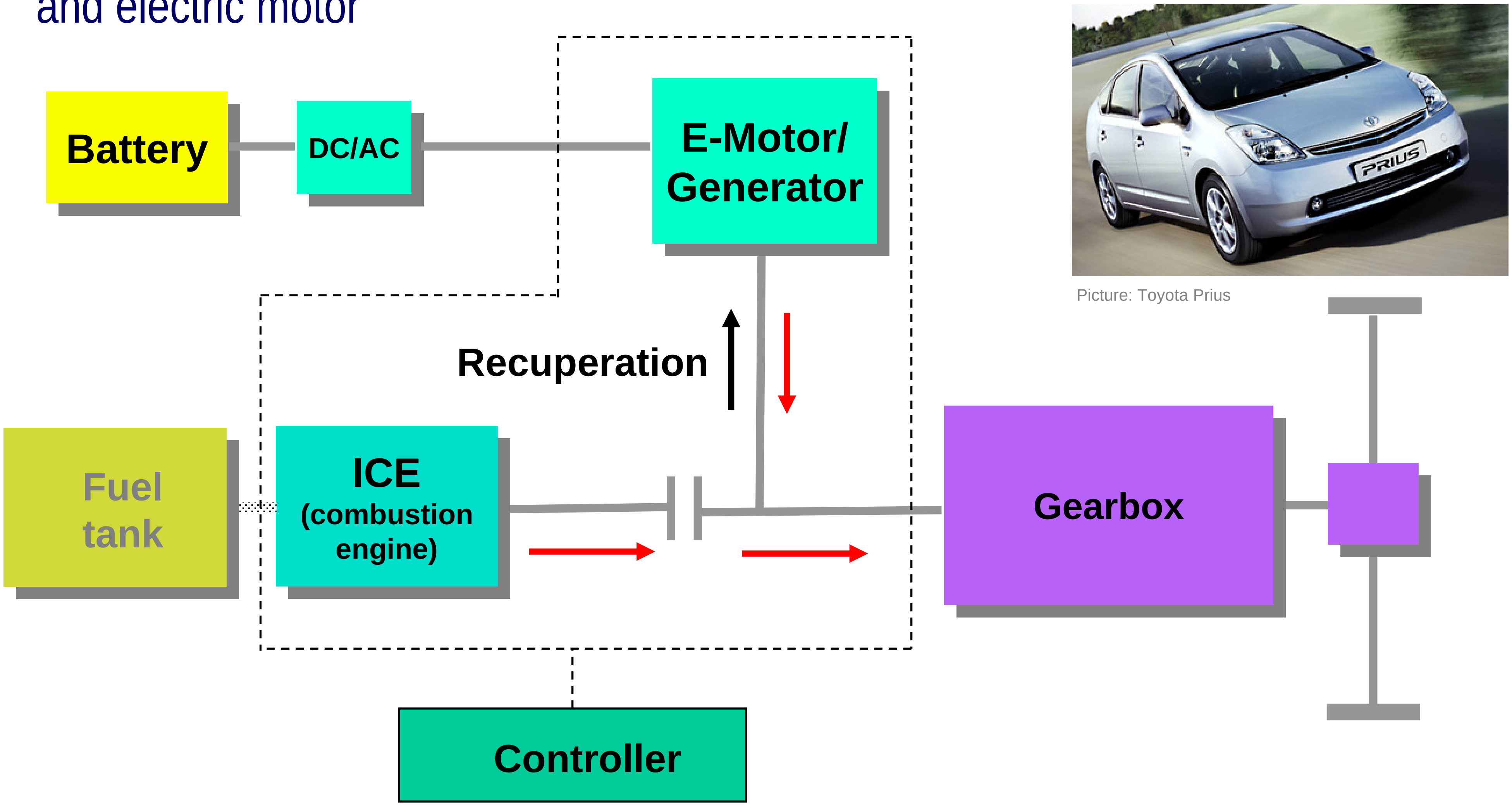
Cost of electricity is typically 70 % of the cost of producing hydrogen by water electrolysis

Source: Ulf Hafseld, StatoilHydro, Stavanger May 13, 2009

Electric vehicles and charging infrastructure requirements

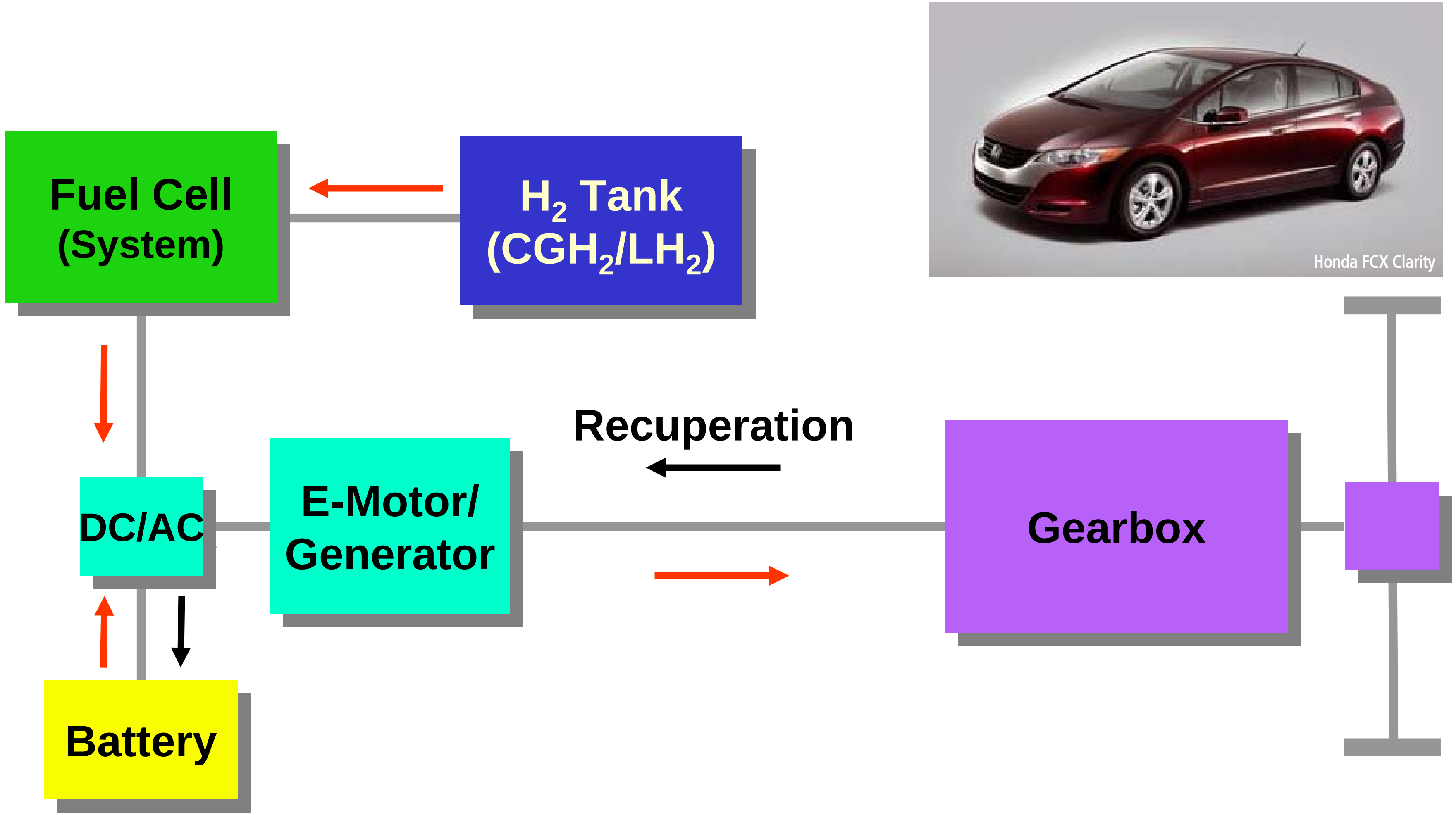
ICE powertrain hybridisation

Hybrid vehicles with internal combustion engine (ICE) and electric motor



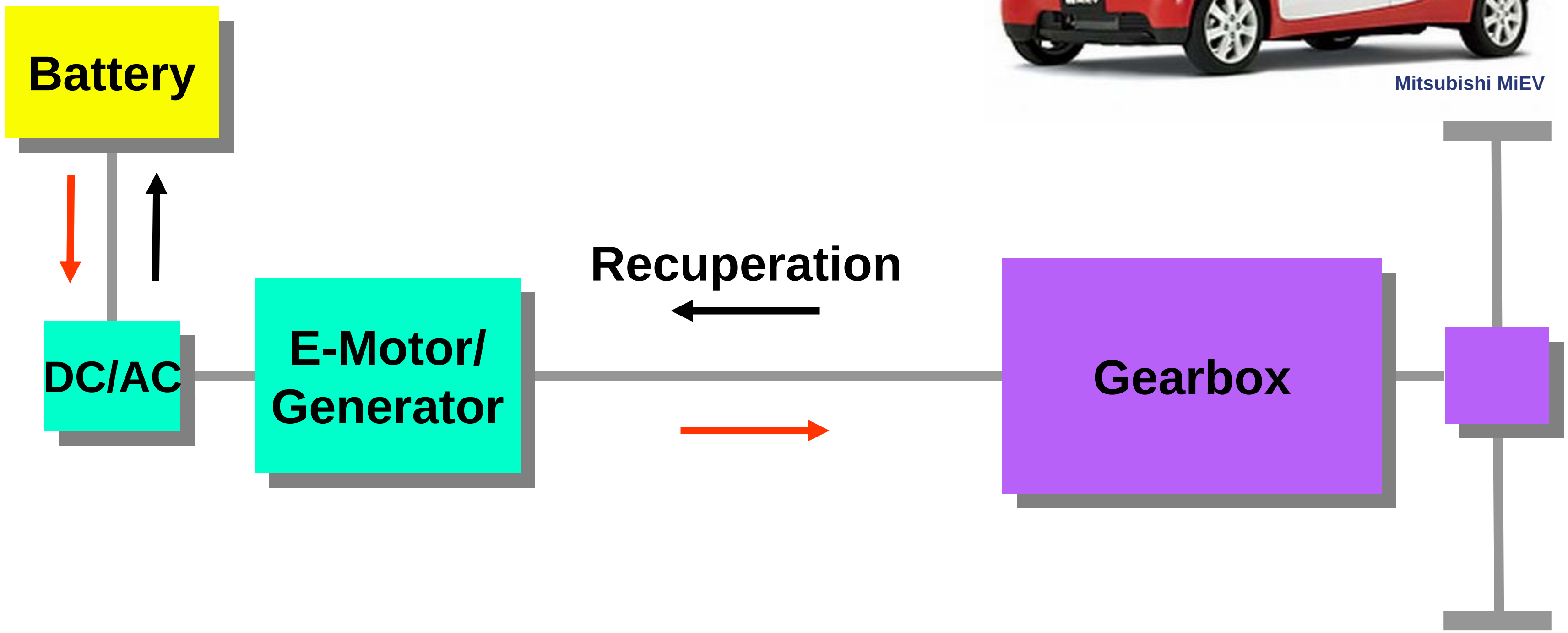
Picture: Toyota Prius

Hybrid vehicles with fuel cell (FC)



Battery-electric vehicle

Mitsubishi MiEV



Fuel consumption “Tank-to-Wheel“

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	Non hybrid [$liter_{GE}$/100km]	Hybrid [$liter_{GE}$/100km]
Gasoline (Otto engine)	**5.9**	**5.0**
Diesel (Diesel engine with DPF)	**5.5**	**4.5**
CNG (Otto engine)	**5.8**	**4.3**
Ethanol (Otto engine)	**5.8**	**5.1**
H_2 compressed storage – CGH_2 (Otto eng.)	**5.2**	**4.6**
H_2 compressed storage– CGH_2 (Fuel Cell)	**2.9**	**2.6**
H_2 liquid storage– LH_2 (Fuel Cell)	**2.9**	**2.6**
Battery-electric vehicle	**1.7**	**-**

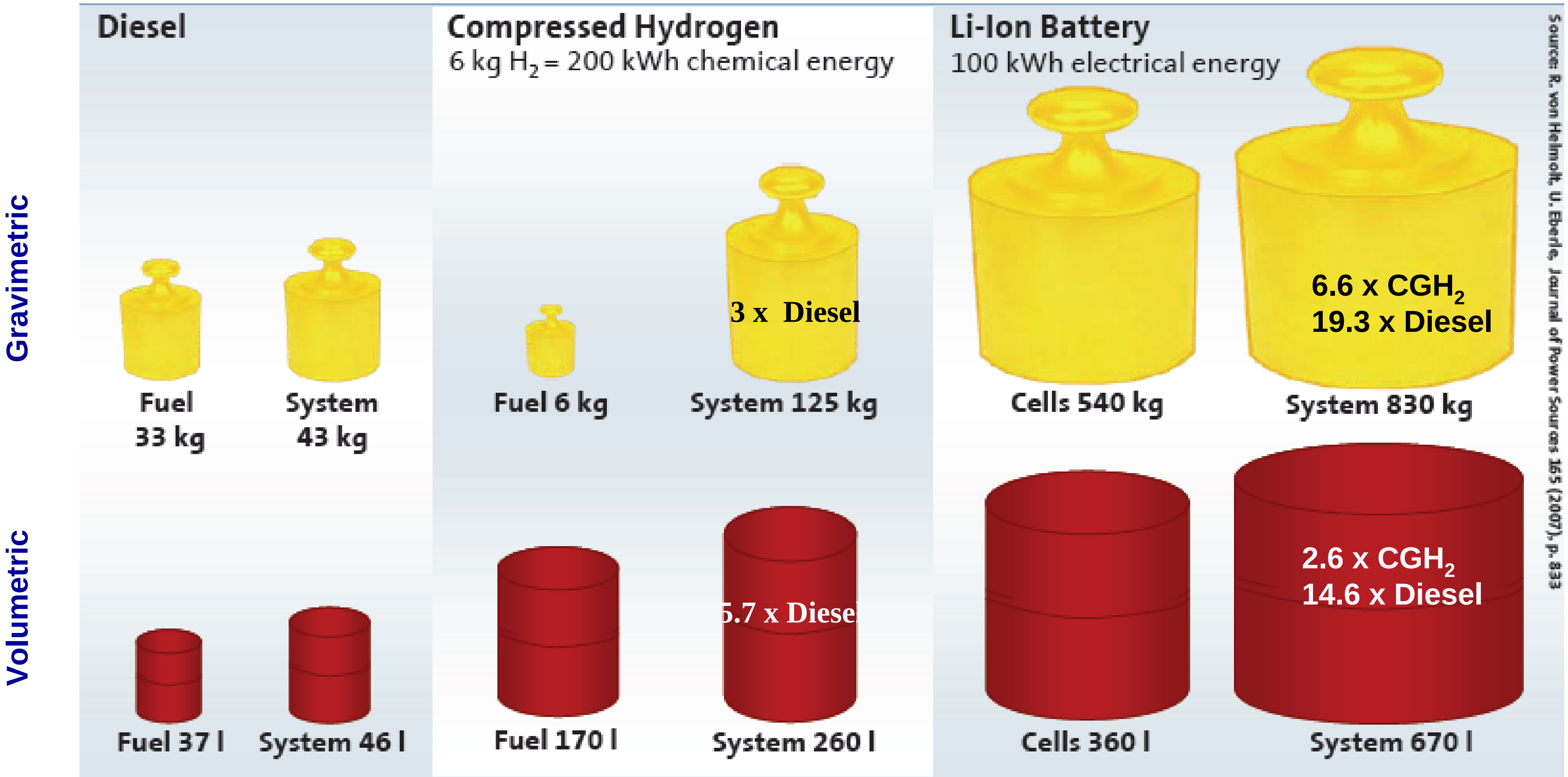
Source: CONCAWE/EUCAR/JRC 2007; LBST

- Reference vehicle: VW Golf
- GE: gasoline equivalent
- DPF: Diesel particulate filter
- LHV: gasoline = 32.2 MJ/l, Diesel = 36.0 MJ/l (3.6MJ = 1kWh)
- Battery electric vehicle: incl. Efficiency of battery charger , Autonomy: 200 km

Comparison of storage system densities [500 km]

Diesel: *w/o egine and gearbox* - CGH_2-FCV: *w/o FC and electric motor* - BEV: *w/o electric motor*

Assumed Li-Ion energy density: 120 Wh/kg



Source: Dr. Rittmar von Helmolt - TechGate Vienna - 13.12.2007

Comparison of storage alternatives

Energy Storage Device	Energy Density	Power Density
	Wh/kg	kW/kg
Lithium Ion	150-200	1
NiMH	<100	0.8
Zebra	~90	~0.2
Bipolar Lead Acid	30	
Super Capacitors	5	<5
Lithium Ion Polymer	100 to 155	0.1 – 0.3
Cr-F-Li		~ 0.7
Flywheel	~50	~ 4
Liquid N2	215	
Air at 300 bar	180	
H2	33,500	
Gasoline	**12,000**	

Source: Ricardo analysis &* EU STORhY Project

- Liquid hydrocarbon fuels are the most dense and lowest cost form of energy for mobile applications
- Current vehicles offer a range of 300-600 miles
- Fuel tank filling rate approaches 30-40 megawatts!
- 350 mile range Li-ion battery (60 kW.hr) will cost €25000+ and weigh over 1000 kg
  - Assuming costs can be reduced to around €500/kW.hr
  - Battery can operate repeatedly to 80% depth of discharge
- Full range electric vehicle unlikely in short-medium term
  - Niche market for city vehicles

Alternative energy storage not competitive with liquid hydrocarbons Li-Ion chemistries still 100x lower energy density than gasoline

Source: Prof. Neville Jackson, Ricardo plc., June 2009

Comparison of Li-Ion Battery Specifications

Vehicle	Battery Supplier	Type	Energy (kWh)	Peak Power (kW)	Weight (kg)	Specific Energy (Wh/kg)	Specific Power (W/kg)
FPBEV	*DOE goal*[1]	*n/a*	*25-40*	*50-100*	*250*	*100-160*	*200-400*
Tesla Roadster	**Tesla Motors**	**Li-Ion**	**53**	**230**	**450**	**118**	**511**
TH!NK City	A123 Systems[2]	Li-Ion	19	no data	260	73	no data
	EnerDel[2]	Li-Ion	26	no data	260	100	no data
n/a	JCS[1]	Li-Ion	24	55	265	90	210
n/a	GAIA[1]	Li-Ion	22	50	200	115	250
n/a	LitCel[1]	Li-Ion	20	155	170	118	912
n/a	Lamilion[1]	Li-Ion	9.2	62	150	60	400
n/a	Kokam[1]	Li-Ion	30	130	265	110	490

[1] Data extracted from Tables 3-2 and 3-6 of the Expert Panel Report
[2] Data reported by Green Car Congress [11]

Source: Dr. Andrew Simpson, Curtin University of Technology, Auto CRC/RMIT Seminar , 22 June 2009

Characteristics of different battery concepts in comparison to compressed hydrogen (CGH_2)

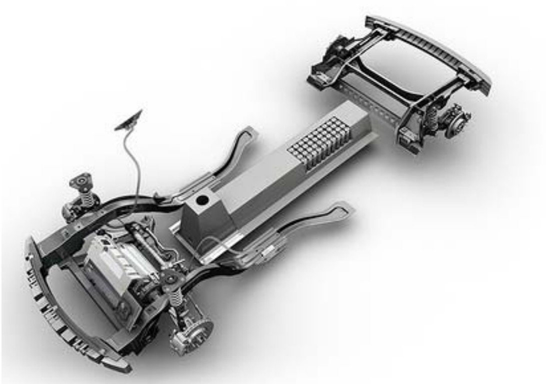
	Lead	Ni/Cd	Ni/MH	Li-Ion	Zn/Br	Na/S	Na/NiCl	CGH_2-35	CGH_2-70
Gravimetric energy density [kWh/kg]	0.025 [1)] – 0.050 [2)]	0.035 [1)] – 0.080 [2)]	0.050 [1)] – 0.120 [2)]	0.060 [3)] – 0.200 [13)]	0.065 [4)]	0.110 [4)]	0.089 [4)]	1.900 [5)]	1.600 [5)]
Volumetric energy density [kWh/l]	0.090 [4)]	0.110 [4)]	0.160 [4)]	0.120 [4)] – 0.190 [11)]	0.065 [4)]	0.120 [4)]	0.113 [4)]	0.526 [5)]	0.718 [5)]
Charge/ di-scharge effi-ciency	0.85 [4)]	0.75 [4)]	0.65 [4)]	0.90 [4)]	0.65 [4)]	0.90 [4)]	0.90 [4)]		
Discharge efficiency [14)]	0.94 [4)]	0.89 [4)]	0.83 [4)]	0.95 [4)]	0.81 [4)]	0.92 [8)]	0.95 [4)]	0.50 [6)]	0.50 [6)]
Life expec-tancy [full cy-cles]	200 [2)] – 800 [4)]	1,500 [2)] – 2,000 [4)]	300 [2)] – 1,000 [4)]	300 [2)] – 8,000 [15)]	1,500 [4)]		1,000 [4)]	20,000 [7)]	20,000 [7)]
Gravimetric power density [W/kg]	100 [4)]	180 [4)] – 1,000 [12)]	100 [4)] – 1.300 [12)]	125 [4)] – 2,000 [12)]	90 [12)] - 100 [4)]	125 [4)] 169 [16)]	109 [4)]		
Operating temperature [°C]	-10 - +40 [4)]	-30 - +60 [4)]	-10 - +60 [4)]	-10 - +60 [4)]	+20 - + 40 [4)]	+320 - +380 [4)]	+250 – 370 [4)]		
Fast charge time [h]	4 [4)] – 16 [2)]	1 [2)] – 2 [9)]	1 – 4 [2)]	2– 4 [2)]	2 [4)]	8 – 10 [10)]	8 – 10 [10)]	0.05	0.05

[1)] [ThermoAnalytics 2001]; [2)] [BatteryUniversity 2003], number of cycles for 80% design capacity; [3)] [Subaru 2003]; [4)] [LBST 1996], [ISE 2001]; [5)] [Quantum 2003]; [5)] [Hopkins 2003], [6)] [CONCAWE 2003]; [7)] pressure vessel [EIHP 2000]; [8)] [Wagner 2002]; [9)] [TWIKE 2003]; [10)] [BMW 2003]; [11)] Lithium Ion High Energy Module [Duong 2001]; [12)] power optimized [IEA 2004]; [13)] [Fortu 1/2004]; [14)] efficiency of battery discharge (i.e. w/o taking into account charging of battery); [15)] [Saft Nov 2007]; [16)] [ZSW, 2005]

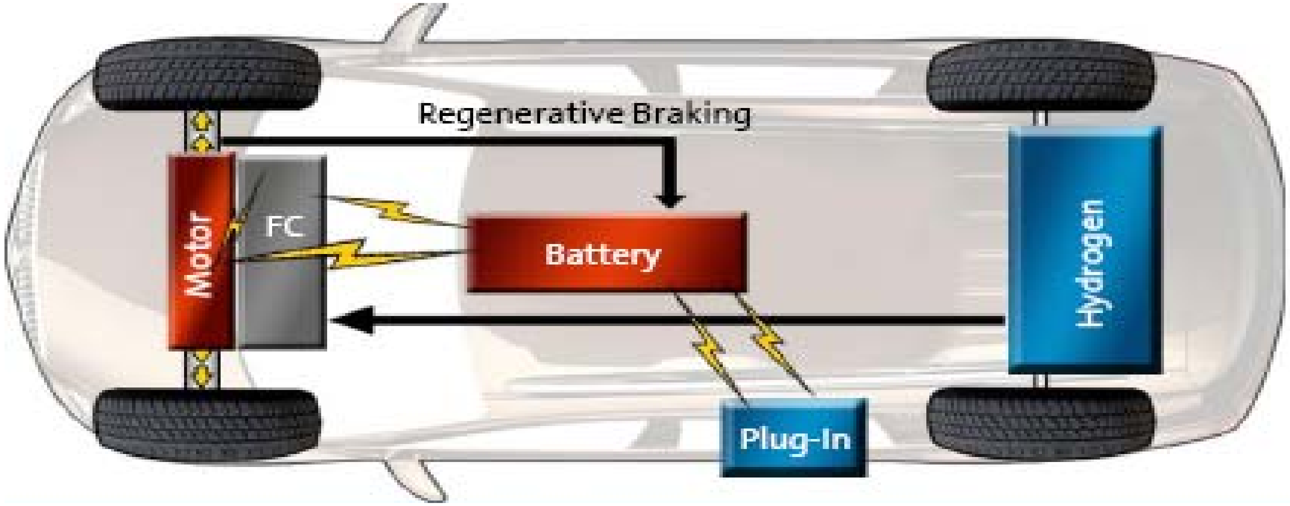
Powertrain Hybridisation – Development towards E-Drive

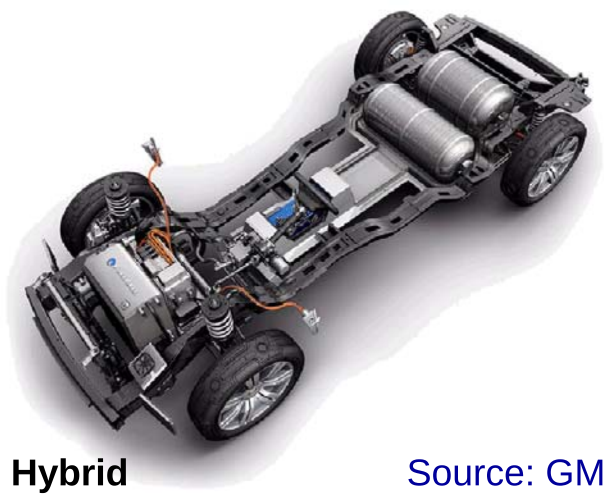
2010 +

Volt ICE (Plug-In) Hybrid



Volt Battery Electric Vehicle





Provoq FC (Plug-In) Hybrid

Source: GM

Nissan Leaf and Better Place/ Renault

Mitsubishi i-MiEV

Hydrogen Propulsion – State-of-the-Art 2009

A Class F-Cell 2004


B Class F-Cell 2009

B Class F-Cell 2009


GM Equinox 2008 - 2010

GM Equinox 2008 - 2010


Toyota FCHV

Honda FCX Clarity 2008


FCX Clarity Vehicle Assembly at Honda New Model Center 2008.06.16

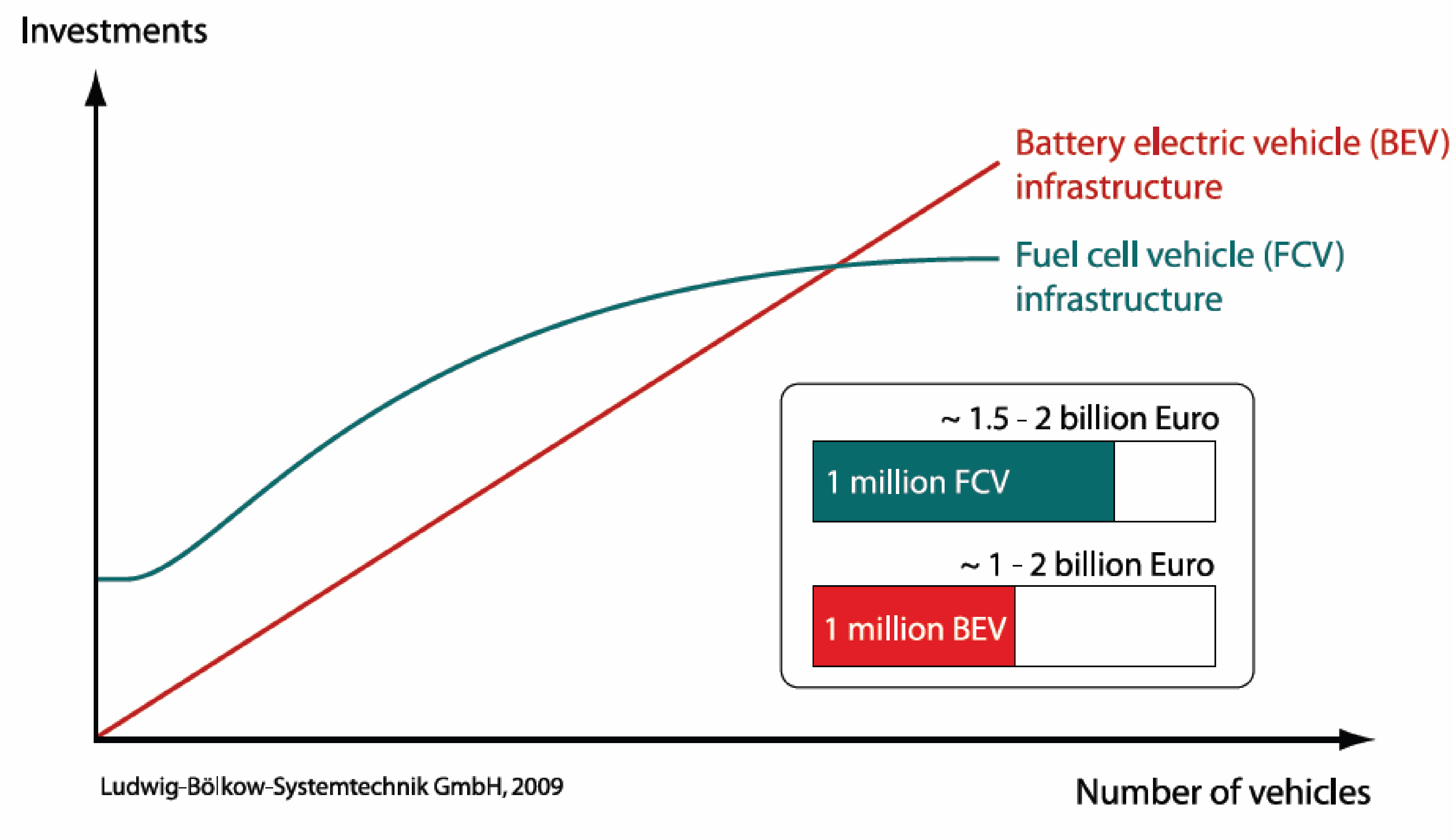

FCX Clarity Vehicle Assembly at Honda New Model Center 2008.06.16

FCX Clarity Vehicle Assembly at Honda New Model Center 2008.06.16


Honda FCX Clarity 2010

Comparison of infrastructure costs for H_2 & electricity filling

ludwig bölkow systemtechnik



Auto-OEM FCV Strategies

Fuel Cell Vehicle Commercialization

Daimler:
..is now in the midst of mass production process development…. Sales start is projected for 2015

Toyota:
... plans to come to market in 2015, or earlier, with a vehicle that will be reliable and durable, with exceptional fuel economy and zero emissions, at an affordable price

Hyundai/Kia:
Specifically it expects a small number of vehicles in customers' hands in 2012 but, by towards the end of that decade, it expects to sell hundreds of thousands of fuel-cell vehicles

Nissan:
..intends to offer an FCV with a price differential of at best 20% compared to a conventional powertrain in 2015

GM:
..the fuel cell program left R&D ... and became part of Powertrain …and financial viability .. In 2017 or 2018

Honda:
Battery driven vehicles presently are merely an alternative for the city ..We bet on fuel cell technology.

Fuel Cell Vehicle Commercialization

Daimler:

At Mercedes-Benz, Dr Dieter Zetsche, the chairman, insisted that the company was “very, very serious” about mass producing fuel-cell cars, something about which others in the industry are now very cautious. The start of that mass production will be in 2010 at an extremely low level in the B-Class but Zetsche says that he is convinced that by 2014-15, distinctive, economically competitive fuel cell models will be in production, probably rising to 100,000 a year.

Source: From the Geneva Motor Show, The Times, 07 March 2008

The breakthrough has been achieved - Interview with Daimler CEO Zetsche

Daimler CEO Zetsche explained that Diamler is now in the midst of mass production process development for the fuel cell vehicle and that the FCV finally has achieved the technical breakthrough. Sales start is projected for 2015. First clients will be environmentally conscious customers. The initial prices will be somewhat higher than those for conventional cars, but more or less in the same order. Also regarding refuelling infrastructure Zetsche sees the Gordian knot being cut through the MoU signed with energy and infrastructure companies to provide a refuelling infrastructure in Germany over the next years.

Source: ADAC Motorwelt of October 2009

Fuel Cell Vehicle Commercialization (2)

Honda:

Statements by Takeo Fukui, the president of Honda

“I would say there's no future for the auto industry without fuel cell cars.”

"I expect that fuel cell vehicles will come very close to a mass production in 10 years' time.“

"For example, if the sales price of fuel cars goes down below 10 million yen (87,700 dollars), then customers who now buy German luxury cars will shift to fuel cell cars."

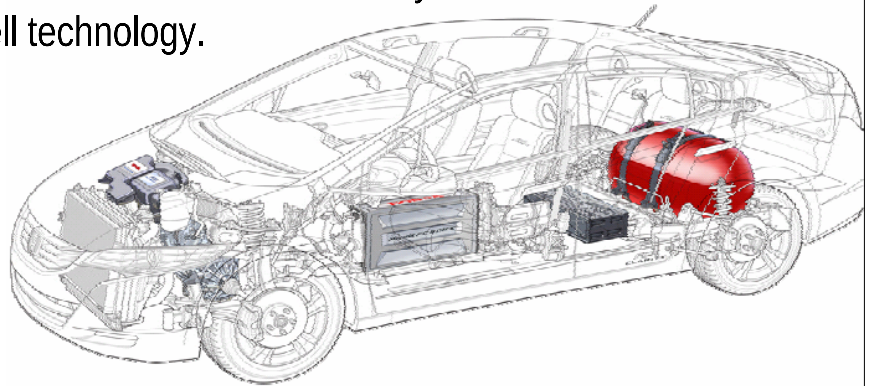
Source: AFX, 23 October 2007

Honda Future – Cruising range is dramatically low - Interview with Honda CEO Takanobu Ito

Focus: According to your competitors the future is primarily battery electric vehicles. Why is Honda so reserved on this?

Ito: Battery electric vehicle have potential. Compared to internal combustion engine vehicles with a fuel tank their cruising range is dramatically low, the batteries make the vehicle heavy – and we do not share the optimism that already soon they will be lighter and cheaper and additionally dispose of enormous storage capacities. Battery driven vehicles presently are merely an alternative for the city – or for customers who own several vehicles. Therefore the battery driven vehicle which we have shown at the Tokyo Motor Show is very small. We bet on fuel cell technology.

Source: FOCUS No. 47 (2009) [extract]



Fuel Cell Vehicle Commercialization (3)

GM:

General Motors Corp plans to have 1,000 hydrogen fuel cell vehicles in California between 2012 to 2014 to comply with the state's goal to put thousands of cleaner cars on its roads.

As the number of hydrogen fuel cell cars on the road increases, Burns said there would be a "tipping point" toward mainstream acceptance and financial viability for its fuel cell vehicles in 2017 or 2018.

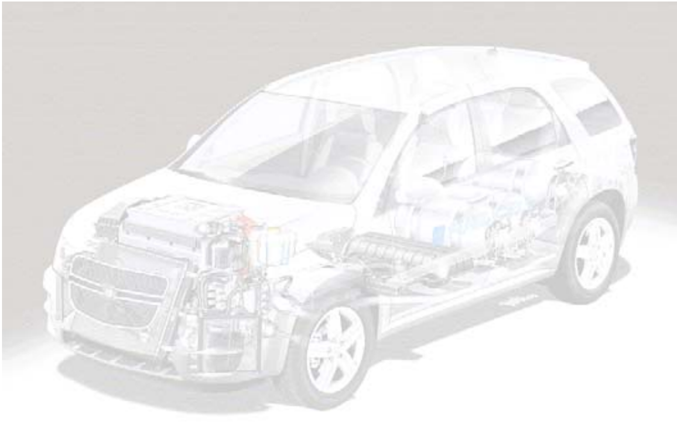
Source: Reuters, 02 April 2008

Larry Burns, GM's [former] vice president of research and development, said in May 2007 that the company aimed to have fuel cell-powered vehicles, which run on hydrogen and emit only water vapor, in showrooms around 2011 or 2012, and to ramp up production to about a million vehicles a year worldwide after 2012.

Source: Reuters, 14 November 2007

Hydrogen Fuel Cell Vehicles-Surviving the Advanced Tech "Valley of Death"
by Charles Freese, Executive Director, Fuel Cell Activities General Motors

With quantifiable learnings from the Equinox fuel cell fleet and a strong technology development effort, the fuel cell program left R&D about a year ago and became part of Powertrain, where it is treated like any pre-production program when it comes to seeking efficiency, cost reduction, design for manufacturability, and other elements of a production program. It is still expensive, but the costs are coming down dramatically. Our next-generation fuel cell architecture is 220 pounds lighter, uses about half the parts and roughly a third of the precious metals, compared to the still-impressive Equinox demonstration vehicles.



Source: fuelcellsworks 17 November 2009

Fuel Cell Vehicle Commercialization (4)

Nissan:

"We intend to offer a fuel cell vehicle with a price differential of at best 20% compared to a conventional powertrain in 2015", says Michael Schweitzer, spokesperson Nissan Germany.

Consequently a Van or SUV, equipped the first time with such a fuel cell would cost not more than 60,000 €.

Source: Financial Times Deutschland, 11 September 2008 [translated from German]

Nissan is part of a Japanese fuel cell collaborative group, along with Honda and Toyota, with targets to ensure fuel cell models and infrastructure are developed by 2015.

Source: Autocar, UK, 13 August 2008

“For the time when oil resources become dramatically scarce and the price hikes show extrems there will be no alternative to the fuel cell technology.” [translated from German]

Source: Taro Hagiware - Nissan Research Center, FOCUS, Germany, 14 July 2008

Fuel Cell Vehicle Commercialization (5)

Toyota:

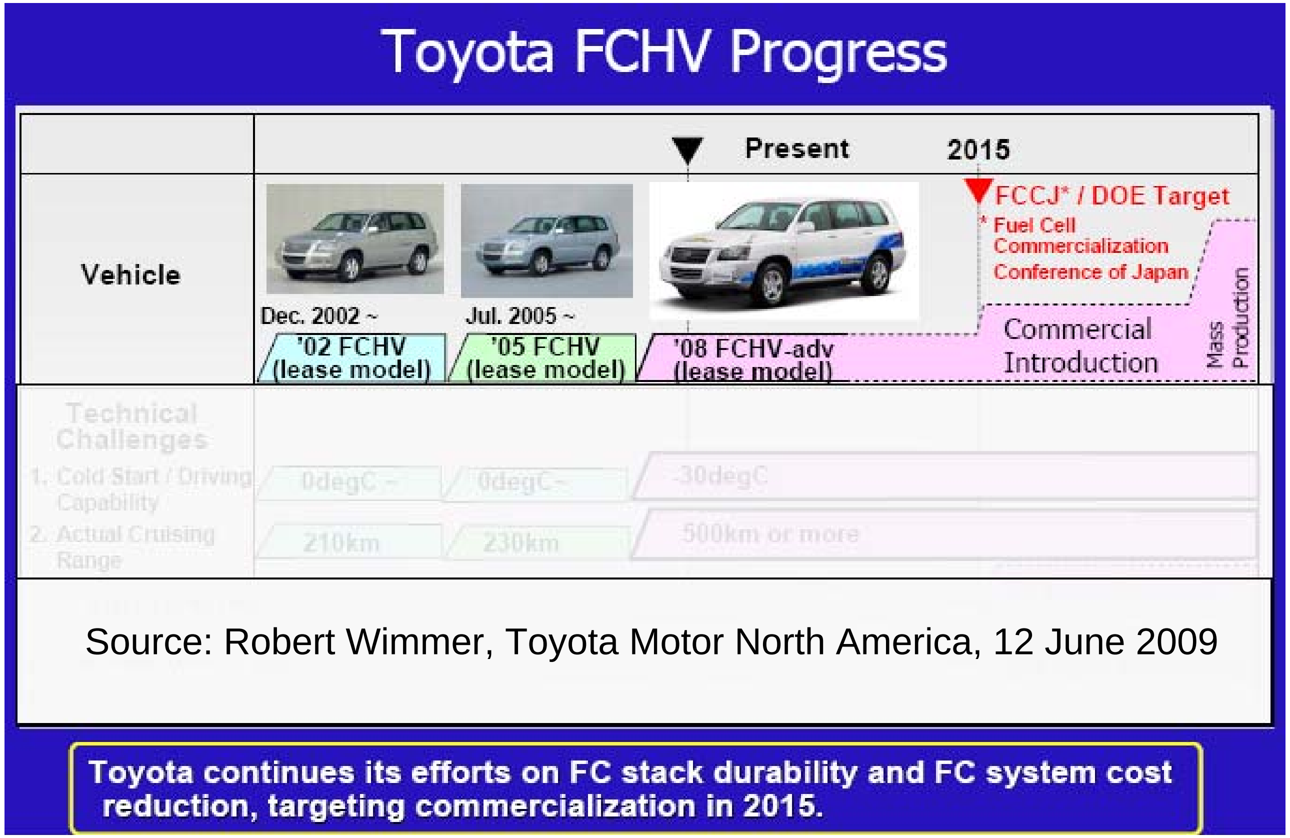
Toyota Motor, the world's top automaker, plans to roll out a fuel-cell car by 2015 in its push to stay ahead in the global race for green autos, vice president Masatami Takimoto said.

His comments came at a shareholders' meeting at Toyota headquarters in Aichi prefecture in response to an investor's question about the company's outlook on zero-emissions technology, but he declined to elaborate.

Source: afp, 23 June 2009

"Limited commercialization begins in 2015 and maybe sooner," spokesman John Hanson said in an interview today, citing comments by Executive Vice President Masatami Takimoto at the North American International Auto Show in Detroit. The exact timing, sales volume and price haven't been decided, Hanson said.

Source: Bloomberg, 14 January 2009



Fuel Cell Vehicle Commercialization (6)

Toyota:

Toyota Fuel Cell Vehicle Demonstration Program Expands

Toyota Motor Sales, USA, Inc. (TMS) announced today that more than 100 Toyota Fuel Cell Hybrid Vehicle – Advanced (FCHV-adv) vehicles will be placed in a nationwide demonstration program over the next three years.

TMS and Toyota Motor Manufacturing and Engineering North America, Inc. will place vehicles with universities, private companies and government agencies in both California and New York. Over the three year course of the demonstration program, as new hydrogen stations come online, additional regions and partners will be added. Toyota's demonstration program expansion will provide one of the largest fleets of active fuel cell vehicles in the country with the primary goal of spurring essential hydrogen infrastructure development. The demonstration program also will serve to demonstrate fuel cell technologies reliability and performance prior to its 2015 market introduction. ……….

"We plan to come to market in 2015, or earlier, with a vehicle that will be reliable and durable, with exceptional fuel economy and zero emissions, at an affordable price," said Irv Miller, TMS group vice president of environmental and public affairs. "Toyota will not be alone in the fuel cell marketplace and building an extensive hydrogen refuelling infrastructure is the critical next step. Hopefully, expansion of demonstration programs like this one will serve as a catalyst."

Source : Toyota Motor Sales, USA, Inc. (TMS), Detroit, 11 January 2010

Fuel Cell Vehicle Commercialization (7)

Kia/Hyundai:

Kia and Hyundai Still Bullish on Fuel Cells by Dave VanderWerp

In recent years, the wave of fuel-cell claims has been displaced by most automakers now diving headlong into battery-powered electric vehicles or electrics with a small gasoline engine as backup propulsion. Those automakers—GM, Nissan, Ford, Chrysler—continue to work on fuel cells but see them as a far-off possibility. Not Kia. While visiting the modern and impressive Hyundai-Kia Eco-Technology Research Institute, near Yong-In City, South Korea, we're assured that Kia is pushing full speed ahead on fuel cells inside the 153,000-square-foot facility and sees them becoming a mass-produced reality in the next decade. Specifically it expects a small number of vehicles in customers' hands in 2012 but, by towards the end of that decade, it expects to sell hundreds of thousands of fuel-cell vehicles. Perhaps the company has a better chance of success in its home country. As Kia points out, nearly half of South Korea's population lives in the greater Seoul area, which means it needs far fewer hydrogen refueling sources (Kia says about 120) to serve a future, fuel-cell-infused vehicle fleet.

Source: CarAndDriver Blog, July 9, 2009 - http://blog.caranddriver.com/kia-and-hyundai-still-bullish-on-fuel-cells/

Kia: Mass-produced fuel cell cars would cost $50,000 today

Regardless, it's clear that Kia, along with corporate cousin Hyundai, believe these issues will be worked out in time. When asked where the Korean automaker currently sits on a production-ready hydrogen vehicle, Ki-Ahn said, "On a scale of one to 10, I'd say we we're at six or seven. Before 2020, many people will be hearing about fuel cell vehicles made by Hyundai-Kia."

Source: Autoblog Green, 23 July 2009

LBST information on hydrogen, fuel cells and energy online

- **H2stations.org**
  Hydrogen Refueling Stations – since 2000
- **H2mobility.org**
  Hydrogen and Fuel Cell Vehicles – since 2000
- **HyWeb.de**
  News, Events – since 1996
- **LBST.de**
  Projects, Reports, Presentations
- **ASPO Deutschland/ Energiekrise.de**
  Peak Oil

ludwig bölkow systemtechnik

Substitution of global fossil based transportation fuel H_2

Comparison hydrogen from photovoltaic electricity (PV) versus plant oil from jatropha

~320 l gasoline/cap. @ 8 billion cap.

	Unit	CGH_2	LH_2	Plant Oil (Jatropha)	
Fuel consumption transport 2004	Mtoe	1,975	1,975	1,975	1,975
	TWh/yr	22,964	22,964	-	-
Efficiency fuel supply		0.60	0.54	-	-
Electricity demand fuel production	TWh/yr	38,086	42,851	-	-
Solar insulation	$kWh/(m^2\ yr)$	1,300	1,300	-	-
Efficiency PV panel		0.15	0.15	-	-
Performance ratio		0.75	0.75	-	-
Electricity yield PV panel area	$kWh/(m^2\ yr)$	146	146	-	-
Fraction of area covered by PV panels		0.33	0.33	-	-
Yield plant oil	t/(ha yr)	-	-	0.7 [1)]	2.7 [2)]
Required area	Mill. km^2	0.8	0.9	29.0	7.3
Land area earth	Mill. km^2	149	149	149	149
Share of land area for fuel production	%	0.5	0.6	19.5	4.9

[1)] 2 t seed per ha and year, oil yield 0.34 kg/kg; without irrigation; [2)] 8 t seed per ha and year, oil yield 0.34 kg/kg; with irrigation;
Source: Abhiskek Maharishi, Centre of Excellence for Jatropha Biodiesel Promotion, India; www.jatrophabiodiesel.org

Compilation: LBST

For comparison: land area of the USA is about ~9.2 million km^2